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The Word-Problem Solving and Explanations of Students Experiencing Mathematics Difficulty: A Comparison Based on Dual-Language Status

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Abstract

In mathematics, the expectation to set up and solve word problems emerges as early as kindergarten; however, many students who experience mathematics difficulty (MD) and dual-language learners often present with specific challenges in this area. To investigate why these populations experience word-problem difficulty, we examined the word, problem solving and oral explanations of third-grade dual-language learners (DLLs; $n = 40$) and non-DLLs ($n = 40$), all of whom were identified as experiencing MD. Students solved five additive word problems and provided oral explanations of their work, which were transcribed and coded for the number of words in each explanation, type of mathematics vocabulary terms used, inclusion of correct numbers in explanations, and descriptions of addition or subtraction. We identified no significant differences in word-problem scores between DLLs and non-DLLs with MD. For both DLLs and non-DLLs, students who answered problems correctly used more words in each explanation and used more mathematics vocabulary terms within their explanations. For incorrectly answered problems, the most common mistake for both DLLs and non-DLLs involved using the incorrect operation to solve the problem.

Keywords

dual-language learners, English learners, mathematics, mathematics difficulty, problem solving

Mathematics achievement often is measured using standardized tests administered at the district, state, or national level. On such high-stakes assessments, students are required to set up and solve word problems to demonstrate mathematics competency. However, many students encounter challenges when solving word problems. Students experiencing mathematics difficulty (MD) and dual-language learners (DLLs), identified as students with a native language other than English, are especially vulnerable to word-problem difficulty (Orosco, 2014; Swanson et al., 2015). In the current study, we use the umbrella term MD to include students with a school-identified specific learning disability and Individualized Education Program (IEP) goals in mathematics, students identified with dyscalculia, or those with persistent and below-grade-level mathematics performance, as defined by other researchers (Bryant et al., 2016; Fuchs et al., 2014).

Word Problems and Students With MD

Word problems, which include numbers within a word-based text (Riley & Greeno, 1988), comprise the majority of items on high-stakes assessments. Solving word problems often proves difficult for students (Krawec, 2014; Powell et al., 2015; Swanson et al., 2014) due to the steps necessary to develop a problem solution. For example, solving word problems requires students to read the problem, identify critical information, plan for a problem solution, and solve the problem (Powell, 2011). In some word problems, students also must locate information in charts or graphs, perform multiple calculations, or use visual representations. Furthermore, word problems may cause difficulty for students because of the language used within word problems (Boonen et al., 2016; Capraro et al., 2012; Fuchs et al., 2018). Because students with MD demonstrate lower rates of understanding mathematics vocabulary (Forsyth & Powell, 2017), the mathematics-specific language within

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word problems may add additional levels of complexity (Morin & Franks, 2010).

In the early elementary grades, students are expected to solve word problems involving addition or subtraction. Additive word problems (i.e., word problems with addition or its inverse, subtraction) fall into three different problem types: Total, Difference, or Change (De Corte & Verschaffel, 1987; Fuchs et al., 2014; Jitendra et al., 2013; Kintsch & Greeno, 1985). In Total problems, parts are put together for a total. In Difference problems, two amounts are compared for a difference. In Change problems, a starting amount increases or decreases to a new amount. Across all three additive problem types, the missing information (i.e., solution) may be the sum or difference, or an addend, the minuend, or the subtrahend.

Students experiencing MD often demonstrate difficulty with word-problem solving compared to students without MD. For example, in the elementary grades, students experiencing MD scored significantly lower on an assessment of word problems than students without MD (Andersson, 2008). Powell et al. (2009) reported similar findings, and determined third-grade students with MD (i.e., performance at or below the 25th percentile) solved fewer additive word problems correctly than students without MD. In a related study investigating why word problems were difficult for students with MD, García et al. (2006) learned students' word-problem difficulty related to the position of the missing information (e.g., word problems that involved solving for an addend were more difficult than that required solving for a sum). Kingsdorf and Krawec (2014) realized students with MD made more errors related to the selection of the appropriate numbers (from the word problem) and operation than students without MD. Furthermore, Wang et al. (2016) discovered irrelevant information (i.e., extraneous numbers within a word-problem scenario not necessary for the problem solution) within a word problem increased its complexity.

Mathematics and DLLs

Dual language learners are students who speak a native language other than English in their home environment (Goodrich & Namkung, 2019). They represent 10% of U.S. students in schools (National Center for Education Statistics [NCES], 2019) and represent the fastest growing subpopulation in schools over the past 20 years. Students with a native language other than English may be identified as meeting specific levels of English proficiency (e.g., ever-English learners; Umansky et al., 2017) or continuing to develop English proficiency. In this study, we focus on the latter and refer to these students as DLLs.

Considering the growth in numbers of the DLL population, the current mathematics performance of DLLs is of concern. On the National Assessment of Educational Progress (NAEP), for example, DLLs scored markedly below non-DLLs on the mathematics assessments (NCES, 2019). In fourth grade, 16% of DLLs scored at or above proficient levels compared to 44% of non-DLLs. The NAEP primarily consisted of word problems, which required students to read the word-problem text to answer mathematical questions. DLLs may have more difficulty with mathematical assessments that embed language (Alt et al., 2014). With a sample of more than 68,000 fourth-grade students, Martiniello (2008) demonstrated DLLs scored almost 9 points lower than non-DLLs on a state high-stakes test in which all items were presented within text.

DLLs may understand mathematical concepts and procedures, yet the language in word problems can create another layer of difficulty (Kong & Orosco, 2016; Leali et al., 2012; Solano-Flores et al., 2013). Goodrich and Namkung (2019) determined both decoding and vocabulary (English vocabulary, not mathematics vocabulary) were significant predictors of word-problem scores for DLLs. Similarly, Swanson et al. (2019) also noted English vocabulary and reading as significant word-problem predictors for DLLs. In a study comparing DLLs with non-DLLs on a word-problem measure, Martin and Fuchs (2019) identified no significant difference between DLLs and non-DLLs on word-problem scores in either the fall or spring of first grade for students with MD. For students without MD, however, the authors did identify a significant advantage for non-DLLs over DLLs at both fall and spring of first grade.

The mathematics-specific vocabulary in word problems may contribute to additional MD for DLLs (Shaftel et al., 2006; Wolf & Leon, 2009). Unfamiliar technical mathematics terms (e.g., *increase*), vocabulary words with one or multiple meanings in English or mathematics contexts (e.g., *difference, altogether*), and homonyms (e.g., *sum*) present a few of the nuances DLLs must navigate in the mathematics classroom (Roberts & Truxaw, 2013). To investigate performance differences related to mathematics vocabulary, Powell et al. (2019) examined the mathematics vocabulary knowledge of third-grade students with and without MD. For students who did not experience any MD, non-DLLs demonstrated a significantly higher average score on a test of mathematics vocabulary than DLLs. The same was true when comparing DLLs and non-DLLs who only exhibited difficulty with mathematics calculation. For students experiencing mathematics word-problem difficulty or comorbid word-problem and calculation difficulty, however, Powell et al. (2019) noted no differences in mathematics vocabulary scores for DLLs and non-DLLs.

In addition to word-problem solving, as students develop mathematical language skills, they are expected to participate in oral discussions and develop explanations to communicate their mathematical thinking and processes (Moschkovich, 2015). Explanation tasks may prove daunting to DLLs, who often provide more limited mathematical explanations than their non-DLL peers. For example, Bailey et al. (2015) asked DLLs at kindergarten, third grade, and fifth grade to determine the quantity of manipulative cubes and provide an explanation of how to show a peer how to count the cubes. DLLs used fewer total words and fewer academic vocabulary terms in their explanations than non-DLLs.

Purpose and Research Questions

To better understand why students with MD and DLLs experience difficulty in the area of word problems, we investigated the additive word-problem solving of DLLs and non-DLLs with MD. We focused on developing an understanding of how DLLs and non-DLLs (a) solve additive word problems and (b) explain their word-problem thinking using language. We asked the following research questions:

1. Does word-problem solving differ between third-grade DLLs and non-DLLs with MD?
2. How do third-grade DLLs and non-DLLs with MD explain their word-problem work? What explanation differences exist between DLLs and non-DLLs?

Method

Participants

For this analysis, we randomly selected participants from the first cohort of a larger study that investigated the efficacy of a word-problem intervention for students with MD (Powell et al., in press). During the first year of the program, we recruited 14 elementary schools in a southwestern urban school district in the United States for participation in the study. Within the 14 elementary schools, we screened 1,111 third-grade students, identified students performing <13th percentile on a word-problem measure (Jordan & Hanich, 2000) as at-risk for MD, and deemed these students eligible for the study. We randomly assigned eligible students ($n = 152$) to either receive one of the two active intervention programs or to participate in a business-as-usual comparison group. Three students moved during pretesting, leaving a total of 149 students who completed the pretest battery.

Of the 149 students, we identified 75 as DLLs and 74 as non-DLLs. Classroom teachers aided with the identification of DLL status by indicating whether the school district categorized each student as DLL or not. For each of the DLLs, teachers reported district-collected data from the *Texas English Language Proficiency Assessment System* (TELPAS), which is designed to assess the progress of students who are learning English. Teachers provided TELPAS proficiency ratings (i.e., *beginning* = 1, *intermediate* = 2, *advanced* = 3, and *advanced high* = 4) in four language areas (i.e., listening, speaking, reading, and writing). TELPAS scores from the four areas were combined for a composite score.

Table 1. Demographic Information.

	Dual-language learners ($n = 40$)		Non-dual-language learners ($n = 40$)	
Variable	*n*	%	*n*	%
Sex				
Female	23	57.5	22	55.0
Male	17	42.5	18	45.0
Race/ethnicity				
African-American	0	0.0	14	35.0
Asian	1	2.5	0	0.0
Caucasian	2	5.0	5	12.5
Haitian	1	2.5	0	0.0
Hispanic	36	90.0	16	40.0
Multiple races	0	0.0	4	10.0
Native American	0	0.0	1	2.5
Dual-language learner	40	100.0	0	0.0
Special education	2	5.0	6	15.0

For this study, we analyzed the performance and explanation of 80 students, given the lengthy transcription time and limited number of coders. Therefore, we assigned a student identification number for each of the 149 participating students. We used a random number generator to select student identification numbers for participation in the transcription analysis. We randomly selected 40 DLLs and 40 non-DLLs from 37 different classrooms in 12 schools for this analysis. Table 1 displays the demographic information for the participants with MD by language status. We did not report reduced-price or free lunch information in Table 1 because the school district did not allow for reporting of reduced or free lunch status by individual student. The school percentages of reduced-price or free lunch were as follows: 15.9%, 17.4%, 18.9%, 29.3%, 31.6%, 62.8%, 75.1%, 84.2%, 92.9%, 94.1%, 94.8%, and 96.2%.

Of the 40 DLLs, we reported the following average TELPAS scores: listening ($M = 2.55$, $SD = 0.83$), speaking ($M = 2.11$, $SD = 0.86$), reading ($M = 1.74$, $SD = 0.86$), and writing ($M = 1.95$, $SD = 0.87$). The average composite score was 1.95 ($SD = 0.75$), which indicated DLLs demonstrated language skills approaching the intermediate level.

In the district, teachers primarily used the *GO Math!, Investigations in Number, Data, and Space*, or *Motivation Math Texas* curricula to guide mathematics instruction. Classroom word-problem instruction for students incorporated general mnemonic devices (e.g., RICE: Read and restate, Illustrate, Calculate, and Explain and edit), key word clues (e.g., altogether means add), and practice in applying problem-solution rules, as self-reported by participating teachers. All students received all mathematics instruction in English.

Measure

Each student participated in three, 45-min pretest sessions. Examiners implemented the three sessions on three separate days within the same school week. The full battery included cognitive, mathematics, and reading measures. For this study, we selected an assessment administered in the third pretest session, *Texas Word Problems* (Powell & Stevens, 2015), for analysis. We administered *Texas Word Problems* to understand the connection between how students solved word problems using written work and the oral explanations accompanying the written work.

With *Texas Word Problems*, students solved five additive word problems, which are a mainstay of any third-grade mathematics curricula (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Each problem focused on a specific additive word-problem type (Fuchs et al., 2010; Kintsch & Greeno, 1985). Problem A was a Total problem (i.e., parts combined for a total) with a missing part: *Mark has 11 blue and red crayons. If 7 of the crayons are red, how many are blue?* Problem B was a Change decrease problem (i.e., an amount that changes) with the start amount missing: *Stephanie had some pencils in her backpack. Then, 5 pencils fell out on the way home from school. Now, she has 9 pencils in her backpack. How many pencils were in Stephanie's backpack to start?* Problem C was a Difference problem (i.e., two amounts compared for a difference) in which the greater amount was missing: *Maria has 4 more books than Juan. Juan has 5 books. How many books does Maria have?* Problem D was a Change increase problem with the change amount missing: *There were 7 birds sitting in the tree. Then more birds flew into the tree. Now there are 13 birds in the tree. How many birds flew into the tree?* Problem E was a Difference problem in which students needed to calculate the difference; amounts were provided on a horizontal bar graph: *How many fewer students like swimming than soccer?* We calculated Cronbach's alpha for this sample as .62.

For each problem, examiners read the word problem aloud. The examiners could reread each word problem up to two times. After reading, the examiners provided time for students to work and solve the problem. On this measure, we provided an outlined rectangular area below the written word problem to allow students to draw or write. Upon completion of the written work, examiners asked each individual student questions about the written work, with student responses captured on digital audio recorders. The examiners first asked, "How did you solve this problem?" If the response was vague, examiners prompted the student, "What is your answer?" and "How do you know?" The examiners repeated this process (i.e., reading, allowing students to solve, asking questions to elicit oral responses) for each of the five word problems.

Procedure

At pretest (i.e., prior to implementing the mathematics interventions), we administered a set of assessments to all 149 eligible students. For the current analysis, we randomly selected 80 of the 149 participants from the larger study. Examiners included graduate students from the local university and one full-time project manager. All graduate students and the project manager were pursuing or had earned graduate degrees in education-related fields. For pretest training, examiners participated in two, 3-hour sessions during which the project manager and first author introduced the testing protocols. Examiners practiced implementing the protocols with other examiners. Before administering assessments to students, examiners met individually with the project manager to demonstrate effective implementation of pretest protocols with fidelity. We collected fidelity of implementation for pretest by recording all testing sessions. We randomly selected 19.8% of audio recordings for analysis, evenly distributed across examiners, and measured fidelity to testing procedures against detailed fidelity checklists. We measured pretest fidelity at 98.0%.

Data Analysis

The research team scored each student's responses to the five word problems from the *Texas Word Problems* as correct or incorrect. Interrater reliability was 100%. We conducted analyses of variance (ANOVAs) to compare means for each of the five word problems by language status. After scoring for correct and incorrect responses, we transcribed the digital audio recordings of oral explanations of students' written work from *Texas Word Problems*. The transcribers played the audio files using a media player and transcribed the data using a word-processing program. We transcribed all clear dialogue between examiners and students verbatim; we marked inaudible portions of the transcription with an underscore. For instances during which the student spoke in another language (e.g., Spanish), we transcribed the audio in the student's native language.

From the transcriptions, the first and second authors counted the number of words in each student's explanations and also counted each mathematics vocabulary term a student used in their explanation. For word count and count of mathematics vocabulary, we followed coding procedures within mathematical explanations established by Bailey et al. (2015). For word count, we identified the total number of words for each explanation. We counted a term as mathematics vocabulary if the term formally or informally described a mathematics concept or procedure. We counted a mathematics vocabulary term each time it was used. For example, if a student said *added* three times in their explanation, they received 3 points. Our list of mathematics vocabulary included: *add/adding/added/addition, altogether, big/bigger/biggest, count/counting/counted, count up/down, difference, different, equal(s)/equaled, equation, extra, fewer, first, graph, greatest, how many, in all, least, less/less than/lesser, little(est), make, math, minus, more/more than, number(s), plus, problem, regroup(ed), second, small, solved, subtract/subtracting/subtracted/subtraction, take away/took away, together, total*, and *third*.

The first and second authors also coded into a database whether a student's explanation used correct numbers (i.e., the number presented in each word problem) and whether the student's explanation focused on addition or subtraction. We coded for addition or subtraction to learn how students interpreted each problem and whether a student understood the schema of the problem. Reliability of coding word count, mathematics vocabulary count, correct numbers, and explanations of addition or subtraction was 98.1%.

Results

With our first research question, we investigated whether word-problem solving differed between DLLs and non-DLLs with MD. Table 2 provides the number and percentage of students responding correctly and incorrectly to each problem. For the 40 DLLs in this analysis, we calculated an average score on *Texas Word Problems* of 1.70 out of a maximum possible score of 5 ($SD = 1.11$). Only one DLL answered all five problems correctly, and three DLLs did not answer any problems correctly. Of the 40 non-DLLs, we calculated an average score of 1.70 ($SD = 1.29$). One non-DLL answered all five problems correctly, and 10 did not answer any problems correctly. We identified no significant differences between the overall word-problem solving of the DLLs and non-DLLS, $F(1, 78) = 0.00$, $p = 1.00$. We also identified no significant differences based on DLL status for any of the five word problems, with p values at .78 (A), .38 (B), .18 (C), .64 (D), and .79 (E).

We examined the qualitative differences between oral word-problem explanations of DLLs and non-DLLs with our second research question. Specifically, we analyzed students' oral explanations for word count, mathematics vocabulary used, inclusion of correct numbers, and descriptions of addition or subtraction. Table 2 also provides the word count and mathematics vocabulary count for correct responders versus incorrect responders by DLL status. For DLLs, correct responders had a higher word count for all five problems but word counts were not significantly different, with p values of .86(A), .63(B), .39(C), .68(D), and .21(E). For non-DLL correct responders, we identified higher word counts on Problems A, B, C, and E. Incorrect responders had a higher word count for Problem D. Across all five problems, however, the word count averages were not significantly different, with p values of .42(A), .44(B), .32(C), .71 (D), and .75(E).

For DLLs, correct responders used more mathematics vocabulary for all five problems. We identified no significant differences between mathematics vocabulary counts for correct versus incorrect responders on Problem A ($p = .30$) or D ($p = .89$). We did identify significant differences in mathematics vocabulary counts with correct responders including more mathematics vocabulary in their explanations for Problem B, $F(1, 38) = 4.089$, $p = .050$; Problem C, $F(1, 38) = 8.629$, $p = .006$; and Problem E, $F(1, 38) = 5.345$, $p = .026$. For non-DLLs, we identified no significant differences between correct and incorrect responders on Problem A ($p = .27$), B ($p = .52$), and D ($p = .70$). We learned of significant differences in mathematics vocabulary counts for Problem C, $F(1, 38) = 6.821$, $p = .013$, as well as Problem E, $F(1, 38) = 5.449$, $p = .025$.

Table 3 provides data about whether explanations used correct numbers and descriptions for addition and subtraction. For correct responders, both DLLs and non-DLLs, almost every student used correct numbers in their explanations. For incorrect responders, most students used correct numbers in their explanations with a slightly lower percentage of non-DLLs using correct numbers on Problems A, B, and E. In the next section, we describe students' oral explanations of their written work, by problem, and provide examples of explanations for how DLLs and non-DLLs answered each problem correctly or incorrectly.

Problem A

Problem A featured the Total schema and required students to find the missing part: *Mark has 11 blue and red crayons. If 7 of the crayons are red, how many are blue?* Students could have added (e.g., 7 + __ = 11) or subtracted (e.g., 11 − 7 = __) to solve the problem.

DLLs. Only eight (20%) DLLs answered Problem A correctly. For the 32 (80%) incorrect responses, 13 (41%) incorrect responders provided an answer of 18, which is the sum of the two numbers provided within the word-problem text (i.e., 11 and 7). Nine (28%) incorrect responders provided an answer of 11, which is the sum of 7 and 4. This answer indicated several students subtracted 11 minus 7 (and the explanations demonstrated such), but then the students added 4 to 7 for a sum of 11. Idiosyncratic responses included 6, 8, 12, 13, 14, 16, and 26. For correct responders, we noted many explanations as procedural and based on operations. Some students used novel terms to explain mathematical processes. Examples included the following:

> I scratched 7 from the, the number 11. I scratched 7, and my answer was 4.

> Because 11 minus 7 equals 4.

Table 2. Performance, Word Count, and Mathematics Vocabulary Count by Problem.

	Dual-language learners (n = 40)				Non-dual-language learners (n = 40)			
	Correct responder		Incorrect responder		Correct responder		Incorrect responder	
Variable	*n* or *M*	% or *SD*	*n* or *M*	% or *SD*	*n* or *M*	% or *SD*	*n* or *M*	% or *SD*
A: Total with unknown part	8	20.0%	32	80.0%	7	17.5%	33	82.5%
Word count	26.1	(16.0)	25.0	(15.0)	37.1	(48.9)	27.0	(24.7)
Mathematics vocabulary count	3.2	(2.3)	2.3	(1.8)	3.1	(1.7)	2.3	(1.9)
B: Change decrease with unknown start	17	42.5%	23	57.5%	21	52.5%	19	47.5%
Word count	28.8	(16.6)	25.0	(18.9)	46.2	(63.0)	33.8	(30.3)
Mathematics vocabulary count	3.4	(3.3)	2.3	(2.1)	3.1	(2.0)	1.9	(1.7)
C: Difference with unknown greater amount	23	57.5%	17	42.5%	17	42.5%	23	57.5%
Word count	29.7	(20.1)	24.8	(15.2)	32.5	(19.3)	26.8	(16.4)
Mathematics vocabulary count	3.3	(2.1)	1.9	(1.8)	3.0	(1.5)	1.7	(1.2)
D: Change increase with unknown change	12	30.0%	28	70.0%	14	35.0%	26	65.0%
Word count	38.4	(30.3)	29.8	(20.7)	32.8	(23.2)	35.8	(25.3)
Mathematics vocabulary count	4.3	(3.9)	2.6	(2.4)	2.6	(1.6)	2.7	(1.9)
E: Difference with unknown difference	8	20.0%	32	80.0%	9	22.5%	31	77.5%
Word count	37.6	(28.0)	26.9	(19.4)	39.0	(32.3)	35.6	(26.2)
Mathematics vocabulary count	4.3	(4.3)	1.7	(2.7)	3.2	(1.5)	1.9	(1.5)

Note. We provide the *n* and % for each problem in terms of correct word-problem answer. We provide the *M* and *SD* for the word count and mathematics vocabulary count in each explanation.

> I subtracted . . . 11 minus 7 because if 7 of the crayons are red I need to find out how many how many more are . . . blue. Then 7 because if 7 and the other number equal 11. I need to find that.

For incorrect responders, many students added 11 and 7 together and provided a brief explanation of how they added. Similar to the correct responders, we noted almost all explanations as procedural and based on the operation. Examples included the following:

> Um, I added 11 and 7.

> I used 11 and 7 . . . I counted them together and I put the number on the bottom.

> Because I, I put 11 plus 7 is 18.

Non-DLLs. Only seven (18%) of the non-DLLs solved Problem A correctly, with 33 (82%) students responding incorrectly. We observed the most common incorrect responses as similar to those of DLLs. Of the 33 non-DLL incorrect responders, six (18%) students provided an answer of 18, whereas 10 (30%) students provided an answer of 11. Idiosyncratic responses included 1, 3, 6 (three students), 8, 12, 17, 21, and 81. Most correct explanations focused on subtraction. Correct responders explained subtraction in several different ways:

> I wrote 11 . . . I wrote 11 down and took away 7.

> If there were 7 crayons . . . So then . . . So um . . . Yea so that means there were 4 blue ones. My mom told me that if there are 7 and if you don't feel like counting down then you can count up to the number and then like that with your fingers.

> I subtracted 11 minus 7, 11 minus 7, 11 minus 7 equals 4.

Several incorrect responders provided explanations that were difficult to interpret:

> I solved it . . . by by looking at the words and . . . and I wrote the, I wrote, I wrote the numbers in the same thing as then I put the 11 on the bottom and then I put then I . . . then I used my fingers to see what the answer it.

> I solved this problem cause these crayons, I knew the darker ones were blue cause I tried my best, I think . . . 6 . . . because I counted the darker ones, that are the blue colors, the darker ones.

> Because I went backwards in the story and seen it.

Problem B

Problem B featured the Change decrease schema with the change and end amounts, and students needed to find the start amount: *Stephanie had some pencils in her backpack. Then, 5 pencils fell out on the way home from school. Now, she has 9 pencils in her backpack. How many pencils were in Stephanie's backpack to start?* Students could have added

Table 3. Explanations by Problem.

Variable	Correct explanations						Incorrect explanations					
	Correct numbers		Addition		Subtraction		Correct numbers		Addition		Subtraction	
A: Total with unknown part												
Dual-language learners	8	100%	1	13%	6	75%	30	93%	19	59%	3	9%
Non-dual-language learners	7	100%	1	14%	4	57%	28	85%	13	39%	4	12%
B: Change decrease with unknown start												
Dual-language learners	17	100%	15	88%	1	6%	23	100%	7	30%	8	35%
Non-dual-language learners	21	100%	15	71%	2	10%	17	89%	3	16%	9	47%
C: Difference with unknown greater amount												
Dual-language learners	22	96%	19	83%	0	0%	17	100%	4	24%	2	12%
Non-dual-language learners	17	100%	11	64%	0	0%	23	100%	4	17%	3	13%
D: Change increase with unknown change												
Dual-language learners	12	100%	7	58%	3	42%	28	100%	19	64%	2	7%
Non-dual-language learners	14	100%	6	43%	3	21%	26	100%	16	62%	3	12%
E: Difference with unknown difference												
Dual-language learners	8	100%	0	0%	5	63%	29	90%	7	22%	2	6%
Non-dual-language learners	9	100%	1	11%	4	45%	27	87%	6	19%	0	0%

(e.g., 5 + 9 = __) or subtracted (e.g., __ − 5 = 9) to solve the problem.

DLLs. Of the DLLs, 17 (43%) answered the problem correctly. Of the 23 (57%) incorrect answers, 10 (43%) students provided an answer of 4, which could be calculated by subtracting the two provided numbers from the word problem (i.e., 9 minus 5). One (4%) student answered 15 but explained the work as 5 plus 9. Similarly, two (9%) students answered 16 with explanations of adding 5 plus 9. Idiosyncratic answers included 5, 9, 10, and 13. Correct responders provided explanations focused on addition. Similar to Problem A, most explanations focused on procedures and operations. For example:

> I put 5 and 9 together cause it's together cause it said she lost 5 and now she has 9 so she had 14 before they dropped.
>
> I added 9 plus 5 because if she had 9 pencils left and 5 pencils fell I need to add them both to see how many were in the backpack.
>
> I solved it using adding. . .adding 5 plus 9.
>
> It says: Stephanie had some pencils in her backpack. Then 5 pencils fell out on the way home from school. Now, she has 9 pencils in her backpack. I add them together so it makes 14.

Incorrect explanations mainly focused on subtraction of 9 and 5. Most explanations were easy to understand, but others (i.e., the third example) were more convoluted. For example,

> I . . . I subtract the numbers . . . Because 9 minus 5 equals to 4.
>
> I solved this problem by using, again, subtraction, and I subtract 9 minus 5 and my total answer is 4.
>
> I solved it because . . . So if I tried 10 it didn't work if I tried 14 I added four more so I took away five and I counted how many more. And I counted these invisible dots and it was 9.

Non-DLLs. Of the non-DLLs, 21 (53%) answered the problem correctly. Of the 19 (47%) incorrect answers, three students (16%) responded with 10, and three students (16%) responded with 4. Two students (11%) provided the answers of 15 and 16. Idiosyncratic responses included the following: 0, 5, 9, and 18. Correct responses described processes of addition and subtraction. One responder used decomposition to develop a problem solution. For example,

> It's because it says how many were in Stephanie's backpack. So this is how many pencils. How many means plus . . . and then I got this answer because 9 plus 5 is 14 so I added 9 plus 5.
>
> I found it because that 9, 15 minus 5 equals 10 so I go down 1 and I got 14 minus 5 equals 9.
>
> I added up 5 and 9 and it maked 14 then I took away 5 and then it left 9.

Incorrect responders provided explanations of different sorts. For example,

> I solved by counting up like this . . . 10.

> So I counted pencils, uh how many were Stephanie, Stephanie has 5 pencils in her backpack from school . . . she brought 9 pencils.
>
> I was counting and I added, I noticed that 9, 5 minus 9 is zero because there's no . . . it's just a 5 not a 9.

Problem C

For Problem C, students determined the greater amount in a problem featuring the Difference schema: *Maria has 4 more books than Juan. Juan has 5 books. How many books does Maria have?* Students could have subtracted (e.g., __ − 4 = 5) or added (e.g., 4 + 5 = __) to arrive at a problem solution.

DLLs. Of the DLLs, 23 (58%) solved Problem C correctly. Of the 17 incorrect responders (42%), eight (47%) provided an answer of 4 and three (18%) provided an answer of 1 (derived from 5 minus 4). Idiosyncratic responses included 5, 6, 8, and 45. Correct explanations primarily focused on addition. Similar to previous explanations, some students discussed counting on fingers. For example,

> I put 4 in front, I put 5 in the beginning and I added with my fingers . . . and I . . . and I . . . and I added them and it equals 9.
>
> Addition . . . I did 4 plus 5.
>
> Since Juan has five books and Maria has 4 books so I did I equal sign and I changed the number to 5 so Maria's books I added 4 more books and counted 5, 6, 7, 8, 9, so the answer is 9.
>
> I added 4 plus 5 and the answer was 9. I got the answer 9 because it tell me in the sentence and this time I added because it says more and more means a lot not minus.

Students with incorrect explanations often resorted to operations, and we learned of several computation mistakes. For example,

> I saw that it says Maria has 4 more books than Juan. So then I did 4 plus 4 . . . 8.
>
> I subtracted 4 from, 4 from 5 and it equals 1.
>
> I can tell that um, I know that 5 came first then came 9, but I switched it so that it went like that . . . I think it was adding.

Non-DLLs. Only 17 (43%) of non-DLLs solved Problem C correctly. Of the 23 incorrect responders (58%), nine (39%) provided an answer of 4, and two (9%) students provided an answer of 1. Interestingly, six (26%) students provided an answer of 8, which they explained as the sum of 4 plus 4. Idiosyncratic responses included 11 and 13. Two students explained the calculation should be 4 minus 5. Many correct explanations focused on counting from 4 to 9. One student explained the method for solution (i.e., fingers) but not the solution itself. For example,

> I counted up from 4.
>
> Maria had 4 and I counted up 4 more and it equaled 9.
>
> I solved it by when you when you read it, I wrote the numbers down and then and then I used my finger how to solved it and then I put the number on the bottom and I was done.

Incorrect explanations demonstrated calculation mistakes and confusion about the problem stem. For example.

> 13. It's because she had, Maria had 4 books, so 4 and then Juan had 5 books, and then how many books does Maria have? So if we put all of these together and 4 more extra books. She will have 13 books. I read 5 books.
>
> So Maria 4 books then.. then James . . . Juan has 4 books. How many books does Maria have? So I got tally marks to count and I went to 8.
>
> First I'll tell you the answer. I put 4 more books and 5 books and Mary has 5 books. It says how many books does Mary have and Mary has 4 books.

Problem D

Problem D featured the Change schema and asked students to determine the change in an increase of birds: *There were 7 birds sitting in the tree. Then more birds flew into the tree. Now there are 13 birds in the tree. How many birds flew into the tree?* Students could have added (e.g., 7 + __ = 13) or subtracted (e.g., 13 − 7 = __) to solve the problem.

DLLs. Only 12 students (30%) responded correctly to the problem indicating 28 (70%) incorrect responses. We identified 20 as the most popular incorrect response, with 12 (43%) students providing this response by adding 7 plus 11. Two students (7%) provided an answer of 19, which is a near calculation of 7 plus 11. Seven (25%) students provided an answer of 13. Idiosyncratic responses included the following: 3, 4, 10, 21, 73, and 110. Correct explanations provided more detail about the process to arrive at a problem solution. For example,

> I solved the problem by 13 minus 7 so that gives me the number, that tells me there are 6 birds in the tree.
>
> There were 7 birds so then I counted up to 13. 7, 8, 9, 10, 11, 12, 13 and I counted up this one 1, 2, 3, 4, 5, 6. And there were 6 more birds that flew into the tree and 7 plus 6 is 13.

> If there were 7 birds I needed to subtract, if there were 7 birds sitting in the tree and more came and there were 13, I need to subtract 7, 7, 7 birds, 7 to 13 to see how many birds could . . . I know because 13 minus 7 equals. If 13 minus 7 equals if there's 13 birds that are not I need to see how many birds came so I they put 7 to subtract and see what other number added what other number needed to make 7 I needed to add to make 7 to make 13 so I subtracted 7 from 13.

Many incorrect explanations focused on addition instead of subtraction, and several students made computation errors. For example,

> I drawed 7 plus 13 and then . . . this is 10 and then I drawed a 1 . . . and then this is 10 . . . 1 plus 1 is 2 . . . Because I counted 17 plus 13 . . . and got 20.
>
> Because 1 plus nothing is 1 and 1 plus 7 is 10 . . . 110.
>
> Um, I added 17 plus, oh, I added, um I added 7 plus 13 and, and I added . . . I added 7 plus 3 equals 10, but I didn't write the whole 10 I just put 0 and in the 10s I put one and you add 1 plus 1 equals 2 so I got the answer 20.
>
> I put 7 plus 13 . . . 21.
>
> I think 7 and the 13 makes like, 19.

Non-DLLs. Only 14 (35%) of non-DLLs responded correctly to the problem. Of the 26 (65%) incorrect responders, six students (23%) provided an answer of 20, and three students (12%) answered with 13. Idiosyncratic answers included the following: 4, 5, 10, 11, 12, 15, 18, 22, and 83. Several correct explanations focused on counting on from 7, whereas one explanation used decomposition to arrive at a problem solution. For example,

> I solve the problem because there were 7 birds and you add 6 more and that makes . . . that makes . . . so 13 birds plus 13 birds, and 6 flew in because I knew because the numbers helped me know.
>
> I started at 7 and then 8, 9, 10, 11, 12, 13 and that equals up to 6.
>
> So I know that 7 plus 7 is 14 so I subtracted one and made it a 6.

Many incorrect explanations focused on addition of 7 and 13. For example,

> Because 7 plus 13 is 20. And the trick is that you have to use the highest number first and then the smaller.
>
> You put 7 and then.. and then.. and then its 8, and 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20.
>
> There . . . were more birds that um flied into the tree and then there would be half and half and put it together to get 13.

Problem E

On Problem E, students compared two amounts for a difference (i.e., Difference schema): *How many fewer students like swimming than soccer?* (Student used a horizontal bar graph with favorite sports to answer the question.) Students could have added (e.g., 2 + __ = 8) or subtracted (e.g., 8 − 2 = __) to identify the problem solution.

DLLs. Only eight (20%) DLLs solved this problem correctly. Of the 32 (80%) incorrect responders, we identified 10 as the most prevalent (34%) incorrect response, which can be calculated from 2 plus 8. Five students (16%) answered with 8, six students (19%) provided both numbers in the problem (i.e., 2 and 8), and two students (6%) used words to provide an answer. Idiosyncratic responses included: 2, 5, 7, and 9. Correct explanations counted up from 2 to 8 or used subtraction. For example,

> Well, so I counted the soccer which is 1 to 6 and umm 6 more students like soccer than swimming.
>
> I decided 8 minus 2 equals 6.
>
> I solved it by, by adding a different number. First I subtract 8, 8 minus something equals 2. So I did 8 and I added how much to add to 2. 1, 2, 3, 4, 5, 6, 6, so that was 6 the answer was 6.

Students who answered incorrectly often added the numbers together within the problem. For example,

> I add 12 and 8. I mean 2 and 8 because swimming was 2 and soccer was 8 and I got 10.
>
> I add the 2 and the 8 and make 10. And the soccer are 10 that like soccer.
>
> 10 . . . addition.
>
> I looked at the graph and saw how many people like swimming and soccer then I added swimming is 2 and soccer is 8 so I add them together and I get the answer 10. But this time I just write the whole answer 10 because there was no. like, like 31 or 10s only 1s.

Non-DLLs. Only nine (22%) of the non-DLLs solved this problem correctly. Of the 31 incorrect responders (78%), five (16%) provided an answer of 10, six (19%) used words for an answer, and three (10%) provided both 2 and 8 as an answer. Other responses included the following: 2, 8, 9, 12, and 27. Students who answered correctly discussed counting on or subtraction. For example,

> Because I put swimming and soccer together . . . swimming and soccer together . . . I put swimming and soccer together . . . And then I did that. 1, 2, 3, 4, 5, 6. And it was 6.

> Because . . . I counted right here.
>
> I got there by subtracting 2 minus 8 would equal 6.

Incorrect responders made calculation mistakes or provided convoluted responses. One student references a common word-problem strategy (i.e., UPSCheck). For example,

> I had . . . 8 . . . I had 8 and I counted the 1 and it made 9.
>
> Because soccer is more bigger and be everybody likes some people like soccer and some people like swimming.
>
> I used the UPS check which is understand, plan, solve and look back. The check is basic but still I used it because it's more, it's another easier way to make me understand so the whole basic of it is to find the answer, how many fewer students like swimming than soccer. So for understand I used swimming and soccer cause that's the only thing I used, I have to use. Then my plan was to add so I used 10, I mean 8 plus 2 which equals 10 because 9, 10. And again it, there's no, there's no, if there's no number than you can use these to and it might make a 10.

Discussion

Performance Differences

With our first research question, we investigated whether word-problem solving differences existed across DLLs and non-DLLs experiencing MD. Across the five additive word problems on *Texas Word Problems*, we identified no significant difference in the average word-problem solving of DLLs and non-DLLs. In fact, the average score was identical. The result of no difference between DLLs and non-DLLs does not align with patterns from prior assessment data (Martiniello, 2008; NCES, 2019), which showed non-DLLs outperforming DLLs. Such data from high-stakes tests, however, only compared DLLs and non-DLLs across all levels of mathematics knowledge (i.e., students with and without MD).

In this study, the lack of a difference in word-problem scores between DLLs and non-DLLs aligns with recent research in the area of MD. For example, Martin and Fuchs (2019) identified no word-problem differences for DLLs and non-DLLs with MD. With a focus on mathematics vocabulary, Powell et al. (2019) also identified no mathematics vocabulary differences between DLLs and non-DLLs with MD. Our results, similar to Martin and Fuchs (2019) and Powell et al. (2019), suggest MD status eclipses DLL status on word-problem tasks.

Explanation Differences

Even without performance differences on *Texas Word Problems*, we explored the oral word-problem explanations of DLLs and non-DLL students with MD with our second research question. Similar to Bailey et al. (2015), non-DLLs provided more words in their word-problem explanations than DLLs, but this trend did not hold true across all five problems. Correct responders, regardless of DLL or non-DLL status, provided more words in explanations than incorrect responders, and we noted higher numbers of mathematics vocabulary terms in explanations for correct responders over incorrect responders. As oral explanations and discourse in mathematics may help students understand mathematics better (Imm & Stylianou, 2012; Moschkovich, 2015), our results suggest students who have a stronger mathematics vocabulary lexicon likely understand word problems better and solve problems correctly.

For both DLLs and non-DLLs with MD, we noted a greater likelihood of answering a problem correctly when the answer could be calculated by adding together the two numbers provided within the word-problem text (i.e., Problems C and D). To confirm many students used this strategy, the most common incorrect explanations in Problems A, B, and E involved addition of the two provided numbers within the word problem. Both DLL and non-DLLs made this mistake, which indicated adding the two numbers from the word-problem text is a common error pattern for many students with MD.

Another common pattern across all students with MD reflected a focus on the selected operation within the word-problem explanation. For explanations with addition, students utilized more formal mathematics vocabulary such as *added, together, plus, all*, and *equals*. Students also used informal language to explain addition (e.g., *plussed, maked*). For subtraction explanations, students used *subtract, minus, take away, difference*, and *equals.* There were no students who described the word problem by the structure or problem type (e.g., Total problem), which would indicate a deeper understanding of the word problem. One student demonstrated use of a word-problem step-by-step attack strategy (i.e., understand, plan, solve, check), but even with this strategy, the student answered the word problem incorrectly.

Limitations and Future Research

We note several limitations. First, due to the lengthy transcription time and limited staff resources, we only coded explanations data from 80 third-grade students (40 DLLs and 40 non-DLLs). Thus, we assumed the written word-problem responses and oral explanations of these students represented the word-problem performance and strategies of all students in our sample. Future research should collect data from larger sample sizes of elementary students to further understand how DLLs and non-DLLs with MD explain their word-problem work.

Second, we administered only five additive word problems. Although the word problems and oral explanations provided insight into students' thought processes, future research may want to include all variations of schemas and positions of unknown information in word problems. Furthermore, future research should consider assessments that include multiplicative word problems and multi-step word problems to explore whether a similar pattern of performance holds for more complicated word problems.

Third, an overwhelming majority of DLLs in our sample spoke Spanish as their first language. Future research should investigate the word-problem solving and oral explanations of DLLs with a native language other than Spanish to determine if results are comparable, regardless of language associated with DLL status.

Conclusion and Implications for Practice

We identified no significant differences in the total word-problem scores of DLLs and non-DLLs. These results may suggest that, when students experience MD, the MD supercedes language status (e.g., DLL or non-DLL) in terms of influence on word-problem solving. We did learn of some variability in students' oral explanations with correct responders, both DLL and non-DLL, providing explanations with more words and more mathematics vocabulary than incorrect responders in most explanations. Therefore, when focused on word problems during instruction, teachers should consider that all students experiencing MD—both DLLs and non-DLLs—may require instruction and practice on solving word problems, providing oral explanations, and using mathematics vocabulary.

Authors' Note

The content is solely the responsibility of the authors and does not necessarily represent the official views of the Institute of Education Sciences or the U.S. Department of Education.

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