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# Putting It All Together: Integrating Academic Math Language into Math Teaching

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My last article outlined the kinds of difficulties that English language learners (ELLs) encounter with the academic language of mathematics. Identifying difficulties is the first step toward ensuring that students master this kind of math. The second step, of course, is teaching the aspects of academic language that have been identified as difficult.

## Identifying Academic Language Difficulties

With practice, teachers of ELLs can learn to recognize aspects of vocabulary, semantics, discourse patterns, and background knowledge that may prevent ELLs from fully understanding or producing the language they need in math classes and textbooks, and on math tests.

One way to identify language problems is to observe students and note actual problems that they encounter. This can be very effective if you are working one-on-one with a single student, and have enough time to work through the language so you can identify exactly what is causing the difficulty, but it is not very practical for larger groups of students.

So a more effective way to identify language problems is to examine textbooks or tests, looking for language that is potentially difficult. The examples in my last article can serve as a guide for the kinds of things to look for. Identifying difficult language items is fairly easy for people who have learned to look *at* language rather than look *through* it. Looking *through* language is like looking through a window. We look at whatever is on the other side of the window, and we aren't aware of seeing the glass itself. Language is like the glass in the window. We don't normally see it, because we look through it in order to see the meaning. Just as we have to refocus our eyes in order to see the glass itself, we also have to refocus our minds in order to see the language. Doing that will help us identify all of those idiomatic phrases, multiple-meaning words, words that carry relational meanings, complex sentence structures, and unknown references that make the language difficult for ELLs.

Even after learning to look *at* the language itself, rather than its meaning, however, we still have to put ourselves in the place of language learners in order to identify potential difficulties. For example, many native speakers of English will not recognize that the phrase *give me a hand* is idiomatic and that its literal interpretation will confuse language learners. Teachers who have little understanding of how language works may find it beneficial to work with an ESL teacher as they identify potential difficulties in their subject area.

## Then What?

What happens after potential or actual difficulties are identified? Do we have to teach academic language, or will students acquire it naturally as long as teachers use it appropriately? If we have to teach it, what's the best way to do that?

Although there is some evidence that social language can be acquired without explicit teaching if certain conditions are met, the same is not true for academic language. Because language normally becomes transparent as we focus on meaning, it is imperative that the forms and functions of academic language be made explicit. "Time alone, that is, simply being exposed to English at school, does not ensure academic English learning. ...Children cannot learn the English they need for academic development on their own" (Wong Fillmore, n.d., p. 3).

Just as it is not effective to teach vocabulary outside of the context in which it is used, teaching academic language outside of the context of a particular content area will not be effective. The academic language of mathematics is obviously best learned within the context of the study of mathematics. Although some of the teaching could be done by spontaneously calling students' attention to language forms as they are encountered, that approach is not systematic enough to ensure that essential language will be mastered. So planning for teaching academic math language must become an integral part of planning for teaching mathematics.

As part of the research that led to the development of the *Academic Language Notebooks: The Language of Math* (Irujo & Ragan, 2007), Course Crafters developed a model for integrating the teaching of academic language into math classes. The model consists of pre-teaching key concepts and essential vocabulary and integrating the teaching of other vocabulary and language structures into the math lesson. The next section of this article describes the model, with examples from a third- or fourth-grade math lesson on the relation of multiplication and division.

The final part of the article describes ways in which the model could be implemented.

## Pre-Teaching Key Concepts and Vocabulary

Key Concepts

Because ELLs don't understand all of the language they hear and read, it is difficult for them to get a good understanding of what it is they are supposed to learn. They may acquire some vocabulary and learn some computations, but never understand essential math concepts. Without these concepts, they may do all right in elementary school math, but will be lost later when they get into algebra.

So the first step in the model is to present the key concept of a lesson in an experiential way, relating it to concepts students know and experiences they have had, and using a minimum of technical math vocabulary. As part of this process, it is essential to identify knowledge that is prerequisite for understanding the key concept, and to be sure that students already have that prior knowledge.

> *The key concept of the example lesson is that multiplication and division are opposite operations. The teacher can do a quick check on whether students understand the basic concepts behind multiplication and division by providing examples of repeated addition/combining equal groups, and repeated subtraction/sharing equally, in appropriate contexts. Having students hold up small whiteboards or slips of paper on which they have written multiplication or division signs will allow the teacher to quickly assess which students have or have not mastered the concepts so additional help can be provided.*
>
> *The introduction of the key concept in this lesson might be done with a situation in which students first share something equally, and then combine their equal groups to get the original number of items. For example, the teacher could divide a set of markers by distributing an equal number to each of several groups of students. Later, the teacher collects the markers, and multiplies to be sure she has collected the same number that she distributed. Through pair, small-group, and whole class discussion, the concept emerges that the teacher divided the markers, and then multiplied them to*

*make sure that she got them all back. Since the number at the end is the same as the number at the beginning, multiplication and division are shown to be opposites. Just as you can* zip *and* unzip *a jacket, or* button *and* unbutton *a shirt, you can* do *and* undo multiplication and division, and when you undo *one, you get the other.*

Essential Vocabulary

Pre-teaching vocabulary to ELLs has become controversial. Those in favor of doing so claim that trying to define and practice essential vocabulary as it occurs during a lesson interrupts the sequence of the lesson, so concepts are more difficult to acquire. Those who are against doing so claim that pre-teaching involves taking the vocabulary out of context, when it is the context that is the most effective tool for providing real meaning.

Our solution to this dilemma is to pre-teach essential vocabulary in context. Because we have already pre-taught the key concept of the lesson, we now use that key concept to teach the essential vocabulary.

I keep repeating the word *essential*, because it is not effective to pre-teach all the unknown vocabulary of the lesson. In pre-teaching, we want to concentrate on a small number of words that are *content-obligatory* (Snow, Met, & Genesee, 1989). These are words without which it would be impossible to understand or show one's understanding of the lesson.

*In the lesson on the relationship of multiplication and division, three words were chosen for pre-teaching:* opposite, operation, *and* related. *All of these words are directly connected to the main idea that has already been taught, so they can be introduced through a review discussion of the activity used to teach the main idea. After the words are introduced, students need to practice them. Sentence frames are very useful to facilitate pair practice. Teachers can begin with very familiar concepts, and then extend the use of the sentence frames to the new math concepts:* How are (big) and (small) ___? They are ___. How are (multiplication) and (division) ___? They are ___. *In the case of multiple-meaning words such as operation, it is helpful to provide practice with both meanings:* A doctor does a medical ___. A math teacher does a math ___.

Any experienced teacher knows that the initial presentation and practice of vocabulary is only the beginning of a lengthy process of acquisition. To facilitate further practice and study, our model uses vocabulary cards. After the introduction of any essential vocabulary (either during pre-teaching or as part of the lesson), students complete a card that has spaces for an example or definition of the term, a drawing that either represents the term or helps the student remember its meaning, an example of the term, and anything else that might help students remember the meaning (such as a native-language translation, a memory aid, and so forth). Teachers use the cards for whole-class or small-group activities, and students use them for pair or independent practice.

With a basic idea of the main concept of the lesson and a working knowledge of several content-obligatory vocabulary terms, students are much better prepared to benefit from the presentation of the lesson itself. The next step is to integrate academic language into every facet of the math lesson, and to explicitly call students' attention to the forms of the academic language used, how they work, and what they do.

## Integrating Academic Language Teaching into the Math Lesson

Vocabulary

As mentioned above, pre-teaching a limited number of content-obligatory math terms is only the beginning of acquiring the vocabulary of math. The teacher also needs to consistently use previously taught words and require that students use them. Although it is often recommended that teachers of ELLs use simple vocabulary and sentence structure in order to

make their lessons comprehensible, academic vocabulary should never be simplified. Students need to master those terms in order to achieve on math proficiency tests.

In addition to the essential vocabulary that has been pre-taught, many other words may impede full understanding. These words need to be taught in context as they appear in the lesson. Teachers must be especially watchful for words that are not specifically identified as math vocabulary. There are many words that do not cause any trouble for native or fluent users of English, but are easily misinterpreted or not acquired by learners. One example is the word *each*, which is essential for fully understanding multiplication and division, but which can easily be overlooked as a word that needs to be taught. Teachers should identify these words while planning the lesson and include notes about explaining them in their lesson plans.

> *In the lesson on the relation of multiplication and division, the teacher should make sure to use* factor, product, divisor, dividend, *and* quotient *consistently, and require that students also use them. The pre-taught words* opposite, operation, *and* relate *will be used in context throughout the lesson, and students will be encouraged to use them in pair or group discussions and activities. Words such as* form, array, each, row, complete, *and* pair *can be presented when needed in the lesson, explained and practiced, and written on the board. At the end of the lesson, the teacher can return to these words, provide additional explanations and definitions as needed, and have students fill out vocabulary cards for them.*

Functions of Language

Sometimes teachers focus so much on vocabulary and correct grammar that they neglect to teach students how to use the language they are learning. Doing math is no longer just a matter of listening to the teacher, doing computations correctly, and solving story problems. Students must be able to analyze, interpret, categorize, compare, describe, explain, demonstrate, present, and so forth. For any of these functions of language, students must know what words, phrases, and sentence structures to use, and how to use them. Functions can be effectively taught through modeling, followed by guided practice and independent practice in pairs or small groups.

> *For this lesson, students will be expected to be able to explain the relationship of multiplication and division. A sentence frame such as* Multiplication and division are ___ *will not suffice, because open-ended sentence frames such as this one do not provide enough of a model for students to follow. In addition, students could complete this sentence frame correctly in several different ways without actually explaining the relationship. So the teacher might use a think-aloud, such as this:*

"I have to explain how multiplication and division are related. I know that they are *opposite operations,* so I'll say that. *Multiplication and division are opposite operations.* But that only *tells* how they are related. It doesn't *explain* it. When I *explain* something, I usually have to use the word *because. Because* tells *why.* So I'll say, *Multiplication and division are opposite operations because one operation undoes the other one."*

> *For guided practice, the teacher can repeat the think-aloud, pausing at key phrases and having students chorally fill them in, until they can produce the explanation on their own. Students will then have a chance to practice explaining in pairs or small groups, using concepts from recent lessons (explaining how addition and multiplication are related, for example) as well as the new concept from this lesson.*

Mini-Lessons

Sometimes there will be important language structures that need additional attention. Items such as passive verbs, complex sentences, comparatives and superlatives, or prefixes and suffixes are best dealt with through mini-lessons on the particular structure. These lessons can be taught as a short break during the math lesson, or at the end of the lesson.

Mini-lessons begin by focusing on the structure as used in the textbook or lesson, followed by a very brief explanation of what the structure means and how it is used. The teacher then provides additional examples, and elicits more examples from students. Students can practice the structure using teacher prompts or sentence frames.

> *There are several possible topics for language mini-lessons in this math lesson. One possibility is a mini-lesson on word parts.* Do *and* undo *lend themselves to extension to many other forms (verbs such as* uncover, *and adjectives such as* unequal *or* uneven, *are useful math terms). After* related *is connected to* relate *and* relation, *those terms can be extended to other important math words (*subtraction, divided, unrelated*). Another possibility is the syntactic structure* Imperative + Infinitive. *Textbook lessons on the relation of multiplication and division often include this structure. Of course, there is no need to teach the grammatical terminology, but it might be very useful to include a mini-lesson on imperative sentences such as* Divide to find how many markers each group gets, *or* Use the array to complete the number sentence.

There should normally be no more than one language mini-lesson within any particular math lesson, so teachers will need to make choices. Decisions should be based on the importance of the language topic for understanding and expressing the math, whether a topic has been previously taught and whether it needs review, and students' language proficiency levels.

Interactive and Hands-On Activities

Any list of best practices for teaching ELLs includes these two practices. They are highlighted here because their use in the development of academic language needs to be more structured than when they are used to develop conversational language. When planning interactive pair and group activities for conversational language learning, any task will work as long as it ensures that all students participate. For academic language learning, however, the task must ensure that students use specific language in appropriate ways. Structuring tasks around solving math problems and monitoring students' use of academic language while they solve the problems will ensure that interactive activities achieve this goal.

Likewise, when hands-on activities are used only to help students learn math calculations and problem solving, teachers will be more concerned with correct answers than with the specific language that students use during the activities. When these activities are used to develop academic math language, however, teachers must make explicit connections between the activities students are doing and the language used to carry them out and describe them. Only with this kind of language can teachers be sure that students are developing the underlying concepts that are needed for more advanced math work later. Teacher participation in hands-on activities is necessary in order to model and facilitate students' use of appropriate academic language.

> *For this lesson, the teacher can model the use of counters to show that multiplication and division are opposite operations, using appropriate language. Two groups of students can then use counters to work on related problems, with one group doing multiplication first and the other doing division first. The teacher should scaffold students' use of language during this group work. Finally, pairs or small groups will create their own problems that show opposite operations, model them with counters, and use appropriate academic language to present the problem, solution, and explanation of opposite operations to the class.*

## Ways to Implement This Model

There are several ways that the integration of language and math instruction required by this model can be achieved. In the elementary grades, many states already require all teachers to be trained in teaching ELLs, so those teachers have the skills to integrate the math and the language, and to teach the model themselves.

In cases where math teachers do not have ELL training, they may not have the language background necessary to identify and teach the academic language, and ESL teachers may not have the math background necessary to teach the math. Team teaching is the ideal solution. Using a "push-in" model, in which the ESL teacher goes into the math classroom to assist ELLs during the math lesson, team teaching will be much more effective than having the ESL teacher sit with the ELLs offering explanations during the lesson. Joint planning is essential to the success of a team teaching model, since the language and math must be integrated. An added bonus of this model is that the pre-teaching of key concepts and essential vocabulary will be of benefit to native speakers of English as well as to ELLs.

In many cases, program design can make any kind of team teaching impossible, but collaborative planning can still be used. Both teachers together identify the key concept and math vocabulary, and the ESL teacher identifies other vocabulary and language structures that may cause difficulties for ELLs. The math teacher recommends effective ways to teach the key concept, and the ESL teacher contributes ideas for teaching vocabulary and language within the math lesson. Then the ESL teacher does the pre-teaching, and the math teacher does the integrated math lesson.

In any of these situations, and especially when none of the above contexts exist, having materials that identify key concepts, essential vocabulary, and difficult language structures and provide suggestions for teaching can be of great help. *The Language of Math* (Irujo & Ragan, 2007) implements the model described above, and is designed to be used to supplement any commonly used math textbook by teachers without training in either ESL or math teaching.

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