What's the story? Examining the functional language of word problems

Jennifer Green and Beth Dillard

Summary: This article describes some key language demands of mathematics word problems. We share what we learned from examining 100 middle school ratio word problems from two different publishers: Illustrative Mathematics and CK-12. Using a functional language approach (like used in WIDA), we found a patterned organization of word problems and multiple language features. In this article, we examine the staged organization of word problems and one of those language features—expanded noun groups.

Keywords: Math, WIDA, language demands, noun groups, word problems

It's been a little over three years since Washington State adopted the WIDA English Language Development (ELD) Standards Framework, 2020 Edition. Educators have gained experience teaching the key language uses (genres): *narrate, inform, explain, and argue*. In this article, we examine a genre not found in the WIDA manual, but which students encounter regularly in math classrooms— the *word problem*. Teachers often say that word problems can be vexing for their students. Therefore, educators continue to ask themselves how to help students make sense of these problems, both mathematically and linguistically.

In this article, we take a linguistic approach, specifically a systemic functional approach, to word problems. We share what we learned from examining 100 middle school ratio word problems from two different publishers: Illustrative Mathematics (2024) and CK-12 (2023). In particular, we describe the patterned organization of word problems and examine one language feature often found in them— *expanded noun groups*.

The word problem genre

WIDA draws on a functional model of language. Put differently, people use language in culturally specific ways to "get things done" (Derewianka & Jones, 2016, p. 7). They write recipes to share with friends how to make pie. They write editorials to convince their neighbors to think differently. They write poems to celebrate nature. As people create these different *genres*, they follow—and also play with—different patterns. A functional view of language helps illuminate and describe these patterned uses of language.

In mathematics, students are called upon to make sense of the multimodal genre of *word problems*. Word problems—also called story problems—use a combination of words, numbers, symbols, diagrams and drawings. They can make math more relatable by helping students imagine real-life applications of math concepts and processes. At the same time, the cultural assumptions and language used to create those imaginary situations can obscure the math, especially when the linguistic complexity of the writing outpaces the language proficiency level of the student (Abedi & Lord, 2001; Vilenius-Tuohimaa et al., 2008; Wilburne et al., 2011). This is not to say that teachers should simplify or remove word problems for students at earlier proficiency levels; on the contrary, amplification of curriculum is more effective because exposure to complex language is critical for language acquisition (Walqui & Bunch, 2019). Instead, teachers should show students how to dissect the complex language of word problems.

Typical organization of a word problem

Genres tend to have particular stages of meaning (Hasan, 1977; Martin, 2001). Take, for example, the narrative *plot mountain*, with its stages of exposition, rising action, conflict, climax, falling action, and resolution. Of course, this is only one culturally recognizable way of telling a story (McCabe, 1997), and even within this pattern one will find variation as stages switch order or are skipped entirely (Derewianka & Jones, 2023). Nevertheless, it's a useful starting point to see how people organize meaning in predictable ways.

As we examined ratio word problems, we noticed two stages characterized by specific functions: a *scenario* and a *question* (See Table 1). Gerofsky (1996) found a similar pattern of *set-up*, *information*, and *question*.

Stage	Characteristics
Scenario	Features of narrative Sets the scene
Question	Prompts student to use math Relies primarily on symbolic discourse

Table 1. Stages and characteristics

Most word problems we examined began with the scenario. The scenario acts much like the key language use of narrative (see, for example, WIDA Narrate, , Language Arts, 6-8, 2020). It has the language functions and features one would expect, though with less rich description, and more focus on actors, actions, and relevant details of time, place, quantity, etc. The scenario sets the scene for the instructions for the question stage. Here students are directed to interact with the scenario by engaging in mathematical processes. Interestingly, the question stage can take the form of either questions or commands (see Table 2).

Question	If she makes 3 cakes, how many eggs will she need?
Command	Compare the ratio of basketballs to footballs.

Table 2. Questions and commands

Within both stages, there are many linguistic features that are typical of word problems (Huang & Normandia, 2008; O'Halloran, 1998; Schleppegrell, 2007). Here, we highlight how the use of expanded noun groups makes meaning in dense and compact ways.

Expanded noun groups

A common feature among word problems is the expanded noun group. A noun group (NG) includes a head noun and all of its modifiers, both that come before (pre-modifiers) and after (post-modifiers). All modifiers give more information about the head noun. In Tables 3 and 4, common modifiers are listed with several examples.

Types of pre-modifiers	Examples
Pointers (articles, demonstratives, possessive determiners)	a, the, those, my, Bob's
Quantifier (can be precise or vague)	seven, many, a few, a pound of
Describers (adjectives)	beautiful, delicious, funny, blue, soft
Classifiers (nouns, adjectives, numerals--how things are categorized)	a math lesson; an electric guitar, a Swedish rug, first place

Table 3. Types of pre-modifiers

Types of post-modifiers	Examples
Prepositional phrases	The vase with the green rim; a collection of rocks; the book on the shelf
Embedded (full relative) clauses	The vase that my grandfather gave me; a collection of rocks which are studied all over the world
Embedded clauses (reduced relative clauses)	The vase my grandfather gave me; the book sitting on the shelf

Table 4: Types of post-modifiers

Some noun groups are single words:

Math is fun.

Some are just a few words:

Word problems are challenging for *many students*.

Noun groups that are more than two or three words are known in WIDA as *expanded Noun Groups*.

Some of these can be very long:

The kind and experienced teacher who taught middle school math at the school down the road loved her job.

NGs can generally be reduced to a pronoun, no matter the length of the original NG:

- It is fun.
- They are challenging for them.
- She loved it.

Noun groups in word problems:

While many word problems have short NGs, it is not uncommon to find expanded NGs that pack in a lot of information pertinent to the problem. Specifically, post-modifiers (prepositional phrases and embedded clauses) further define the head noun.

The density of this language can be difficult for students to parse, as we show below in two examples. Our first example (Figure 1) is a 7th grade ratio problem from CK-12 ("5.13 Scale Factor to Find Actual Dimensions" section).

> Calvin drew a map of his neighborhood. The scale factor he used for his map was 1/800. The actual distance between Calvin's house and his best friend Frank's house is 80 meters. What should be the distance, in centimeters, between those two places on his scale drawing?

Figure 1. Word problem 1

First, we separate the problem into the scenario and question

stages (Figure 2). The scenario stage asks the student to imagine two people, Calvin and Frank, and an imaginary situation where Calvin is drawing a map. The word problem ends with the question, directing students how to interact with the scenario as they do their own math.

Stage: Scenario

Calvin drew a map of his neighborhood. The scale factor he used for his map was 1/800. The actual distance between Calvin's house and his best friend Frank's house is 80 meters.

Stage: Question

What should be the distance, in centimeters, between those two places on his scale drawing?

Figure 2. Stages for word problem 1

Next, we identify the NGs and all of their modifiers (Table 5).

NG #	Pre-modifiers	Head Noun	Post-modifiers
1		Calvin	
2	a	map	of his neighborhood
3	The scale	factor	he used for his map
4		1/800	
5	The actual	distance	between Calvin's house and his best friend Frank's house
6	80	meters	
7	the	distance	between those two places

Table 5. Noun groups for word problem 1

This word problem relies on modifiers to guide students in correctly solving this problem. Prepositional phrases as post-modifiers are especially common (NGs 2, 5, 7). Notice that the post-modifiers in NGs 5 and 7 define the same distance, but NG 7 replaces *Calvin's house and his best friend Frank's house with those two places*. These details are critical for comprehension. Notice also the use of in centimeters. This preposition is not part of the NG. Rather, it interrupts the NG to let the reader know what unit to use. The commas help to signal that this is an interruption. Because interruptions can be confusing for students, we recommend explicitly pointing out such features to students.

Our second example comes from Illustrative Mathematics (IM) (2024) and is a 6th grade word problem ("Unit 2 Lesson 2" section) that exemplifies dense NGs (Figure 3). Once more, we separate the problem into stages (Figure 4) and identify the head nouns and noun groups (Table 6).

In a recipe for fizzy grape juice, the ratio of cups of sparkling water to cups of grape juice concentrate is 3 to 1. Find two more ratios of cups of sparkling water to cups of juice concentrate that would make a mixture that tastes the same as this recipe. Describe another mixture of sparkling water and grape juice that would taste different than this recipe.

Figure 3. Word problem 2

Stage: Scenario

In a recipe for fizzy grape juice, the ratio of cups of sparkling water to cups of grape juice concentrate is 3 to 1.

Stage: Question

Find two more ratios of cups of sparkling water to cups of juice concentrate that would make a mixture that tastes the same as this recipe. Describe another mixture of sparkling water and grape juice that would taste different than this recipe.

Figure 4. Stages for word problem 2

NG #	Pre-modifiers	Head Noun	Post-modifiers
1	a	recipe	for fizzy grape juice
2	the	ratio	of cups of sparkling water to cups of grape juice concentrate
3		3 to 1	
4	Two more	ratios	of cups of sparkling water to cups of juice concentrate that would make a mixture that tastes the same as this recipe
5	Another	mixture	sparkling water and grape juice that would taste different than this recipe

Table 6. Noun groups for word problem 2

First, notice how this scenario stage looks different than in the prior example. Rather than a story with characters and actions, the setup is simply providing the information that students will be working with. It gives students the recipe and implicitly asks them to imagine making fizzy grape juice.

Next, look at the noun groups in this example. Looking at Table 6, it is evident that this word problem has some extended NGs. In fact, NG 4 is 25 words long! It is also clear that most of the expansion is in the post-modifiers. The post-modifiers communicate what the ratios and mixtures are composed of; and that relationship is compressed into these long post-modifiers. Although it looks initially like the

post-modifiers are prepositional phrases, starting with *for* or *of*, upon closer inspection, these prepositional phrases are followed by embedded clauses in the fourth and fifth noun groups. In fact, NG 4 has two embedded clauses: *that would make a mixture and that taste the same as this recipe*.

There is one noun group that is not a word at all: *3 to 1*. It is a symbolic way of writing out *3 cups to 1 cup*. Here one can see how the symbolic language of math—which has its own syntax—does not always map on neatly to the syntax of English. We are treating *3 to 1* as a head noun, as the two numbers and *to* together represent the *ratio*.

Understanding that the term *ratio* (NGs 2 & 4) refers to a relationship between two things—in this case cups *of* water *to* cups of grape juice—is also important. This allows the students to take the third NG: *3 to 1* and connect the 3 to the water and the 1 to the juice.

Finally, the authors move from using *ratio* to *mixture*. Authors of word problems use synonyms to create cohesion. Students may not immediately notice that the two words are used to refer to the same concept. Again, by examining NGs carefully, educators can help students better understand what is given and what is requested in word problems.

Connections to the classroom

How can teachers make these layers of linguistic meaning and symbolic representation explicit to students? One excellent way to do this is by thinking aloud about the language of the word problem. In the section that follows, we show a short example of how one might do this with students identified at levels 3 and higher in WIDA (2020). There is also a longer video example linked below.

Start by identifying the scenario and question phases as well as separating the sentences. Images 1 and 2 show the word problem before and after the think-aloud.

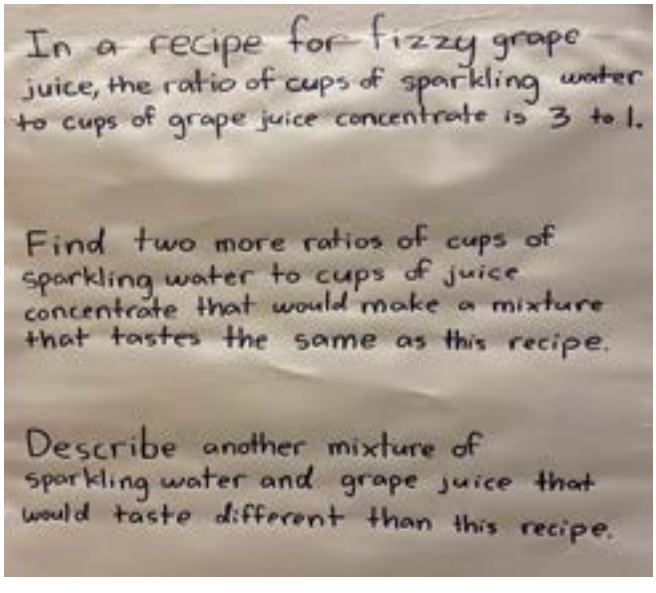


Image 1. Word problem 2 without annotations

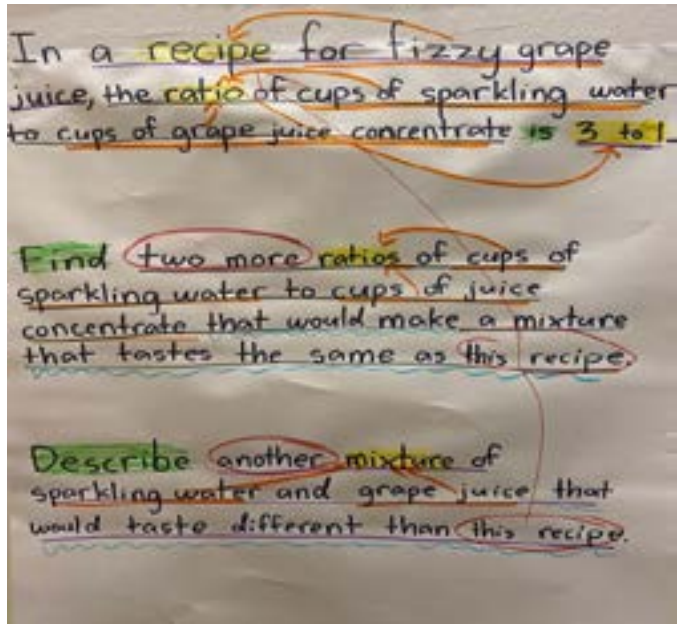


Image 2. Word problem 2 with annotations

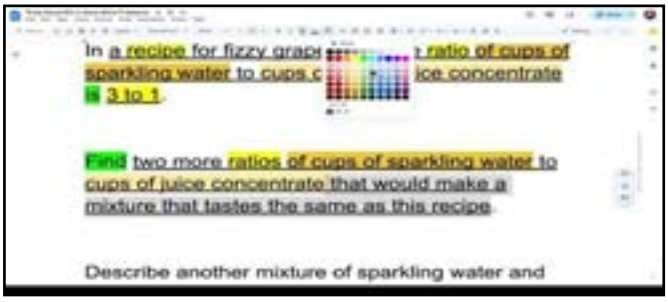
After separating the sentences, help students identify the head nouns. They may be drawn to words like *grape* and *water*, things that are concrete. In reality though, the head nouns in this example are most often *ratio* and *mixture*. Helping students see this can help them parse the language of the word problem, and better grasp the mathematical concept of ratio as a relationship between two things.

This example think-aloud assumes that students have learned about NGs as a grammatical structure previously, and that they are using this knowledge to now help them with comprehending word problems. Here is a sample portion:

> "Let's look at the first sentence in the question stage. I see the *verb* find starts the sentence. We need to find something. What is the one word that tells us what we need to find? Are we looking for *water*? Are we looking for *recipes*? No. We are look ing for *ratios*.
>
> Now, we need to figure out more about these ra tios. All the words around the word *ratios* give us this information.
>
> Let's start with the pre-modifiers, or the words that are in front of the head noun, *two more*.
>
> Okay, so we need *two ratios* in addition to the ra tio we already have (3 to 1). What are the things in this ratio? Cats to dogs? Coffee to creamer? No--*cups of sparkling water to cups of juice concentrate*..."

Please click on the link to watch the full think-aloud:

Noun Groups in Ratio Word Problem: A Think Aloud



Conclusion

Math word problems can be confusing to students, both mathematically and linguistically. In our linguistic examination of middle school ratio word problems, we identified stages and noun groups as two features that may be helpful for students to recognize when solving word problems. Teachers can engage in thoughtful think-alouds as a means of apprenticing their students in noticing these features themselves.

References

Abedi, J., & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education*, 14(3), 219-234. https://doi.org/10.1207/s15324818ame1403_2

CK-12 Middle School Math Concepts—Grade 6 (2023). https://flexbooks.ck12.org/cbook/ck-12-middle-school-math-concepts-grade-6/

Derewianka, B., & Jones, P. (2023). *Teaching language in context*. (3rd ed.) Oxford University Press.

Gerofsky, S. (1996). A linguistic and narrative view of word problems in mathematics education. *For the Learning of Mathematics*, 16(2), 36-45. https://www.jstor.org/stable/40248203

Hasan, R. (1977). Text in the systemic-functional model. In W. Dressler (Ed.), *Current trends in textlinguistics* (pp. 228-46). Walter de Gruyter.

Huang, J. & Normandia, B. (2008). Comprehending and solving word problems in mathematics. In Z. Fang & M. Schleppegrell (Eds.), *Reading in secondary content areas: A language-based pedagogy* (pp. 64 – 83). University of Michigan Press.

Illustrative Mathematics. (2024). *IM 6-8 Math*. https://illustrativemathematics.org/math-curriculum/6-8-math/

Martin, J. R. (2001). Language, register and genre. In A. Burns & C. Coffin (Eds.), *Analysing English in a global context: A reader*(pp. 149-166). Routledge.

McCabe, A. (1997). Cultural background and storytelling: A review and implications for schooling. *The Elementary School Journal*, 97(5), 453-473. https://doi.org/10.1086/461876

O'Halloran, K. L. (1998). Classroom discourse in mathematics: A multisemiotic analysis. *Linguistics and Education*, 10(3), 359-388. https://doi.org/10.1016/S0898-5898(99)00013-3

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly*, 23(2), 139-159. https://doi.org/10.1080/10573560601158461

Vilenius-Tuohimaa, P. M., Aunola, K., & Nurmi, J. (2008). The association between mathematical word problems and reading comprehension. *Educational Psychology,* 28(4), 409–426. https://doi.org/10.1080/01443410701708228

Walqui, A., & Bunch, G. C. (Eds.). (2019). *Amplifying the curriculum: Designing quality learning opportunities for English learners.* Teachers College Press.

WIDA. (2020). *WIDA English language development standards framework, 2020 edition: Kindergarten-Grade 12*. WIDA, University of Wisconsin–Madison. https://wida.wisc.edu/teach/standards/eld

Wilburne, J. M., Marinak, B. A., & Strickland, M. J. (2011). Addressing Cultural Bias. Mathematics Teaching in the Middle School, 16(8), 460–465. http://www.jstor.org/stable/41183648

Cite this article

Green, J. & Dillard, B. (2025). What's the story? Examining the functional language of word problems. *WAESOL Educator, 50*(1), 12-16.