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Preservice Science and Mathematics Teachers and Discursive Metaknowledge of Text

Through the juxtaposition of traditional and new literacy tasks and through explicit attention to problematic texts and literacy practices, these preservice teachers developed discursive metaknowledge of the centrality of literacy to learning content.

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Literacy—even narrowly construed as reading and writing—is central to learning science and mathematics, and teachers of science and mathematics can better teach their students if they understand literacy's role in learning (Moje, 2007; Yore, Bisanz, & Hand, 2003). Recent scholarship has emphasized the need to build more powerful connections between literacy approaches and disciplinary content instruction (Conley, 2008; Moje, 2006, 2007; Shanahan & Shanahan, 2008) in order to improve the learning opportunities for adolescent learners (Ippolito, Steele, & Samson, 2008). But despite the consensus about literacy's importance to teaching and learning in the content areas, secondary preservice teachers are often dismissive of efforts to incorporate practices that focus explicitly on literacy (Moje, 2006; O'Brien & Stewart, 1990; O'Brien, Stewart, & Moje, 1995). The question is: What would science and mathematics preservice teachers need to understand about literacy to better appreciate its role in teaching and learning content?

This article explores that question and takes an approach uncommon in the research on teacher education in content area literacy. As science and mathematics teacher educators, we start with a focus on content knowledge rather than on literacy strategies. We know that many preservice teachers believe that the most effective way to learn content is by directly engaging with subject matter. In science this might be through hands-on inquiry investigations, and in mathematics, by solving real-world applied problems. Further, preservice teachers often perceive content area literacy strategies to be a burdensome collection of technical terms and protocols rather than a vehicle for supporting learning (O'Brien et al., 1995). Consequently, texts are often seen as supplementary resources for—or even barriers to—the applied learning to which preservice teachers are most committed.

Perspectives that disconnect content learning from literacy practices are rapidly becoming untenable (Norris & Phillips, 2003). With the Internet commanding an increasing part of our daily lives, the classic science or mathematics classroom consisting of a teacher, students, and a printed textbook is fast becoming obsolete (Walker & Bean, 2003). Information is no longer

easily vetted by teachers, librarians, or publishers, and new skills are required to capitalize on the information potential of the World Wide Web. Researchers have begun to examine student practices related to digital literacies (Brem, Russell, & Weems, 2001; Coiro, 2005; Damico & Baildon, 2007; Leu, Kinzer, Coiro, & Cammack, 2004; McNabb, 2006; Wilder & Dressman, 2006), but little work has examined what teachers know about these new literacy practices or how such knowledge builds on established understandings of the role of literacy in mathematics or science learning (Shanahan & Shanahan, 2008).

With the infusion of new information sources, we see expanded opportunities to help preservice teachers develop more sophisticated understandings of content area literacy. This article describes and analyzes one such opportunity—an assignment given within the context of a preservice secondary science and mathematics content-methods course. First, we briefly examine how scholars have accounted for the resistance of preservice teachers to content area literacy approaches. Second, we build upon Gee's (1989) notions of metaknowledge and powerful literacy to explain how these constructs illuminate preservice teachers' perspectives on content area literacy and content learning. Third, we show how an assignment problematized school science and mathematics literacy practices and provided the preservice teachers with opportunities to develop valuable discursive metaknowledge. Finally, we discuss implications of this work for teacher educators.

Background

Preservice Teachers' Views of Content Area Literacy

The extensive literature on preservice teachers and content area literacy offers a compelling account for preservice teachers' resistance to literacy approaches that weaves together at least three major strands. One strand argues that the structures of traditional content instruction resist content area literacy approaches (Alger, 2007; Moje, 2006; O'Brien et al., 1995). For instance, many content area literacy approaches aim to disperse instructional authority across students and teachers, while traditional content instruction centers authority on the teacher and textbooks (Draper, 2002).

A second strand suggests that teachers' pedagogical goals resist content area literacy approaches. The problems with texts that many preservice teachers see as pressing are simply not addressed by literacy strategies (Donahue, 2000; Fisher & Ivey, 2005). Many teachers (and their students) view reading science and mathematics texts as boring—and reading strategies generally fail to make boring texts more interesting. Instead, preservice teachers want strategies to make the subject matter instruction more experiential and applicable to the real world and less text based. Compounding this perceived misalignment of goals is the fact that content teachers may feel poorly qualified to teach using content area literacy approaches (Hall, 2005; Lesley, Watson, & Elliot, 2007), further reducing the likelihood of their use.

A third strand in the literature considers preservice teachers' beliefs about teaching and how such beliefs frame—and ultimately resist—their content area literacy experiences in teacher education programs. Holt-Reynolds (1992) showed how beliefs filter experiences and dramatically shape what is learned in teacher education courses. For example, based on their own experiences, preservice teachers may believe listening to lectures is active engagement in learning and simply dismiss teacher educators' arguments that such learning is passive (Holt-Reynolds, 1992).

Across these accounts, we find compelling reasons for why content area literacy approaches are not visible in preservice teachers' emerging practices. But we also notice an important feature common to each strand: Content area literacy is largely positioned as a set of strategies external to science or mathematics content. Content area literacy is seen by preservice teachers as a "literacy" approach that is secondary, rather than central, to teaching and learning in the content areas.

For this study, we begin with the assumption that preservice teachers' success in and commitment to their disciplines also makes it difficult for them to see how literacy practices are central to the learning of content. We recognize that our preservice teachers have achieved considerable success in school science and mathematics while pursuing disciplinary subject majors. Like many secondary teachers, their

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primary identities are as disciplinary experts (Beijaard, Verloop, & Vermunt, 2000; Helms, 1998). Because they have been successful at learning anatomy or organic chemistry or calculus, the literacy practices of the disciplines have become largely invisible to them (D. Hartman, personal communication, March 28, 2007).

To make the literacy practices of content learning visible, we use a novel strategy that compares how students in schools engage with both traditional and Internet text. The content of these texts appropriates features of legitimate science or mathematics subject matter but is in fact nonsensical. We show how the insertion of problematic content into the literacy practices of school disrupts the invisibility of text and illustrates how literacy practices fundamentally shape understanding. We use Gee's (1989) concepts of metaknowledge and powerful literacy to explain what our preservice teachers learned from this assignment and how the exercise rendered previously invisible literacy practices visible.

Discursive Metaknowledge and Content Area Literacy

Gee (1989) equated literacy with the ability to participate in social situations or discourses. Although much of Gee's later work in discourses emphasized issues in addition to participation (e.g., identity), we find his earlier formulation of literacy to be useful for this study. Gee (1989) noted two different types of literacies or discourses: "primary discourses," which develop in familial surroundings, and "secondary discourses," which are used in all other contexts (p. 22). From Gee's perspective, the purpose of schooling is to help students participate in and gain control over secondary discourses that are valued by society. Discourses so valued are considered "dominant discourses" (Gee, 1989, p. 20).

Gee argued that the alignment between mainstream culture and dominant discourses helps explain why mainstream students generally have less difficulty participating in such discourses than do other students. Because the dominant discourse is similar to their experiences, there is less difference to overcome. We argue that a parallel exists here—that because content area teachers are highly proficient in their dominant discourse, they, like mainstream students, are challenged to notice it. This has the effect of rendering the discursive practices of subjects such as science and mathematics, like the proverbial water to the fish, invisible to the teacher.

Gee (1989) called the knowledge of discursive practices "powerful literacy" (p. 23). Powerful literacy goes beyond participation in—or control of—a discourse to include the metaknowledge required to critique that discursive practice. For example, one kind of discursive metaknowledge useful for teachers includes understanding how reasoning in everyday situations compares to reasoning in science and mathematics. If a teacher explicitly understands how the dominant discourses of school science and mathematics work—as discursive practices—then this knowledge can be used to help students who do not control these discourses to bridge the gap. Indeed, researchers have shown that traditional science instruction often excludes students' personal experiences as resources for evaluating scientific claims (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Teachers who have discursive metaknowledge of how claims work, both in students' everyday reasoning and in school science, can help students understand how school science is both similar to and different from everyday life.

Gee's notions of metaknowledge and powerful literacy provide a useful frame for considering our content area literacy work with science and mathematics preservice teachers. As teacher educators, we aim to prepare teachers who understand and can bridge the differences in the dominant discourses of school mathematics and science and the secondary discourses of their students. Because university content courses generally fail to develop metaknowledge of science and mathematics as discursive practices, teacher education has an important role to play. In this article, we illustrate how one assignment was useful

in generating metaknowledge of important features of school science and mathematics discourse that are particularly important for understanding the central role of literacy in teaching and learning content.

Approach

Participants

Thirteen science and 11 mathematics preservice teachers in the final year of a five-year teacher education program completed a semester-long science and mathematics teaching methods course taught by the authors. These secondary preservice teachers were concurrently taking a practicum in local middle and high schools. This content methods course precedes a semester-long student teaching experience. All preservice teachers participated in this assignment and granted their permission for us to examine their reports for this study; all names used in reporting results are pseudonyms.

Assignment

The assignment was to investigate how secondary school students made sense of traditional literacy practices compared with online literacy practices. We use *traditional literacies* to denote practices associated with reading and comprehension of print text and *new literacies* to denote those practices associated with online reading and comprehension (Leu et al., 2004). The assignment was to conduct think-aloud protocols with practicum students as they engaged with a traditional literacy task that consisted of a paragraph of informational text and an associated line graph and with a new literacies task that asked the student to use the Internet to find additional information related to the text and graph. During these two tasks, the preservice teachers took field notes and recorded what students said and did. The preservice teachers then wrote a three- to five-page analysis paper of their work with students.

To scaffold our preservice teachers' abilities to productively investigate the student literacy practices, we modeled using the tasks during the methods classes. First, we showed them how to conduct the think-aloud using a paragraph different from the text used in the assignment. Then the preservice teachers worked in pairs to do the tasks, one taking the role of the investigator and the other playing the role of a secondary school student. After the pairs of preservice teachers finished, we debriefed as a group. In the next three weeks, the preservice teachers conducted their investigations and wrote their analysis papers.

Description of Tasks

The traditional print task, reproduced in Figure 1, consisted of a paragraph of informational text and a line graph illustrating the relationship described in the text. The content of the task appropriated features common to science and mathematics texts but was, in terms of factual content, nonsensical. The major claim of the paragraph is that change in global temperature is related to the decreasing number of pirates in the world. This text was selected to see how students coordinated the information in the paragraph and the line graph. In addition, the text made problematic use of correlation to argue a causal claim, and the graph contained a number of inaccuracies. In the Internet task, we were curious to see what challenges students encountered as they searched for information (e.g., how and where search strategies broke down). The first part of the investigation had the preservice teachers ask the student to think aloud while reading the print text about pirates and global warming; the second part had the student think aloud while using the Internet to answer the question, How might pirates affect global warming?

Data and Analysis

We drew upon the 24 preservice teachers' analysis papers and our own reflective notes and memos written as we conducted this work. We used inductive coding (Miles & Huberman, 1994) as we looked systematically at the reports using qualitative data analysis software. We found that the papers contained patterns for how students and preservice teachers view content-specific literacy practices. These patterns formed the basis for our identification of the three types of discursive metaknowledge we describe next.

The Development of Discursive Metaknowledge

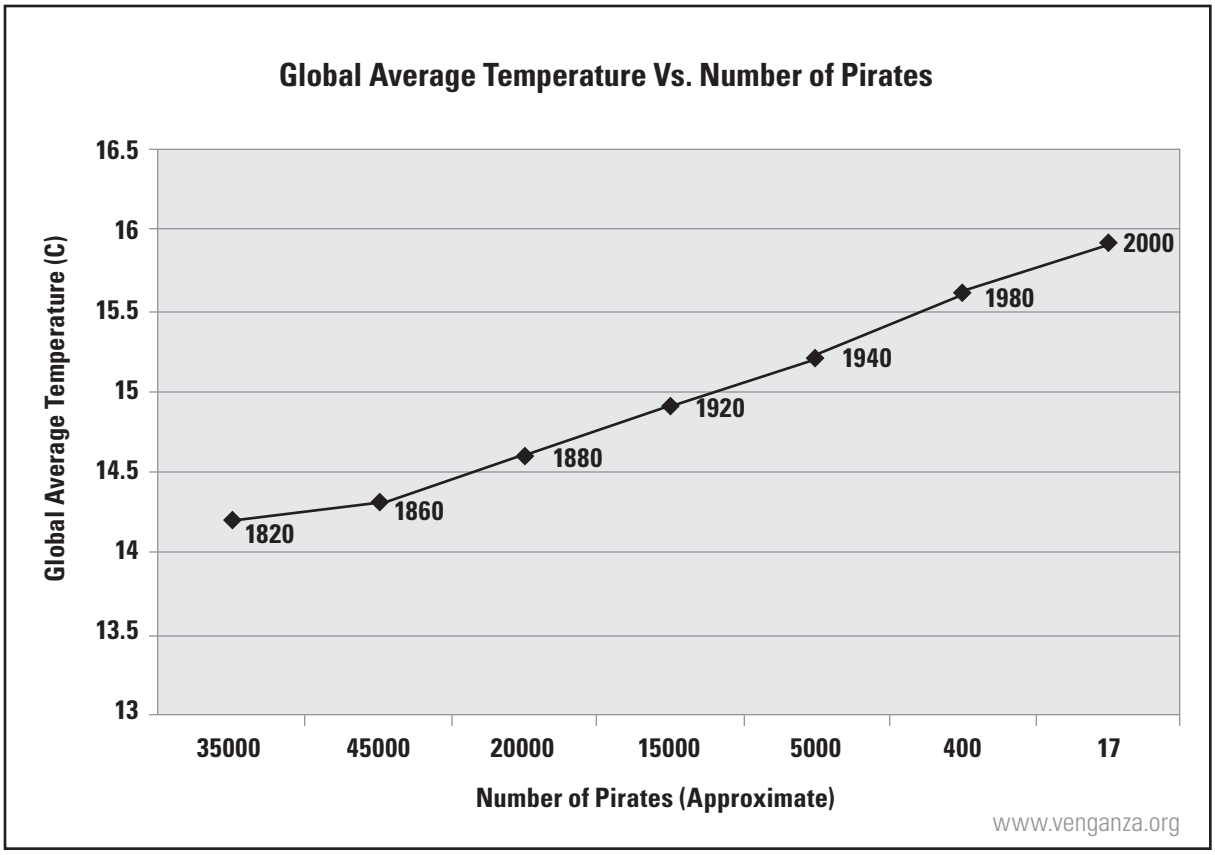
To explain how these problematic texts served as opportunities to develop metaknowledge about school

Figure 1 Traditional Print Task

Part one of the task was to conduct a think-aloud with a student reading this text and the second part was to ask the student to think-aloud while using the Internet to answer the question, How might pirates affect global warming?

Rising Global Temperature

You may be interested to know that global warming, earthquakes, hurricanes, and other natural disasters are a direct effect of the shrinking numbers of Pirates since the 1800s. The graph below shows the approximate number of pirates versus the average global temperature over the last 200 years. As you can see, there is a statistically significant inverse relationship between pirates and global temperature.



Note. Reprinted with permission from www.venganza.org

science and mathematics discursive practices, we look at two sites within the process—the practice session where the preservice teachers used the tasks for the first time and the preservice teachers' written reports. In particular, we found that these tasks helped preservice teachers develop the following three types of metaknowledge:

1. How textual authority shapes reading
2. How literacy practices are dialogic
3. How literacy practices are contextual

Although such metaknowledge has long been a part of the discourse community of literacy educators (Moje, Dillon, & O'Brien, 2000; Wells, 2007), these ideas

were new to our preservice teachers. In the juxtaposition of traditional and new literacy tasks and through explicit attention to the problematic texts and literacy practices, preservice teachers developed discursive metaknowledge of the centrality of literacy to learning content.

How Authority of Text Shapes Reading

Textual Authority Metaknowledge Developed in Practice Session. The first type of metaknowledge—how the authority of text shapes reading—was developed in the context of the preservice teachers' practice session with the tasks. One teacher, Karen, who took the role of a student in the practice session, read the traditional information text in what was initially a surprising way. Instead of reading the word *pirates* to mean sea-faring outlaws, Karen pronounced the word "pur-ah-tees" and interpreted the text to be about an obscure animal or plant species. That is, she read the text to be about the decline of an authentic species as the result of global warming. When she described what she'd done in the subsequent class discussion, a number of her classmates initially laughed, but it was clear that Karen wasn't trying to be funny. When asked to explain what she was thinking about as she read the text, she explained that she had initially considered, and rejected, the sea-faring outlaw interpretation because then "the paragraph wouldn't make sense." She also explained that, as a student in science, there were many times when she had to read things that didn't initially make sense—but that she had to learn them. Karen's explanation was intriguing and, as a class, we looked again at the features of this text that made it appear authentic.

Indeed, we identified a set of features that make quite a compelling case. For instance, the pirates text used features of scientific discourse such as technical language (e.g., *statistically significant*, *inverse relationship*), it considered a scientific "problem" (e.g., global warming, earthquakes, other natural disasters) and cued presumed authority structures (e.g., the prompt was offered as a text provided by a teacher in a class). From this vantage point, the class came to recognize that it was quite plausible and reasonable for a reader to see the pirates text as an authentic school science text. As Karen alluded to in her own explanation, when one is reading in school science and mathematics, the authority of the text positions reading as the process of extracting meaning from that text.

Because her peers recognized Karen as an excellent student, this was a poignant demonstration that different interpretations of text do not simply align with some facile notion of "reading skill." Karen's interpretation showed that a reader's perception of the authority of the text shapes how one interprets that text. We also recognized that what Karen did was, in fact, what is generally expected of students in school reading. How such a presumption can radically shape the interpretation made a deep impression on all of us.

Textual Authority Metaknowledge Developed in Reports. The preservice teachers' reports also document how presumptions of textual authority shaped students' engagement with the tasks. The students tended to read the traditional print task very carefully, often considering each word or rereading sentences. One preservice teacher wrote, "With the paper reading, the student ran his finger over all of the words in order not to miss a word and to understand the print." In contrast, the preservice teachers reported that the students seldom read carefully on the Internet, instead quickly scanning search results and webpages to identify if relevant information was presented. Another preservice teacher, Jenn, explained this pattern, stating, "If the student felt uncomfortable with information on a certain site, they just left it and looked for another site that made them feel comfortable."

Most students made quick judgments about the authority of a website. For instance, one student explained why she left one page as soon as she determined it was a blog: "Blog pages are not credible! Blogs are websites where people post their opinions." Other students simply selected the link returned first by the search engine and then quickly scanned the website for keywords, often reading only a small portion of the page. Still other students found websites related to scientific organizations that were deemed trustworthy. The key point here is that the preservice teachers saw clear differences in the students' approaches to text; how students approached the text was related to the perceived authority of that text. This metaknowledge of discursive practice was further developed by the observed contrasts of the print

text reading and the online reading approaches employed by students.

If we consider traditional print text reading as part of one discursive practice and reading online as part of another (Coiro, 2005; Leu et al., 2004), then we would expect to see differences in student participation. Here, the traditional task was embedded within the discourse of school science and mathematics. Consequently, the students generally aimed to read the print text carefully and to consider each word. In the discourse of online reading, students showed that textual authority was based on types of websites (e.g., blogs, commercial sites, educational institutions) as well as on how successfully the site matched the search terms. One preservice teacher, David, felt that the Internet opened up opportunities for students to become more critical thinkers because the presumption of authority in traditional texts was removed. He found that "when searching for information, [his] student was truly engaged in critically analyzing information and reading with a bit of skepticism. This was in great contrast to how she read the paper-based material earlier."

This comparison of the approaches to text in traditional print and Internet formats provided opportunities for the preservice teachers to develop metaknowledge of how authority shapes practices. The second type of metaknowledge the preservice teachers developed in their investigations concerns the dialogic nature of literacy practices.

How Literacy Practices Are Dialogic

Dialogic Metaknowledge Developed in Practice Session. The second type of metaknowledge—that literacy practices are dialogic rather than one-way transmissions of information—developed in the practice session in the following way. Karen's "purah-tees" interpretation had been a dramatic demonstration of how reading involves interaction between the reader and the text. The way Karen had understood the text was not due to an inability to decode text. Because informational text in school science and mathematics is considered to be objective and to have unambiguous meaning, this example showed how a reader's perspective and choices shaped her reading of text.

The realization of the importance of the interaction between reader and text was surprising to our preservice teachers. And because preservice teachers may fail to recognize the ways in which text in science and mathematics is dialogic, this experience provided them with a vivid example that reading is more than extracting meaning from text and that the reader's perspective shapes what is understood.

Dialogic Metaknowledge Developed in Reports. The preservice teachers found that, like Karen, how their students engaged with the tasks was related to how they made sense of the content. One student immediately suspected that the premise of the traditional task was false. Therefore, he "looked for ways to interpret the passage and graph as incorrect." For students who did not examine the premise, the approach could be quite different. For instance, Erin explained, "[one student] read exactly what was on the page and restated what she read or thought she read. The student did not try to interpret the graph." This student "did not once argue with [the claim] or question the data presented to her." The use of problematic content for the traditional task showed the preservice teachers that reading is a dialogic process that depends not only on the student's ability to decode text but also on how the student approaches the text.

Differences in approaches to text were even more striking in the Internet task. Each preservice teacher's report attempted to characterize either the success or failure of the student to conduct a fruitful search and to productively interpret information on websites. How this was done varied: Some students simply clicked the first website returned by the search engine, but others made selections from the search page. Some students selected the "cached" version of the search result because the search terms were highlighted on the linked page. Other students used the key combination "control + f" to immediately begin searching the linked page for their search terms.

Across the two tasks, the preservice teachers saw that how students engaged with the task shaped what meaning they made. Instead of a straightforward process of decoding text, a dynamic and idiosyncratic process was observed by the preservice teachers. As Jordan summarized in her report, "[It] was particularly interesting to see exactly how students gain

information, decide whether the information is credible, and whether the information is relevant to the task with which they are presented." It was clear to the preservice teachers that students engaged with the texts in multiple ways. The dialogic nature of literacy practices is metaknowledge similar to the third type we discuss—the contextual nature of literacy practices.

How Literacy Practices Are Contextual

Not only did the preservice teachers see how students engaged with the tasks dialogically, but also they saw that, for some students, facility with one task did not mean facility with the other. That is, some were adept at reading the traditional text and yet demonstrated difficulty in reading on the Internet and vice versa. The preservice teachers were struck by this observation due to their presumption that reading online would be similar to reading print text—that is, reading is reading is reading.

Preservice teachers documented the ways in which students either did or did not demonstrate facility with Internet text. Overall, they found that students needed to develop a more robust set of Internet reading comprehension strategies. This was surprising because, as Susan noted, "I think that a lot of times, teachers assume that since students have grown up with this technology that they'll automatically know how to use it." Further, it was not the case that students read the traditional task the same way as the Internet task—showing that reading printed text is different from reading online (Coiro, 2005; Coiro & Dobler, 2007). Doug explained this difference as follows:

> For the traditional portion of the activity, I felt that because there were no other materials to reference and compare the information to she may have felt satisfied in believing it and not questioning its validity. As for the new literacies portion of the activity, I felt that the student spent much more of her time critically evaluating what she read.

Doug's explanation suggests that the reading practices of an individual student differ based on the context. The examination of these literacy practices showed that "critical evaluation" was not a stable trait and that students' literacy practices varied by context.

Implications

The approach we have taken in this study adds to our understanding of the resistance of preservice teachers to content area literacy. It also demonstrates how a convergence of perspectives from teacher educators in both literacy and the content areas can be generative of new insights and questions (Draper, 2008; Forman & Ansell, 2001; Lemke, 1990; Shanahan & Shanahan, 2008; Tuckey & Anderson, 2008). Such questions include: How does coming to understand the literacy practices of a content area reshape preservice teachers' own understandings of content knowledge and how to teach it? The work begun here also suggests that teachers need to understand not only the literacy practices of their content area but also the literacy practices of their students. What does such understanding look like, and how might it develop? What approaches might foster this kind of learning within preservice teacher education?

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A basic challenge facing content area literacy instruction has been to convince preservice teachers that literacy belongs in the content classroom. Our approach of focusing on problematic content tasks helped preservice teachers see that literacy practices are actually already there. Rather than focusing on content *and* literacy, we made progress toward an emergent understanding of the literacy practices of content. We suggest that the discursive metaknowledge of literacy practices of content contributes to a productive notion of powerful content literacy for teachers. Although most teachers would agree that knowing students well is important for motivating learning, our work shows that teachers should also know how students' discursive practices shape opportunities to learn science and mathematics.

Further, teachers' abilities to recognize and address students' struggles with school-based discursive practices may depend, in part, on their abilities to understand how meaning is shaped by authority, how

literacy practices are dialogic, and how literacy practices are contextual. These are promising avenues for influencing knowledge and dispositions of mathematics and science preservice teachers. In turn, this may help them to meet the needs of diverse learners in this changing literacy landscape.

In summary, we contend that the literacy practices surrounding content understanding in science and mathematics are so familiar to preservice teachers as to be largely implicit. This investigation challenged preservice teachers' basic presumptions about the role of literacy in the learning and teaching of science and mathematics content. In doing so, previously invisible discursive practices were made visible. We believe that teachers who see how literacy is central to understanding content can also see how content area literacy approaches help students learn content better. Teachers will need this kind of powerful literacy to help their students learn in the 21st century.

Notes

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