"Why Are There So Many Words in Math?": Planning for Content-Area Vocabulary Instruction

Mathematics involves an astonishing amount of reading. For example, to introduce a chapter on linear functions, a recent-edition Algebra 1 textbook illustrates the concept of graphing constant speed in this way:

> Most people believe there is no speed limit on the German autobahn. However, many stretches have a speed limit of 120 km/h. If a car travels continuously at this speed, y = 120x gives the number of kilometers that the car would travel in x hours. (Seymour et al., 2007, p. 289)

Teachers may wonder about this example. Does it help students if they have never heard of the German autobahn? Will students be able to connect this linear function example to existing background knowledge?

We have been working with approximately 100 middle and secondary mathematics and science teachers on a project named Teaching Mathematics in a Technical World (TMTW), now in its third year. TMTW workshops, held throughout the year, aim to help teachers integrate technology, real-life experiences, and instructional literacy strategies into classroom practice to increase the achievement of diverse groups of young adolescents, including English Language Learners (ELLs) and students with a wide range of background experiences. We asked TMTW participants about the German autobahn algebra example. Many teachers thought their students would be unfamiliar with the word *autobahn*. Living in rural and oftentimes remote communities, these young adolescents would mostly be familiar with two-lane roads, with or without stripes or pavement. For these middle level students and their teachers, this real-life example appears to add complexity and new vocabulary to the lesson rather than connecting a new idea to students' existing knowledge.

Thinking about the challenge presented by vocabulary in math class, one TMTW middle school math teacher observed,

> The biggest challenge I face is that my students come from different backgrounds, but also they come to me with different experiences and levels of learned vocabulary. I need to be more alert as to which students fully understand the vocabulary and which students still need more work with understanding.

We wondered how we might assist teachers in deciding which words to teach that would help middle level students understand content-area texts and make connections between new concepts and background knowledge.

By thoughtfully selecting words to emphasize, teachers can design instruction to help young adolescents comprehend content-area texts and develop connections between background knowledge and new concepts.

In this article, we describe a planning tool for vocabulary instruction called the 5 Cs, which we developed to help teachers consider which words to teach in content-area classes such as mathematics, science, and social studies. By thoughtfully selecting words to emphasize, teachers can design instruction to help young adolescents comprehend content-area texts and develop connections between background knowledge and new concepts.

Content-Area Literacy and Mathematics Vocabulary

The conceptual load of content-area texts is remarkable. Abstract concepts, reading level, sentence structure, and academic vocabulary all contribute to the complexity of textbooks and other curriculum materials (Barton, Heidema, & Jordan, 2002). One specific challenge is the large number of new or unfamiliar words that may inhibit connections to students' existing knowledge and create barriers to comprehending content-area texts (Kieffer & Lesaux, 2010). Vocabulary knowledge, a significant predictor of reading comprehension, is a major challenge for students from diverse backgrounds, especially for ELLs in terms of academic vocabulary and the specialized meanings associated with these words (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006).

In common usage, *product* means something produced for consumption, while mathematically it means the result of multiplying a set of numbers.

Content-area literacy addresses this vocabulary challenge by emphasizing ways to make sense of the various texts adolescents encounter across disciplines (Draper, Smith, Hall, & Siebert, 2005). It supports the view that students take part in a process of constructing knowledge through reading, writing, and discussion from different perspectives (Fisher & Ivey, 2005). Content-area literacy remains focused on conceptual understanding of subject matter, with reading strategies playing a supporting role in helping students construct conceptual knowledge and make connections to background knowledge (Fordham, 2006). Clearly, a focus on vocabulary is a key element of content-area literacy.

Mathematics vocabulary is unique in that many words have both general and specific meanings, while at the same time key terms must be defined in a precise manner (Shanahan & Shanahan, 2008). This seeming contradiction creates several challenges to teaching and learning mathematics vocabulary. First, some words may be unfamiliar to students, while others have common meanings that are different from their usage in mathematical contexts. *Product* is an example of this type of word. In common usage, *product* means something produced for consumption, while mathematically it means the result of multiplying a set of numbers. Students' existing knowledge of words like *product* may mislead them in terms of conceptual understanding in a mathematics context.

Second, mathematics curriculum materials may contain new words that represent new concepts. While such vocabulary may have limited application beyond the specific mathematical contexts in which they are taught, these words represent new knowledge students must build to understand key concepts. Third, curriculum materials may present additional words that are meant to help connect concepts to real-world experiences but that also increase the vocabulary complexity of mathematics lessons. The word *autobahn* from the example represents this kind of word. This combination of word types presents special challenges to ELLs, who may be less familiar with common mathematical terms, specialized uses of these terms, or specific words to describe real-life contexts (Harper & de Jong, 2004).

Careful and deliberate selection of words is a key principle of effective vocabulary instruction (Fisher & Blachowicz, 2005). Identifying vocabulary in advance helps teachers anticipate the kinds of support needed to make lesson content comprehensible, especially for ELLs or students who struggle to comprehend what they read (Harper & de Jong, 2004; Lager, 2006). A challenge for content-area teachers is to choose vocabulary that will help young adolescents both understand new concepts and make connections between real-world experiences and existing background knowledge. These kinds of connections help students build conceptual models and deepen their understanding of mathematics (Conley, 2008).

At the same time, teachers must consider a balance of concept-related vocabulary and words

specific to the context in which the concepts are introduced. Teachers need to combine what Beck, McKeown, and Kucan (2002) describe as tier 2 words—high-utility words found in written text but less common in everyday conversation—and tier 3 words—words specific to content-area domains such as mathematics, science, or social studies. The goal is to select a relatively small number of words and to focus on building a deep understanding of them (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006).

Once a set of words is selected, teachers must provide students with multiple exposures to vocabulary in meaningful contexts, instruction focused on individual words, and opportunities to explore ways in which words are conceptually related to one another (Graves, 2006; Stahl & Nagy, 2006; Vacca & Vacca, 1999). This kind of vocabulary instruction takes time, so the process of selecting a set of key words is crucial.

Planning for Vocabulary Instruction: The 5 Cs

The purpose of the 5 Cs tool is to help teachers consider vocabulary in content-area curriculum materials and decide which words to teach. The 5 Cs are: Concepts, Content, Clarify, Cut, and Construct. This tool is based on research that shows students learn vocabulary by connecting new words to known words and ideas, focusing on a small number of key words, and experiencing the words in multiple contexts and through discussion (Bromley, 2007; Moschkovich, 2002; Stahl & Nagy, 2006). The 5 Cs tool guides teachers through a process of identifying words that may be new or unfamiliar to middle level students, categorizing them by importance and relevance to lesson goals, and deciding which words to teach as well as when in the lesson to teach them. Figure 1 is a template of the 5 Cs.

In the following sections, we use example curriculum materials from the National Council of Teachers of Mathematics (NCTM) to illustrate each step of the 5 Cs process. This middle-grades lesson, Illuminations: On Fire (NCTM, 2008), is particularly relevant to TMTW participants and their students, as many of them live in areas prone to wildfires. These materials contain large numbers of both concept-related mathematics vocabulary and words from the content-specific real-life topic of wildfires. Figure 2 shows a completed 5 Cs plan sheet based on vocabulary found in these lesson materials. Figure 3, The Fire Environment, is an information page attached to Heating Up, a worksheet for students that is an integral part of the lesson.

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Concepts: What Mathematics Words Are in This Lesson?

The first C helps teachers focus on mathematical concepts by asking them to identify words that are essential to a conceptual understanding of the lesson. These are words that may be new to students, may have different meanings in mathematics compared to their typical definitions, and may be discipline-specific words that young adolescents may not encounter elsewhere. The words *probability* and *average* from the On Fire lesson are examples, as both may be familiar to students but not necessarily deeply understood.

Content: What Subject-Matter Words Are in This Lesson?

The second C asks teachers to identify words in the lesson that are not mathematical terms but that may be unfamiliar to students. Many of these subject-matter words come from the real-life examples included in texts to help middle level students connect background knowledge to mathematical concepts. On Fire puts mathematics in a rich context, but in doing so adds a large number of challenging words to the lesson. Students may recognize some words, such as *factor* and *rapidly*, but other words may be new, such as *devastation*, *steepness*, and *catastrophic*. Understanding these subject-matter words will help

Vocabulary: 5 Cs of Planning for Instruction

1. **C**oncepts: What mathematics words are in this lesson?

2. **C**ontent: What subject-matter words are in this lesson?

3. **C**larify: Which words should I mention or clarify?

4. **C**ut: Which words should I rephrase or eliminate?

5. **C**onstruct: Which words should I teach?

Word	Definition or Context	When to Teach

Figure 1. Blank template for the 5 Cs of planning for content-area vocabulary instruction

students make sense of the context in which the math concepts of the lesson are presented and explored.

Clarify: Which Words Should I Mention or Clarify?

The remaining three Cs help teachers decide what to do with the lists of words from the first two steps in the process. *Clarify* asks teachers to select words from the first two Cs that might cause confusion but are not crucial to the main ideas or concepts in the lesson. These words may simply be mentioned or clarified in class, without spending additional time on them. For example, young adolescents may be familiar with an everyday meaning of the word *fuel* but not understand

Vocabulary: 5 Cs of Planning for Instruction

1. **C**oncepts: What mathematics words are in this lesson?

probability	percent	adjacent	proportional	average
grid	conjecture	outcome		

2. **C**ontent: What subject-matter words are in this lesson?

burn rate	destruction	wildfire	iteration	ignition
devastation	factor	forest fire	subdivision	manipulation
contained	out of control	density	moisture	vegetation
steepness	topology	fuel	material	topography
marshland	terrain	desert	drainage	intensity
decaying	raging	densely	aspect	environment
weaves	uninterrupted	rapidly	catastrophic	boundary
portion				

3. **C**larify: Which words should I mention or clarify?

proportional	outcome	adjacent	devastation	intensity
grid	contained	steepness	environment	forest fire
aspect	moisture	destruction	rapidly	boundary
factor	out of control	terrain	fuel	uninterrupted
raging				

4. **C**ut: Which words should I rephrase or eliminate?

conjecture	iteration	marshland	material	desert
decaying	weaves	catastrophic	subdivision	drainage
portion	topography	ignition	manipulation	densely
topology	vegetation			

5. **C**onstruct: Which words should I teach?

Word	Definition or Context	When to Teach
probability	"How can you reduce the probability of a fire spreading to your home?"	Before activity
wildfire	"If you live in an area where wildfires occur, what can you do to protect your family and property?"	Before activity
percent	"If the probability of the fire spreading to an adjacent tree is 25%, what percent of the forest do you think will burn?"	During activity
average	"What was the average number of squares that caught fire for each group?"	During activity
burn rate	Term on Fire Behavior worksheet, explained as "acres per hour"	After activity
density	"If the trees are spread out, there is less chance of the fire 'jumping' from one tree to another."	After activity

Figure 2. Example of a completed template for the 5 Cs of planning for content-area vocabulary instruction, using words from the mathematics lesson Illuminations: On Fire.

the specific meaning of this word in the context of wildfires. Clarifying this word during the lesson would help students connect the new meaning of the word to the everyday meaning they already know. Some other subject-matter words are closely related to one another and could be identified as (relative) synonyms; examples of these words include *raging/out of control* and *devastation/destruction*. A few of the mathematical content words, such as *grid* and *outcome*, may have been learned previously in class and would simply need clarification before or after the lesson.

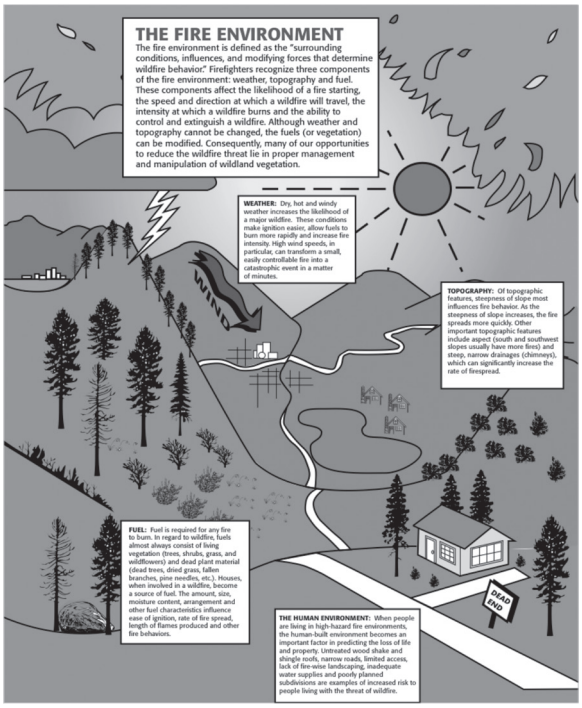

Figure 3. Sample student text from the lesson Illuminations: On Fire, Heating Up. (Available from http://illuminations.nctm.org/LessonDetail.aspx?ID=L565.) Copyright 2008 by the National Council of Teachers of Mathematics. The Fire Environment is taken from the publication *Living with Fire*. Used with permission from the University of Nevada Cooperative Extension.

Cut: Which Words Should I Rephrase or Eliminate?

The fourth C asks teachers to identify words, again from the first two Cs, that could be eliminated in order to reduce vocabulary complexity. While words cannot be easily eliminated from textbooks or other permanent materials, teacher-guided activities or consumable worksheets can often be modified. *Topology*, *topography*, and *subdivision* are examples of words that could be eliminated from the lesson as a way to make the materials more accessible. Assessment materials are also important to consider. *Marshland*, *terrain*, *desert*, and *decaying* occur in the assessment for the lesson but not in any of the activity materials. These words could be replaced with similar words occurring elsewhere in lesson materials to reduce student confusion and streamline the assessment questions.

Construct: Which Words Should I Teach?

The final C asks teachers to decide which words to select from the first two Cs to teach as part of the lesson. These may be mathematical concept words, subject-matter content words, or both, but the total number of words for any one lesson should remain small. These words may be placed on the planning grid along with definitional and/or contextual information and a notation about whether to teach the word before, during, or after the lesson.

Out of the 44 words from the On Fire lesson we identified in the first two Cs, we would only focus on 6 as part of our instruction in order to help students understand key ideas and connect new concepts to existing knowledge. These words are *probability*, *percent*, *average*, *wildfire*, *burn rate*, and *density*. They represent both mathematical concepts and subject-matter ideas, making these words worth the class time spent exploring them through interactive vocabulary activities. The key terms *probability* and *wildfire* would be suitable to introduce and teach before the lesson, in order to activate background knowledge and assess students' familiarity with these words and the concepts they represent. *Percent* and *average* would be good words to teach during the lesson so that students could consider them in the context of the wildfire scenario. *Burn rate* and *density*, crucial to understanding probability in the wildfire context, would be good words for students to discuss after the lesson, connecting the activity to their existing background knowledge.

After the Planning . . . What?

Next Step: Moving from Planning to Instruction

Once key words are identified by using the 5 Cs tool, the next step is to teach these words in a meaningful way. Instruction that involves discussion, active participation, and the use of target words in meaningful contexts helps students develop a deeper understanding of key vocabulary (Graves, 2006). As part of the ongoing TMTW

project, we are working with teachers to implement a variety of approaches to teaching vocabulary, including the four-square activity (Stahl & Nagy, 2006), interactive word walls (Harmon, Wood, Hedrick, Vintinner, & Willeford, 2009), and clues and questions (Blachowicz & Fisher, 2010). These activities emphasize active learning and the importance of focusing on words that are crucial to understanding mathematical concepts and making connections between new and existing knowledge. The 5 Cs planning tool helps teachers select key words for these activities.

Teacher Thoughts about Vocabulary and the 5 Cs

Mathematics vocabulary presents a significant challenge to both teachers and students. Thinking about this challenge, one high school mathematics teacher noted, that "students often struggle with retaining vocabulary unless they can make connections to something they already know. It is a challenge to trim it down to just essential vocabulary in lessons, because often students need to know all of the vocabulary terms."

Students often struggle with retaining vocabulary unless they can make connections to something they already know.

The 5 Cs planning tool provides teachers with a process for working through this challenge by considering the vocabulary demands of a lesson and planning instruction focused on essential terms. One middle school math teacher, thinking back over several months of implementing the 5 Cs, commented, "I like the 5 Cs process. It gives me a checklist. It

CONNECTIONS FROM READWRITETHINK

Math Literacy

The following lessons from ReadWriteThink.org provide additional resources on math.

Bridging Literature and Mathematics by Visualizing Mathematical Concepts

During interactive read-aloud sessions, students identify how an author conveys mathematical information about animals' sizes and abilities. They then conduct research projects focusing on the same mathematical concepts.

http://www.readwritethink.org/classroom-resources/lesson-plans/bridging-literature-mathematics-visualizing-822.html

Talking, Writing, and Reasoning: Making Thinking Visible with Math Journals

Students explore how their problem-solving strategies work by writing in math journals as they work in small groups to solve a math puzzle with multiple solutions.

http://www.readwritethink.org/classroom-resources/lesson-plans/talking-writing-reasoning-making-820.html

What If We Changed the Book? Problem-Posing with Sixteen Cows

After reading a piece of math-related children's literature aloud, students pose and solve new problems by what-if questions about the events in the story.

http://www.readwritethink.org/classroom-resources/lesson-plans/what-changed-book-problem-815.html

Preparing Students for Success with Reading in the Content Areas

In this strategy guide, you'll learn how to determine the level and type of support you need to provide students based on careful preparation as a content-area expert.

http://www.readwritethink.org/professional-development/strategy-guides/preparing-students-success-with-30516.html

Lisa Fink
www.readwritethink.org

makes me break apart the lesson and think about more than just the mathematical vocabulary. It's great for my kids because their vocabulary is limited due to lack of experiences."

Teachers in the TMTW project have worked to use the 5 Cs tool as part of lesson planning—a way to help them think about the vocabulary presented in curriculum materials and how to filter through these words to focus on those that are essential to understanding math and science concepts in context.

Conclusion

Many young adolescents face the daunting task of learning new concepts while also struggling to understand the discipline-specific vocabulary and real-life experiences used to describe and illustrate these concepts. All things considered, there are too many words to teach in content-area classes, especially when time is scarce. We developed the 5 Cs as a way to help teachers stay focused on building conceptual knowledge while also supporting word learning and reducing the vocabulary load presented by curriculum materials. By working through the process of identifying conceptual and content-area words, deciding whether to clarify or cut words from a lesson, and focusing on constructing word understanding through meaningful activities, vocabulary instruction becomes less overwhelming to teach and more accessible for students to understand. As Marzano and Pickering (2005) observe, "Teaching specific terms in a specific way is the strongest action a teacher can take to ensure that students have the academic background knowledge they need to understand the content they will encounter in school" (p. 1). Considering and selecting words to teach is an essential step in this process.

We developed the 5 Cs as a way to help teachers stay focused on building conceptual knowledge while also supporting word learning and reducing the vocabulary load presented by curriculum materials.

From our experience working with teachers in the TMTW project, integrating purposeful vocabulary instruction with math lessons can be a positive experience for teachers and students alike. While not every confusing word can be addressed, considering vocabulary and choosing words thoughtfully helps reduce frustration and make conceptual learning more accessible through meaningful instruction. Ultimately, all students benefit from the careful consideration and instruction of vocabulary necessary to connect new ideas to background knowledge and to understand central concepts of the discipline.

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References

Barton, M. L., Heidema, C., & Jordan, D. (2002). Teaching reading in mathematics and science. *Educational Leadership, 60*(3), 24–28.

Beck, I. L., McKeown, M. G., & Kucan, L. (2002). *Bringing words to life: Robust vocabulary instruction*. New York, NY: Guilford Press.

Blachowicz, C. L. Z., & Fisher, P. J. (2010). *Teaching vocabulary in all classrooms* (4th ed.). Boston, MA: Allyn & Bacon.

Blachowicz, C. L. Z., Fisher, P. J., Ogle, D., & Watts-Taffe, S. (2006). Vocabulary questions from the classroom. *Reading Research Quarterly, 41,* 524–539.

Bromley, K. (2007). Nine things every teacher should know about words and vocabulary instruction. *Journal of Adolescent & Adult Literacy, 50,* 528–537.

Conley, M. W. (2008). Cognitive strategy instruction for adolescents: What we need to know about the promise, what we don't know about the potential. *Harvard Educational Review*, *78*, 84–106.

Draper, R. J., Smith, L. K., Hall, K. M., & Siebert, D. (2005). What's more important—literacy or content? Confronting the literacy-content dualism. *Action in Teacher Education, 27*(2), 12–21.

Fisher, D., & Ivey, G. (2005). Literacy and language and learning in content-area classes: A departure from "Every teacher a teacher of reading." *Action*

in Teacher Education 27(2), 3–11.

Fisher, P. J., & Blachowicz, C. L. Z. (2005). Vocabulary instruction in a remedial setting. *Reading & Writing Quarterly, 21*, 281–300.

Fordham, N. W. (2006). Crafting questions that address comprehension strategies in content reading. *Journal of Adolescent & Adult Literacy, 49,* 390–396.

Graves, M. F. (2006). *The vocabulary book: Learning & instruction*. New York, NY: Teachers College Press.

Harmon, J. M., Wood, K. D., Hedrick, W. B., Vintinner, J., & Willeford, T. (2009). Interactive word walls: More than just reading and writing on the walls. *Journal of Adolescent & Adult Literacy, 52*, 398–408.

Harper, C., & de Jong, E. (2004). Misconceptions about teaching English-language learners. *Journal of Adolescent & Adult Literacy, 48*, 152–162.

Kieffer, M. J., & Lesaux, N. K. (2010). Morphing into adolescents: Active word learning for English-language learners and their classmates in middle school. *Journal of Adolescent & Adult Literacy, 54*(1), 47–56.

Lager, C. (2006). Types of mathematics-language reading interactions that unnecessarily hinder algebra learning and assessment. *Reading Psychology, 27,* 165–204.

Marzano, R. J., & Pickering, D. J. (2005). *Building academic vocabulary: Teacher's manual*. Alexandria, VA: ASCD.

Moschkovich, J. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning, 42,* 189–212.

NCTM. (2008). Illuminations: On fire (Lesson 1: Heating up). Retrieved from http://illuminations.nctm.org/LessonDetail.aspx?ID=L565.

Seymour, D. G., Burger, E. B., Chard, D. J., Hall, E. J., Kennedy, P. A., Lainward, S. J., Renfro, F. L., & Waits, B. (2007). *Algebra 1*. Geneva, IL: Holt McDougal.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review*, *78*(1), retrieved from http://www.edreview.org.offcampus.lib.washington.edu/harvard08/2008/sp08/p08shana.htm.

Stahl, S. A., & Nagy, W. E. (2006). *Teaching word meanings*. Mahwah, NJ: Lawrence Erlbaum.

Vacca, R. T., & Vacca, J. A. (1999). *Content area reading: Literacy and learning across the curriculum* (6th ed.). Menlo Park, CA: Longman.

Antony T. Smith is an associate professor in the Education Program at the University of Washington, Bothell. He can be reached at ansmith@uwb.edu. **Robin L. Angotti** is an associate professor in the Education Program at the University of Washington, Bothell.