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Multimedia Educative Curriculum Materials (MECMs): Teachers' Choices in Using MECMs Designed to Support Scientific Argumentation

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ABSTRACT

In this article, we describe the development process for designing multimedia educative curriculum materials (MECMs) focused on supporting teachers in argumentation. We also describe results from a study with 46 teachers. We were interested in whether teachers' backgrounds or characteristics of the MECMs impacted MECM use. Overall, 89% of the teachers used the MECMs. Teachers' use was not related to their background, such as years teaching; however, placement of the MECMs and the type of support impacted use. Teachers were more likely to access MECMs embedded in lesson plans or reflective self-assessment prompts compared to a separate library. In addition, teachers were more likely to watch videos earlier in the curriculum and the 1st time a new activity structure was introduced.

KEYWORDS

argument; curriculum; digital; educative; multimedia; science practices

With the increasingly widespread implementation of the Next Generation Science Standards in the United States (Heiten, 2016; NGSS Lead States, 2013), science teachers face many new challenges. A notable feature in the new standards is the concept of three-dimensional instruction: the idea that disciplinary core ideas, science practices, and crosscutting concepts should be integrated into instruction and assessment. Science practices, as envisioned in these standards, represent a shift and expansion from earlier conceptions of scientific inquiry (Pruitt, 2014), and this shift places new demands on teachers. Specifically, in this work we focus on one science practice, engaging in argument from evidence, which, although it plays a key role in the practices of scientists, is frequently absent from kindergarten–Grade 12 classrooms (Osborne, 2010). Furthermore, a number of studies have documented the challenges teachers face when curriculum materials provide a lack of support for engaging in science practices (Bismack, Arias, Davis, & Palincsar, 2014) as well as teachers' struggles with incorporating scientific argumentation into their instruction (Berland & Reiser, 2011; Herrenkohl & Cornelius, 2013).

Thus, teachers need more support around argumentation, and educative curriculum materials—curriculum materials designed with features intended to support teacher learning—could be an efficient and scalable avenue for that support (Ball & Cohen, 1996; Davis & Krajcik, 2005; Davis et al., 2014). Educative curriculum materials have shown some evidence of positive effects on teacher practice (Arias, Bismack, Davis, & Palincsar, 2016; Cervetti, Kulikowich, & Bravo, 2015) and student outcomes (Cervetti et al., 2015). However, research on educative curriculum so far has focused almost entirely on text-based educative supports, which may have limits in terms of how effectively they can support science practices such as argumentation. For example, Alozie, Moje, and Krajcik (2010) argued that print-based curriculum materials alone are unable to capture and scaffold the complexity of dialogic student discussions, a key aspect of scientific argumentation.

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uste.

Consequently, we developed and researched multimedia educative curriculum materials (MECMs) to support teachers in scientific argumentation. Considering the limited work in this area, we drew from more general research on using digital supports for online learning (not specific to teacher learning; U.S. Department of Education, 2009) as well as research on video and other multimedia use in teacher professional development (Roth et al., 2011; van den Berg, Wallace, & Pedretti, 2008; Watters & Diezmann, 2007) to inform our design process. Furthermore, we were specifically interested in how teachers used those supports, as work with text-based curricula has found that teachers use them in a variety of ways, which impacts their science instruction (Schneider, Krajcik, & Blumenfeld, 2005). In addition, existing research on teachers' use of text-based educative curriculum materials has relied on teacher self-reports of their use or inferences about teacher use of materials based on classroom observations (Arias et al., 2016; Schneider, 2013; Schneider & Krajcik, 2002). The incorporation of MECMs into a Web-based teacher's guide provided an opportunity to collect back-end data on which educative elements teachers actually chose to view. Buxton and his colleagues (2015) described the concept of teacher agency in professional learning, noting that agency involves both "deciding *what* professional learning to engage in and *how* to engage with the work ... based on teachers' knowledge of and goals for their students" (p. 491). We extend that notion to teachers' interactions with educative curriculum materials: An understanding of teachers' decisions about accessing educative curriculum features is important if experts are to maximize the effectiveness of educative curriculum materials. In this article, we first describe and illustrate our three design principles for developing the MECMs. Next we present the results from a study in which we investigated the following research questions: (a) What percentage of teachers used the Web-based curriculum and the MECMs? (b) Did teachers' backgrounds (e.g., years teaching science) impact their use of MECMs? (c) Which characteristics of the MECMs were related to teachers' use? and (d) What were teachers' rationales for how they used the Web-based curriculum and the MECMs?

Theoretical framework

Scientific argumentation

Our approach to scientific argumentation is consistent with others in the field of science education in that we focus on both structural and dialogic aspects of argumentation (Jiménez-Aleixandre & Erduran, 2008). Scientific arguments have a particular structure (Sampson & Clark, 2008; Toulmin, 1958) that, in a form simplified for students, can incorporate a claim and evidence and make clear the reasoning that connects the evidence to the claim (McNeill, Lizotte, Krajcik, & Marx, 2006). However, equally important is the dialogic aspect of argumentation: the idea that argumentation is a social and communicative process in which, through the interaction of members of a scientific community, arguments are constructed, critiqued, and improved (Berland, 2011; Berland & Reiser, 2011). This latter aspect of argumentation is particularly difficult to represent within the limitations of text-based curriculum materials because it is challenging to represent rich student discourse in text (Alozie et al., 2010).

The role of and teachers' use of curriculum

Curriculum materials can be an important support for instructional reform by providing teachers with concrete materials aligned to reform efforts (Banilower et al., 2013; Powell & Anderson, 2002; Remillard, 2005). Teaching reform-oriented curriculum can support teachers in shifting their instruction toward an inquiry orientation (Williams, Linn, Ammon, & Gearhart, 2004), aligning more closely with the recent focus on science practices. Consistent with other researchers (Brown, 2009), we consider curriculum use to be a design activity. According to this perspective, there are multiple acceptable enactments of a curriculum rather than one correct way to teach each lesson (Remillard, 2005), and successful implementation is determined by alignment with the overarching goals of the curriculum rather than by whether teachers follow scripted procedures (McNeill, Marco-Bujosa, González-Howard, & Loper, 2016). Thus, one goal of educative curriculum materials is to provide teachers with the rationale for instructional decisions in order to enable them to successfully adapt the resources to meet the needs of their particular students and context (Beyer, Delgado, Davis, & Krajcik, 2009). However, prior to adapting curriculum teachers must first read and evaluate the materials (Sherin & Drake, 2009). Therefore, understanding patterns of teachers' use of curriculum requires first understanding what teachers choose to read (or in the case of MECMs, view). Although researchers using text-based educative curricula have begun to explore how to support teachers, there is limited research focused on digital or multimedia educative curriculum. We were able to find only three examples of research on Web-based educative curriculum materials. In two of these examples (Davis, Smithey, & Petish, 2004; Golan Duncan, El-Moslimany, McDonnell, & Lichtenwalner, 2011) researchers created a Web-based science curriculum that included educative supports. However, in both cases these supports were text only and did not incorporate multimedia elements. Another study, in social studies (Callahan, Saye, & Brush, 2014), did include a multimedia component: Educative videos were incorporated into a Web-based curriculum guide. However, these educative elements were incorporated into only three lessons, and the materials were tested with only three teachers. Thus, the potential of MECMs remains largely unexplored, and our project expands on these efforts both by going beyond text-based supports and by investigating MECMs in a larger scale study.

Design and development process

We developed a set of MECMs to be incorporated into three units from a Next Generation Science Standards–designed middle school program (Regents of the University of California, 2016). The three units had a heavy focus on argumentation but were also designed to address disciplinary core ideas in earth and space sciences and integrated crosscutting concepts such as matter and energy. The development of the MECMs followed an iterative process, incorporating both theoretical and empirical input, similar to the process described by Davis et al. (2014). This 3-year, iterative development process included first, observations and case studies of teachers' use of preliminary versions of the curriculum, along with teacher focus groups on drafts of the resources (McNeill, Marco-Bujosa, et al., 2016); second, the development and piloting of drafts of the MECMs within field trial versions of curricular units (Loper, McNeill, Peck, Price, & Barber, 2014); and third, the incorporation of both teacher and researcher feedback on the field trial materials, resulting in the revision and production of the final version of the MECMs for use in a year-long study.

This theoretical and empirical work led us to three basic design principles that informed the development of the final version of the MECMs:

(1) Use multimedia representations of practice that illustrate scientific argumentation in real classrooms.
(2) Target challenge areas in enacting curriculum focused on scientific argumentation.
(3) Support active learning by encouraging teacher reflection and connections to teachers' own practice.

We describe the basis for and implementation of each of these principles in more detail next.

Design principle 1: Use multimedia representations of practice

In our preliminary research in classrooms with argumentation-focused curriculum, we found significant gaps between curricular intent and teacher enactment (McNeill, Katsh-Singer, González-Howard, & Loper, 2016). We analyzed the curriculum using the educative criteria developed by Beyer and her colleagues (Beyer & Davis, 2009) and found limitations in terms of conveying both the structural and dialogic aspects of argumentation in text. These findings suggested the need for richer representations of argumentation, such as those that can be provided using video. Research has found that video-based multimedia cases, when grounded in a rich context and directly relevant to the classroom practice of the teachers viewing the video (van den Berg et al., 2008; Zhang, Lundeberg, Koehler, & Eberhardt, 2011), can help illustrate the intricacies and subtleties of effective teaching practices (Lieberman & Mace, 2010).

Thus, we took advantage of the affordances of media to create 24 educative videos that included classroom footage, interviews with teachers and scientists, narration, and graphics. The use of video made it possible to smoothly integrate narrative and expository content, two kinds of content that Beyer and her colleagues found to have different affordances and limitations in educative curriculum (Beyer & Davis, 2009; Davis et al., 2014). Although the videos focused on argumentation, it was always within the context of specific disciplinary content, such as explanations for regional climate patterns. We produced four categories of videos: rationale, approach, activity, and strategy. These categories are described in Table 1. A subset of the videos we created are available at argumentationtoolkit.org.

The videos were integrated into the curriculum in two ways. The curriculum consisted of a total of 62 lessons in three units: (a) Rock Transformations ("Rocks"), (b) Currents and Earth's Climate ("Currents"), and (c) Space and Gravity ("Space"). The videos were embedded in the Session Prep section within appropriate lessons throughout the Web-based teacher's guide. For example, Figure 1 shows how a video was embedded in the Rocks unit in Session 1.14.

In addition to the lesson plan pages, there was a tab in the Web-based teacher's guide titled "The Argumentation Toolkit" that included all of the digital supports outside of the specific lessons in a library format (see Figure 2).

Table 1. Categories of educative videos.

Rationale	Approach	Activity	Strategy
Provides teachers with reasons for incorporating argumentation into their science instruction.	Describes fundamental concepts in argumentation.	Describes a particular activity structure that engages students with argumentation.	Describes a specific strategy teachers can use within an argumentation activity.

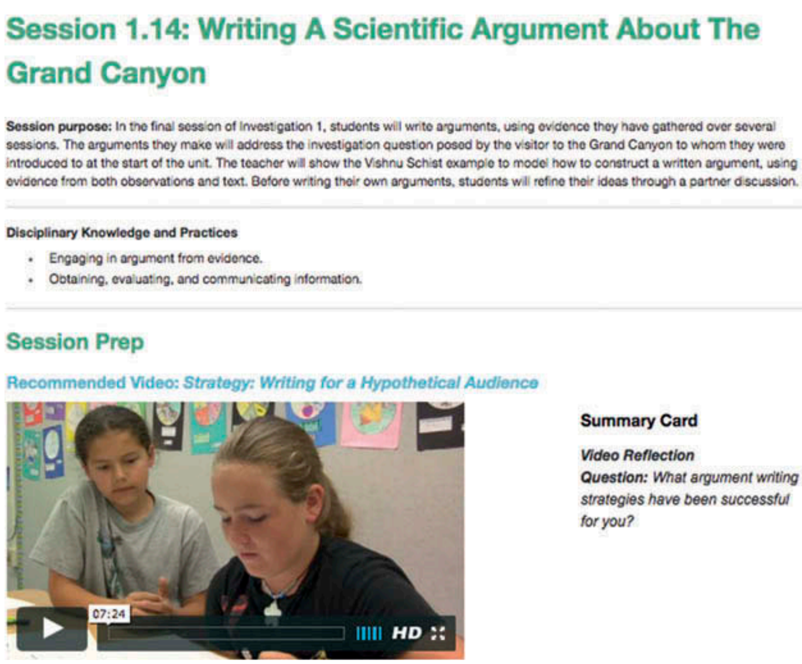

Figure 1. Screenshot showing a video embedded in the Session Prep section of a lesson.

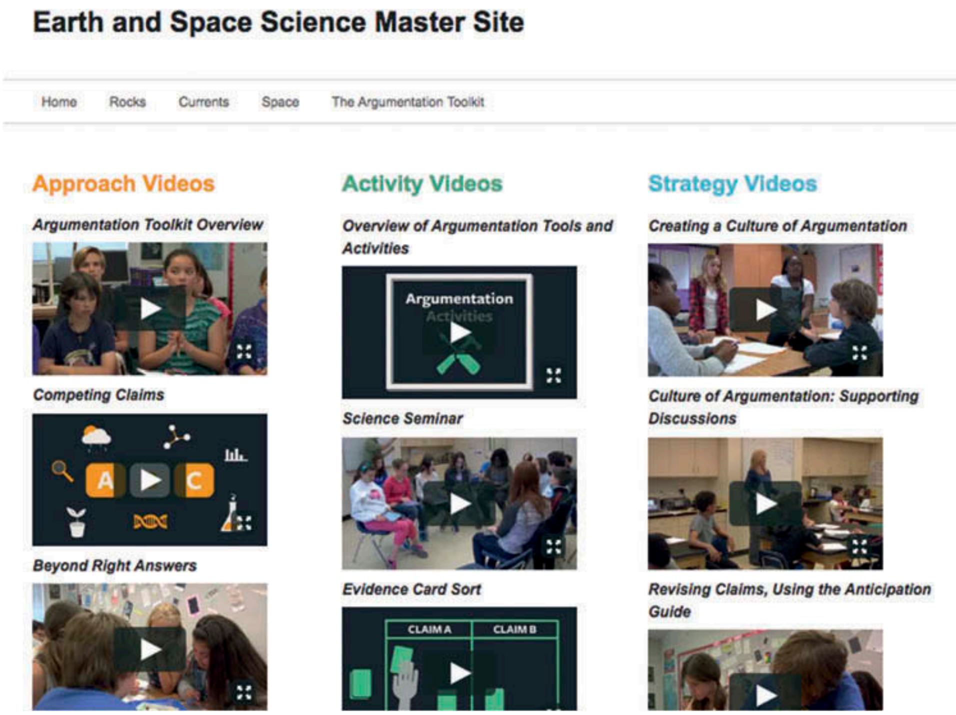

Figure 2. Screenshot of videos displayed in a library accessed through a separate tab.

Design principle 2: Target challenge areas

Given the demands on teacher time and attention, educative materials should target areas of teacher need. To incorporate this design principle, we considered areas of challenge identified in the existing research literature. For example, in terms of the structure of argumentation, teachers can have difficulty understanding and developing instructional strategies for scientific reasoning (McNeill & Knight, 2013). Teacher challenges in supporting reasoning can be targeted using professional development and online tools (Delen & Krajcik, 2016). In addition, in terms of the dialogic process, classroom discourse is typically dominated by the teacher (Roth & Garnier, 2006), with limited opportunities for students to question, critique, and build on the ideas of their peers (Osborne, 2010). Furthermore, we conducted pilot studies with teachers to identify challenges with this specific curriculum (see McNeill et al., 2016, for more detail). From the literature and our own research, we identified four challenge areas: Two challenges focused on the structure of arguments, and two challenges focused on the dialogic aspects of argumentation (McNeill, González-Howard, Katsh-Singer, & Loper, 2016; see Table 2). Based on findings from our teacher focus groups, we described these as challenges for students rather than teachers, because our focus group teachers stated that MECMs labeled as *supporting teacher learning* would be seen as appropriate for beginning teachers only (Loper et al., 2014).

These four challenge areas were introduced in the first video in the curriculum, *Argumentation Toolkit Overview*. As the four challenges are described, four different icons appear to correspond with each challenge (see Figure 3). These icons are used throughout the rest of the videos to align with these four student challenges. In addition, because it can be difficult for teachers to notice students' successes and challenges with argumentation, we used a number of strategies to highlight the four elements of argumentation in the videos, described next.

Table 2. Four challenge areas for teaching argumentation.

Structural	Dialogic
Evidence Students use high-quality evidence to support their claims.	*Interaction* Students build off of and critique one another's ideas.
Reasoning Students make clear how their evidence supports their claim.	*Competing Claims* Students critique competing claims.

Figure 3. Scene from the *Argumentation Toolkit Overview* video showing icons representing the four challenges.

Pop-up bubbles around challenges

First, we used pop-up bubbles overlaid on the video as students were talking to make explicit the area of argumentation being addressed. For example, in Rocks Session 2.1 students conduct a card sort in which they evaluate the quality of pieces of evidence to support a scientific claim. The Session Prep includes a video titled *Activity: Evidence Card Sort* that includes clips of students talking as they engage in the card sort. Pop-up bubbles appear to highlight aspects that teachers should focus on. For example, in the scene in Figure 4, the video encourages teachers to notice and think about the "reasoning" students are using to explain why the evidence on that card supports the claim.

Figure 4. Scene from the *Activity: Evidence Card Sort* video showing a pop-up bubble used to make explicit an area of argumentation that is the focus of the video clip.

Reflections around challenges

Second, we included footage of curriculum developers and teachers reflecting on these challenges. For example, in Space Lesson 1.1 students use, for the first time, the Reasoning Tool, a tool that supports them in explaining why their evidence supports their claim. The video embedded in the Session Prep introduces the tool as well as the challenges students can have around this process. Early in this video, one of the curriculum developers explains,

> We found that it is very difficult for middle school students to make their reasoning clear—to articulate their reasoning. And we found the Reasoning Tool helps with this challenge because it lays out for the students a structure that helps them see . . .

Including this explicit reflection helps to make the challenges more visible to teachers and hopefully make them more conscious of how they are addressing the challenges in their own classroom.

Students articulating challenges

Third, we made sure to include footage that showed students expressing difficulty with an argumentation element. For example, the *Reasoning Tool* video includes the following discussion:

Teacher: Do you have reasoning to put here too? [points to girl's paper]
Girl: That is what we were stuck on.
Boy: Yeah.
Teacher: That is what you were stuck on.
Boy: We were confused with that.
Teacher: Okay. For this row, we are focused on the blue. And in the blue the claim is . . .

The teacher goes on to help the students think about what would count as reasoning for their argument. Capturing an explicit moment in which the students recognize their difficulty offers an opportunity for other teachers to consider whether their students may have the same challenges with this specific science lesson or reasoning more broadly.

In summary, we focused the 24 educative videos primarily around different aspects of the four challenges we identified and used a variety of strategies to highlight and explain the challenges as well as to provide teachers with support in addressing them.

Design principle 3: Support active and reflective learning

The Web-based teacher's guide platform affords the opportunity to create a more interactive experience, which is in line with recent research. For example, in a meta-analysis of online learning studies for the U.S. Department of Education (2009), one of the practices that positively impacted learners was the inclusion of active learning environments that gave individuals control over their interactions with media. Another important feature of online environments that incorporate active learning is supporting learner reflection. Online environments that included a tool to support individuals' reflection or self-assessment resulted in stronger outcomes (U.S. Department of Education, 2009).

Consistent with this research literature, we attempted to create an active and reflective learning experience through two methods: (a) video reflection questions associated with each embedded video that supported teachers in making connections to their own practice and (b) reflective self-assessment prompts that pushed customized video recommendations based on teachers' responses.

Video reflection questions

A reflection question for the teacher was displayed adjacent to every video embedded in the curriculum to encourage teachers to connect the video to their own classroom practice. For example, in one lesson in which students wrote a scientific argument, the Session Prep included a video, *Strategy: Writing for a Hypothetical Audience* (see Figure 1), that discussed the instructional strategy of encouraging students to consider a particular audience to make their written arguments more persuasive. The reflection question associated with it asked "What argument writing strategies have been successful for you?" The goal was to encourage the teacher to think about strategies used in the past to better adapt the lesson to meet the needs of his or her students.

Reflective self-assessment prompts with customized responses

For a number of lessons in the teacher's guide, teachers were presented with a prompt such as "How confident do you feel about developing a culture of argumentation in your classroom?" or "How do you feel about how the Science Seminar went?" Teachers could select from a set of multiple-choice responses, and depending on their selection they were pushed a specific video recommendation to better meet their needs. For example, in the Rocks unit students engaged in a Science Seminar in Lesson 2.10. When the teachers clicked on the next lesson in the unit, 2.11, they saw a prompt at the top of the lesson that asked them to evaluate how the Science Seminar went (see Figure 5).

Depending on which choice the teacher selected a window then popped up with a customized video or other recommended resource. If the teacher rated his or her first Science Seminar excellent, the response was, "It sounds like your seminar was pretty successful. That's great! You may consider watching this strategy video to help you further improve your future Seminars. *Strategy: Stepping Back During Science Seminars*." If the teacher chose the option "not good at all," the response was, "It sounds like your seminar was not as successful as you would have liked, but don't give up! Sometimes it takes several seminars before students are comfortable sharing and engaging in argumentation ..." This prompt gave several suggestions of strategies and also recommended a different video, *Strategy: Promoting Student Interaction During Science Seminars*. In both cases, the recommended video was embedded in the response so teachers could click on it and play it immediately if they so chose.

Video reflection questions were displayed with each of the 24 MECM videos embedded in the Session Prep sections, and reflective self-assessment prompts were included in 17 of the 62 lessons. These two elements, video reflection questions and reflective self-assessment prompts, were intended to make the experience of using the MECMs active and reflective.

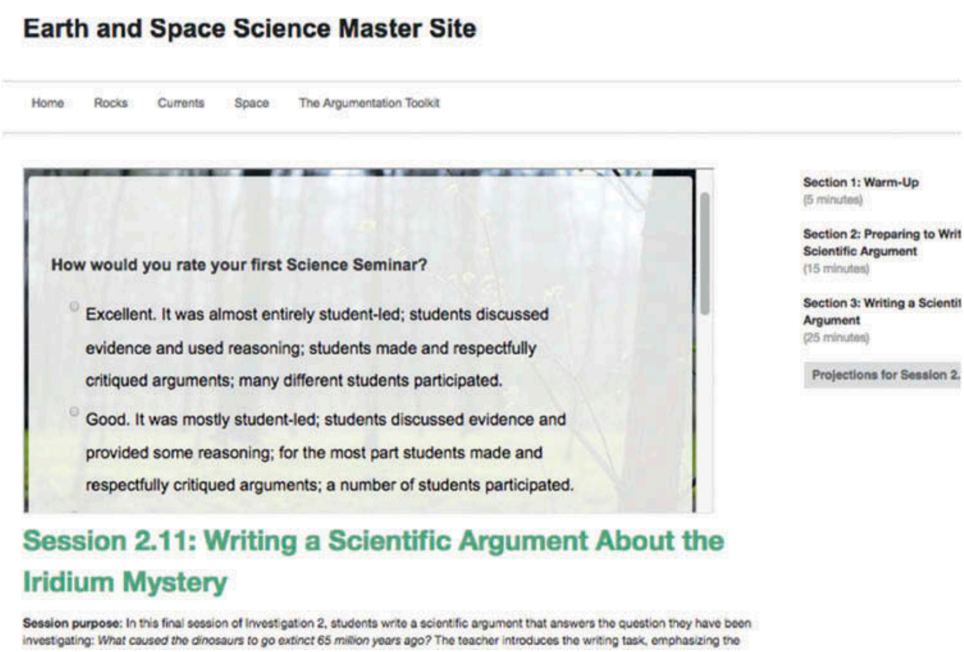

Figure 5. A reflective self-assessment prompt displayed in a lesson.

Methods

In this section, we describe an empirical study in which we investigated teachers' use of the Web-based curriculum and the different types of multimedia educative supports. Specifically, we were interested in the choices teachers made about which supports to use and whether there were trends based on the teachers' backgrounds, the type of support, or where the supports were placed within the unit. To address this research question, we collected multiple data sources, including pre- and postsurveys, curriculum site page views, reflective self-assessment prompt responses, and counts of video plays.

Participants

Middle school science teachers were recruited from across the United States. Only teachers who had not previously used curriculum materials from this project were admitted. A total of 46 teachers completed the study. The teachers taught in public, private, and charter schools; represented a range in terms of years of experience and educational background; and also had a range of experiences with teaching scientific argumentation (see Tables 3 and 4).

Each teacher was provided with an individual, password-protected copy of the Earth and Space Science curriculum site with a unique uniform resource locator (URL). The curriculum site included detailed lesson plans as well as downloadable PDFs of student sheets and images for teachers to project during the lesson. Teachers were also mailed a kit of physical materials needed to teach the curriculum, such as rock samples, balloons, and water tanks. The study began in September, but some teachers were admitted to the study later in the year to compensate for attrition. Depending on when they entered the study, teachers had between 3 and 6 months to access the materials. Teachers were told to use the curriculum materials in whatever way they would normally use curriculum materials and were not required to read or teach any set number of lessons.

Table 3. School and teacher background information (N = 46).

Characteristic	Teachers (n)
Type of school	
Public	43
Private	2
Charter	1
Faith based	0
Other	0
School locale	
City	16
Suburb	10
Town	6
Rural	14
Not sure	0
Years teaching science	
0–2	6
3–5	9
6–10	12
11–15	8
16+	11
Highest level of science education	
No response	4
Bachelor's degree	38
Master's degree	3
Doctoral degree	1
Highest level of education	
No response	1
Bachelor's degree + teaching certificate	26
Master's degree	18
Doctoral degree	1

Table 4. Teacher experiences with argumentation ($N = 46$).

Experience	Teachers (n)
Taught a curriculum focused on argumentation	
Yes	5
No	41
Number of workshops, professional development sessions, or classes focused on argumentation	
None	27
One	5
Two or three	10
Three or more	4
Included argumentation in classroom instruction	
Never	17
Once	3
A few times	18
Many times	8

Data collection

Pre- and postsurveys

Teachers completed pre- and postsurveys. The presurvey included teacher background and demographics (see Tables 3 and 4), and the postsurvey included questions about teachers' use of the curriculum. One postsurvey item was an open-ended question about teachers' use of the curriculum. We developed a coding scheme from an iterative analysis of the data for the open-ended responses (Miles & Huberman, 1994). Two independent raters coded the item, overlapping on 20% of the responses. Interrater reliability was 94%, and all disagreements were resolved through discussion.

Curriculum site page views

Using the back-end analytics features of the website on which the curriculum was hosted (Weebly), we recorded the number of page views for each teacher's curriculum site. Because each teacher had a unique URL, these data could be linked to individual teachers, providing an indication of how many times teachers accessed the curriculum online. The curriculum site had a total of 73 webpages.

Video plays

Using the back-end analytics features of the website on which the MECM videos were hosted (Vimeo), we recorded the number of times each video was played and from which URL the play was initiated. Videos could be accessed in three ways: through (a) the Session Prep section of a lesson, (b) The Argumentation Toolkit tab, or (c) a reflective self-assessment prompt. Data related to each of these methods of access are described in more detail here.

Video plays from the Session Prep section of a lesson. Each educative video was embedded in the Session Prep section of a lesson at a point at which the curriculum developers felt it would be helpful. For example, a video about supporting students with an evidence card sort was included in the first lesson in which students did this activity in the curriculum. These plays could be tied to individual teachers. A total of 24 videos were linked in the Session Prep sections of 24 different lessons.

Video plays from The Argumentation Toolkit tab. The same 24 videos were also displayed in a library format on a separate tab within the curriculum website (see Figure 2). Teachers could select this tab, see a display of all of the available videos, and choose one to play. We could also tie these plays to individual teachers.

Video plays from a recommendation in a reflective self-assessment prompt. When teachers completed the reflective self-assessments (see Figure 5), a response was given that in most cases

Table 5. A summary of ways in which teachers could use the MECMs.

Teacher use	Data recorded	Quantity	Linked to individual teacher?
View curriculum pages	Page views	73 pages	Yes
Select and play videos from the toolkit tab	Video plays	24 videos	Yes
Play recommended videos from Session Prep section of lessons	Video plays	24 videos	Yes
Complete multiple-choice reflective self-assessment	Self-assessment responses	17 reflective self-assessment prompts	No
Play video recommended after completion of reflective self-assessment prompt	Video plays	10 videos linked from 15 reflective self-assessment prompts	No

included an embedded video from the Argumentation Toolkit collection. Because Weebly functionality did not allow the creation of these interactive prompts, they were created within a different platform, Qualtrics, and embedded within the Weebly pages. Thus, they were not accessed from the teachers' unique URLs, and we are not able to associate these video plays with individual teachers. A total of 15 reflective self-assessments had linked videos recommended as at least one of the responses (the remaining two self-assessment prompts had no videos linked as a response). Across these 15 reflective self-assessment prompts, the recommendations linked to a total of 10 out of the 24 videos (some videos were recommended as a response to more than one prompt).

Reflective self-assessment prompt responses

As described previously, in 17 lessons a reflective self-assessment prompt was embedded at the beginning of the lesson. The number and content of the responses for each prompt was recorded through the Qualtrics site. Although Qualtrics recorded the Internet Protocol address from which the prompt was accessed, it could not record the linking URL from which the teacher accessed the prompt, and therefore the responses could not be attributed to individual teachers. If multiple responses were received from a single Internet Protocol address within a 30-min window, we inferred that this was the same teacher responding multiple times and treated those as a single response (it appears that some teachers responded multiple times to the same question in a short timeframe, apparently testing out the results of each response).

Table 5 summarizes the interactions teachers could have with the curriculum and the MECMs and the data we collected on each kind of interaction.

Data analysis

After collecting the multiple data sources, we then analyzed them, looking for trends in the types of supports teachers chose to use in the units and looking for patterns in relation to time, type of support, and teacher background information. We created visualizations, such as summary tables and graphs, to facilitate the process of looking for patterns (Miles & Huberman, 1994). For some analyses, such as teacher demographics, we conducted multiple one-way analyses of variance to look for significant differences between groups for the different factors of interest. In addition, we used the multiple data sources, such as comparing the page views and video plays to responses on the postsurvey, to test the viability of the patterns by examining confirming and disconfirming evidence (Erickson, 1986). Our goal in these analyses was to identify trends in teachers' choices in order to better design future MECMs to meet teacher needs.

Results

In this section, we describe how teachers used the Web-based curriculum and the MECMs. First we describe teachers' general use of the Web-based curriculum and videos, as the digital platform was new for the majority of teachers. Next we present an examination of whether there was a relationship between teachers' backgrounds and their use of videos. Then we discuss teachers' choices in the use of the different educative supports, including the videos and the self-assessment prompts. Finally, we share the rationales that teachers provided for the ways in which they used the Web-based curriculum.

Teachers' overall use of Web-based curriculum

We first examine how teachers accessed the Web-based curriculum itself. As mentioned previously, there were 62 lessons in the unit. The average number of page views was 299, with a range from 62 to 576. This means that the majority of teachers visited each lesson multiple times. This large range in page views raises questions about how the teachers used the curriculum. During our case studies (McNeill et al., 2016), we found that some teachers printed the materials instead of using the online resources. Consequently, on the postsurvey teachers were asked the most common way in which they used the curriculum; they were asked to select one of the following: (a) Used the student materials only (i.e., did not use the online teacher's guide at all), (b) Printed materials from the website, (c) Used website to create own materials, (d) A combination of using the website and printing or creating materials, or (e) Used the website online. Figure 6 shows the results. Of the 46 teachers, five teachers said that the most common way they used the curriculum was to print materials from the website. Thus, the remaining 41 teachers (89%) reported that the most common way they used the materials included using the website itself rather than only materials printed from the website.

In addition to self-report, we also examined the back-end data collected on teachers' use of the videos. Figure 7 shows how many times individual teachers played videos, including all video plays that occurred from either Session Prep or The Argumentation Toolkit tab. Of the 46 teachers in the study, 87% (40 teachers) played at least one MECM video. The number of video plays ranged from zero (six teachers) to 37 (one teacher). As shown in the graph, about 25% of teachers played a video 11 or more times. We find it promising that the majority of teachers viewed at least one video and that many teachers viewed numerous videos.

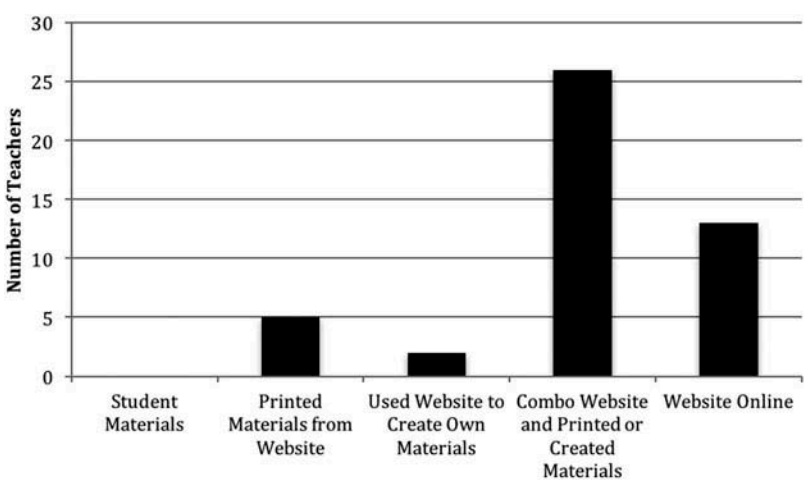

Figure 6. What was the most common way in which teachers used the curriculum?

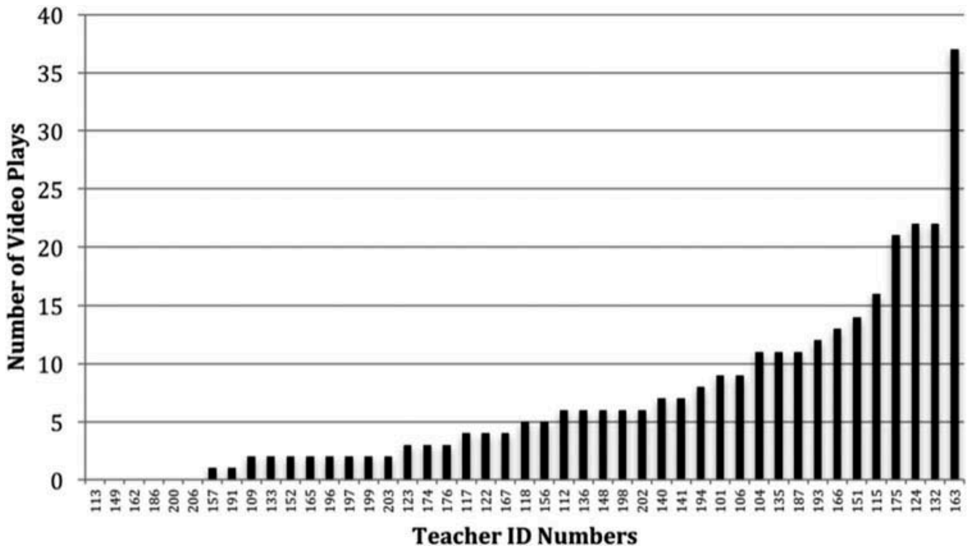

Figure 7. How many times did teachers play the multimedia educative curriculum material videos? ID = identification.

Relationship between MECM use and teachers' backgrounds

Given the range in video views, we further examined whether any relationships existed between teachers' backgrounds and the number of times they watched MECM videos. For example, we were interested in whether new teachers would be more likely to watch the videos or whether teachers who had attended professional development on argumentation would be less likely to watch the videos. We performed separate one-way between-subjects analyses of variance and found there to be no statistically significant relationships between video views and years teaching science; number of workshops, professional development sessions, or classes on argumentation; or the frequency with which teachers reported previously including argumentation in their classroom instruction: years teaching science, $F(4, 41) = 0.606$, *ns;* number of workshops, professional development sessions, or classes on argumentation, $F(3, 42) = 0.539$, *ns;* frequency with which teachers reported previously including argumentation in their classroom instruction, $F(3, 42) = 0.159$, *ns*. Consequently, we did not find a relationship between these teachers' background variables and their video views.

Patterns of use of MECMs

The videos were designed to be a toolkit from which teachers could make selections based on their need and interest rather than a prescribed sequence for teachers to progress through. Thus, we were interested in the choices teachers made in terms of viewing videos and using other elements. We were interested in whether there were patterns of use with respect to different characteristics of MECMs, such as their placement in the curriculum or the type of MECM.

Use of MECM videos over time

We were interested in whether the viewing pattern changed over time. Figure 8 shows the percentage of teachers who played each video, with the videos listed chronologically according to the curriculum sequence. As shown in the graph, in general there was a higher view rate for videos that were embedded earlier in the sequence, but there are a few interesting exceptions. We see an increase in viewing rate relative to the overall pattern for Videos 11, 15, and 16. One possible explanation is that all three of these videos are associated with the first time an activity is used in the curriculum. Video 11 introduces the evidence card sort, Video 15 is embedded in the lesson in which students

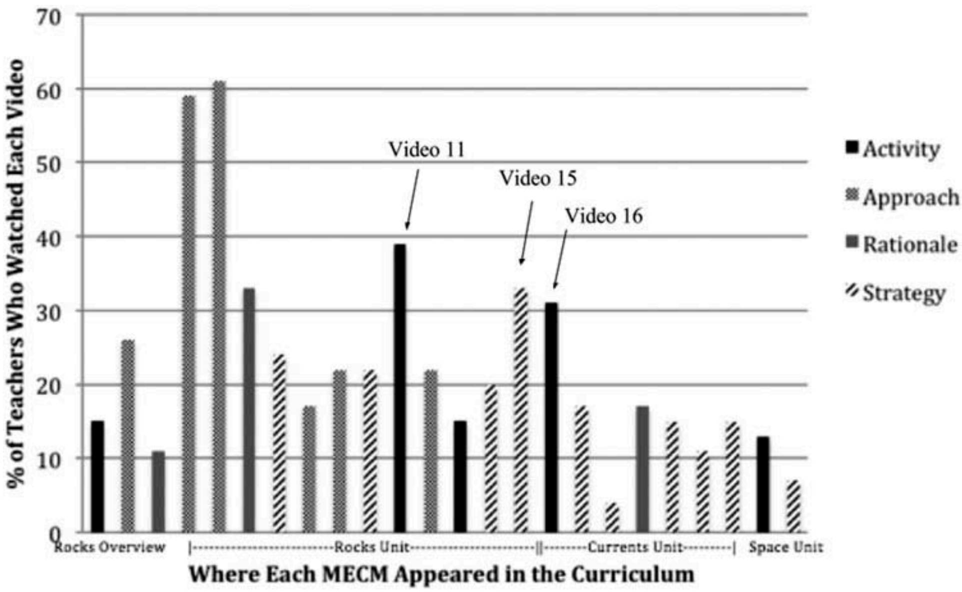

Figure 8. Which multimedia educative curriculum materials (MECMs) were viewed by the most teachers?

participate in their first Science Seminar, and Video 16 introduces the Evidence Gradient Tool. Figure 8 also identifies the category of each video; we could not discern any patterns of viewing related to the video categories.

Use of reflective self-assessment prompts over time

As described earlier, in addition to the MECM videos there were 17 reflective self-assessment prompts embedded at the beginning of a lesson that teachers could respond to by either selecting a multiple-choice option or completing a written response. For these reflections, we do not have data identifying which teachers completed the reflections; rather, we only have the number and content of the responses. Figure 9 shows the number of times each reflection was completed, organized in chronological order according to the position of the reflection in the curriculum sequence. Like the video viewing data, this graph shows a general trend of decreasing use of MECMs positioned later in the sequence.

Comparing across types of MECMs

As mentioned earlier, one of our design principles, Design Principle 3 (support active learning and reflective learning), was drawn from findings that interactivity and opportunities for reflection improve learning outcomes. One question we had was whether embedding the MECM videos in an appropriate place within the lesson context rather than a central library made them more appealing to teachers. We were also interested in how likely teachers were to view an MECM video when it was a customized response to a reflective self-assessment.

Because there are different numbers of these different types of MECMs, it is somewhat difficult to make comparisons across these types of use. However, one way to compare them is to scale them according to their opportunities for use. We determined an opportunities for use value for each type of MECM that represented the number of uses there would have been if every teacher had used each instance of that feature exactly once. We could then represent the total number of uses of each type of feature as a percentage of this opportunities for use value. For example, there were 24 videos teachers could play from the Session Prep section of the lesson. If every teacher had played every video once, the total number of plays would have been 46 × 24, or 1,104 plays. The actual number of plays was 298, so the use as a percentage of opportunity to use was 298/1,104, or 27%. This

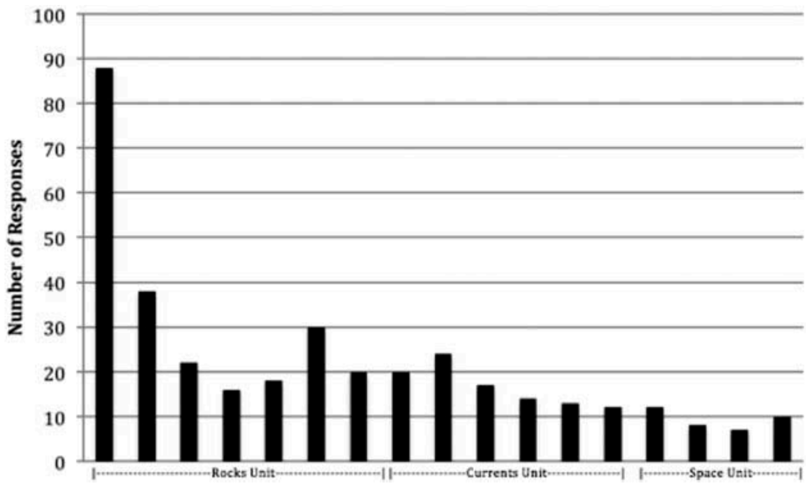

Figure 9. How did teachers use the reflection multimedia educative curriculum materials across the curriculum?

calculation provides a gross measure of scale of use that enables us to compare across types of MECMs.

Figure 10 shows use as a percentage of opportunities for use for three different ways that teachers could access the MECM videos: (a) directly through the Argumentation Toolkit library of videos (2%), (b) as a customized recommendation after the teacher responded to the reflective self-assessment prompt (19%), and (c) linked to the Session Prep section of a particular lesson (27%). The most notable pattern in these data is the low use of the Argumentation Toolkit library. Although we expected teachers to use the library less than they used the videos recommended in the prep section, we were surprised by how extremely low access to the library was. These data also suggest that teachers were somewhat less likely to watch the videos suggested as customized recommendations than they were to watch the videos that were simply linked as a recommendation in the Session Prep section of the lesson.

In addition to MECM video use, we also calculated use, as a percentage of opportunity to use, of the reflective self-assessment prompts. There were 17 prompts. The first prompt, in Lesson 1.1, received 88 responses. Because this was almost double the number of teachers in the study, we decided that this result might not reflect real reflective use and might just be an artifact of the prompt appearing in the first lesson of the curriculum. When this prompt is eliminated from the data, 16 prompts remain. If each teacher had

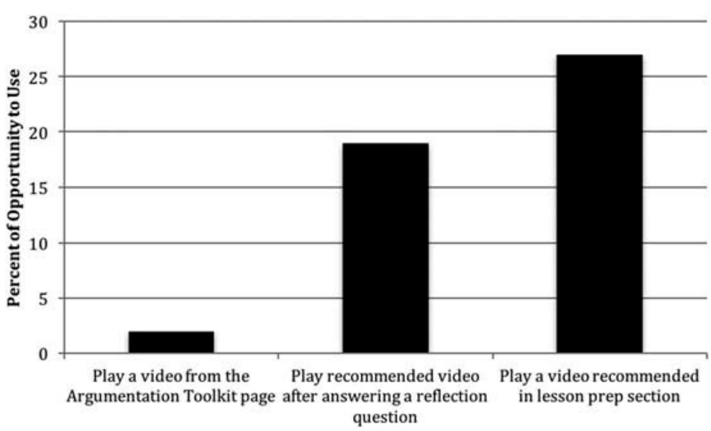

Figure 10. Use of multimedia educative curriculum materials as a percentage of opportunity to use.

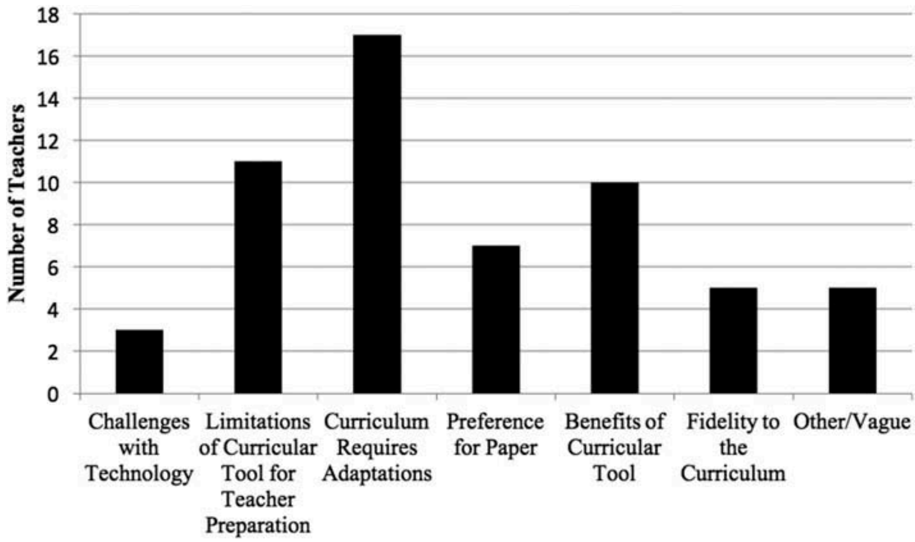

Figure 11. Why did teachers use the curriculum in this way?

responded to each prompt once, the number of responses would have been 16 × 46, or 736. The actual number of responses was 281, resulting in a use as a percentage of opportunity to use of 38%. It is interesting that this percentage is higher than any of the opportunity to use percentages for the video in Figure 10.

Rationale behind curriculum use

Finally, we were interested in the reasons teachers expressed for the ways in which they used the Web-based curriculum and the MECMs. For example, we were interested in knowing why some teachers chose to print materials from the website rather than use the online materials, as this choice affected their ability to access the MECMs. We asked the teachers to provide reasons for the way in which they used the curriculum through an open-ended question on the postsurvey (see Figure 11). Teachers described both positive and negative factors that affected how they used the curriculum materials. For instance, Teacher 132 described the benefits of an online curriculum, saying, "I predominantly used the website online because it was very user friendly. I liked that it was always there … I could access it from home or wherever as long as I had Internet service and my code." Teacher 197 mirrored this sentiment in responding, "It was easy to use and navigate. I liked the convenience of having everything right there." However, other teachers mentioned factors that negatively impacted their curriculum use, including challenges with the technology ("I could not show the slides and access the script at the same time," explained Teacher 133) and limitations of the curricular tool for teacher preparation ("I like to thoroughly read and take notes about the curriculum I am teaching. It is much easier for me to have a paper copy to do this," noted Teacher 167).

Discussion

Our overarching goal in this research and development effort was to create educative curriculum materials that support teachers in teaching argumentation. This effort requires both creating effective materials and finding ways to make them convenient and accessible to teachers. We hypothesized that the affordances of a Web-based teacher's guide could support both the creation of more helpful features (e.g., videos rather than just text) and enhanced opportunities for accessing the features (e.g., multiple means of accessing videos, interactive elements that customized access). The fact that 89% of the teachers reported using the curriculum through the website and 87% used one or more of the educative videos suggests that MECMs are a potentially powerful tool for supporting future teacher learning.

This study makes two main contributions to the field. First, we provide a proof of concept for how MECMs can be designed to support a science practice such as argumentation, including an example of a development process and a preliminary set of design heuristics. Second, because (to our knowledge) there have not been any other studies that have collected back-end data on teachers' use of educative curriculum materials, this study provides an initial data point that can be used as a baseline for future efforts as we develop improved resources to meet teachers' needs. This study provides several insights to support future design and research efforts around both the design of multimedia educative supports and the design of Web-based curriculum materials more broadly.

Designing multimedia educative supports

One size does not fit all, but more needs to be known about reasons for variation

Because we designed the resources as a toolkit that offered a variety of supports to different teachers, we did not intend for each teacher to use every resource, but we were interested in the patterns of use that the MECMs received. Our results are consistent with the findings of other researchers that teachers' use of educative curriculum materials varies widely (Arias et al., 2016; Billman, Mihocko, & Cervetti, 2014; Schneider, Krajcik, & Marx, 2000). Some teachers used the MECMs heavily, whereas others did not use them at all. However, this variation was not related to the teacher background variables that we investigated (such as years teaching science or prior training in argumentation). Consequently, future research needs to consider other variables that may explain this variation, such as teacher orientation toward curriculum (Remillard & Bryans, 2004). These findings suggest a need to both learn more about what encourages or discourages teachers from using the MECMs as well as continue in our efforts to make the MECMs more customizable and more tailored to the needs of individual teachers.

Just-in-time supports

Our results suggest that just-in-time educative features embedded in the flow of teachers' lesson planning process are likely to get more use than a separate library of resources. Although this is consistent with a basic principle of educative curriculum materials, that part of their value is that they are inherently situated in teachers' everyday practice (Ball & Cohen, 1996; Davis & Krajcik, 2005; Schneider et al., 2000), we were nonetheless struck by how strongly the data support this approach. There were 15 times more views of videos embedded in lesson preparation sections than views of those exact same videos embedded on the library page. In our focus groups, teachers had stated that they wanted to be able to access videos in both ways (both within a lesson and through a library), and it may still make sense to provide the library to teachers as a resource, but embedding videos in lessons appears to be a much more powerful way to reach teachers.

Reflective self-assessments

Reflective self-assessments got a modest but encouraging level of use by teachers and may be an avenue for improving the customization of the educative features provided to teachers. As described in our design principles, active learning and reflection have been shown to improve learning outcomes in online learning (U.S. Department of Education, 2009). However, we expected that it would be challenging to get teachers to voluntarily respond to reflection prompts. On the contrary, we found a relatively high frequency of use for this feature (38% of the opportunities for use). This type of educative feature, afforded by the Web-based teacher's guide, is worth further exploration. For example, one shortcoming in our curriculum was that teachers were unable to see how they had responded to previous reflective self-assessments. Creating a synthesis of prior responses or more customized curriculum based on teachers' responses may encourage even greater response.

Other areas for improvement

Because teacher use dropped off for MECMs that were placed later in the curriculum, it may be important to make sure that the first few videos provided to teachers specifically meet their needs and attract them to watch future videos. In addition, when new student activities were introduced we observed spikes in the number of teacher views. More specifically labeling these activities as new could encourage other spikes in observation. In addition, realizing that these spikes may occur could be important for the design of videos around new activities.

Furthermore, our project advisors suggested labeling the embedded videos more clearly to provide teachers with more information about why they might wish to play the video. For example, we could phrase the titles as questions to clarify the kind of support the video provides (e.g., "How can I help students distinguish between relevant evidence and irrelevant evidence?"). Other areas of improvement could include customizing the videos more precisely to fit their location in the curriculum.

Also, although teachers were more likely to answer a reflection question than they were to watch an embedded video in a lesson, the videos that were recommended as responses to reflection questions got relatively little use (19% of opportunity to use). We had expected the opposite: that recommendations customized to teachers' responses would get more use than recommendations simply embedded in the lesson. However, one possible explanation is that there was not enough customization in the customized responses. With only 24 videos to choose from, the same videos were recommended multiple times, and the alignment between the response and the recommendation was not always strong. Future development efforts could investigate how to improve the fit between teachers' needs, as indicated by their reflection responses, and the customized supports provided. Supporting teacher reflection and active learning can be essential for helping teachers develop richer pedagogical content knowledge and classroom instruction (Schneider & Plasman, 2011).

Designing Web-based curriculum materials

In order for MECMs to be used at all, teachers must be convinced that using the Web-based teacher's guides is more useful than print (Petish, 2004). A small but significant number of teachers reported that they printed the lesson plans and worked only from paper versions, thus ensuring that the MECMs would not get used at all by those teachers. If we want to be able to take advantage of the affordances of the Web-based teacher's guide to create enhanced educative features, we must address some of the shortcomings teachers have found with using a Web-based teacher's guide. For example, teachers expressed a desire to be able to add notes and highlight aspects of the curriculum itself as they taught the curriculum, so future versions of the digital curriculum could include an annotation feature to address this need.

Limitations and future directions

Although our data on embedded video views and library video views were tied to individual teachers, a portion of our data (reflection responses and video views from recommendations to reflections) were not tied to individual teachers. Thus, it is difficult for us to establish clear patterns in the use of all of the MECMs. Future research should gather additional individual back-end data on teacher use of reflective features in order to provide greater insights into these resources. In addition, this study did not investigate the relationship between the teachers' use of the curriculum and their actual classroom instruction or their student outcomes, both of which are important areas for future research.

This study contributes to understanding of teachers' use of MECMs in the context of a Web-based teacher's guide. Our results suggest that teachers do use these materials and that providing MECMs may be a promising way of supporting educational reform, in particular as a support for the new focus on science practices like argumentation. However, our results also show that teacher use varies widely, though it is interesting that it does not vary significantly by teacher background characteristics, such as years of teaching experience or previous teacher education experiences (e.g., professional development or class) on argumentation. Future research efforts should focus on how to maximize the value of these materials in order to make it more likely that all teachers will use them effectively. In particular, MECMs that are customized for teacher needs and support active learning and reflection could be a promising avenue for further research.

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