The Development of Mathematics-Vocabulary Measures for Elementary Students

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Thanks

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The University of Texas at Austin
College of Education

The Meadows Center
FOR PREVENTING EDUCATIONAL RISK

Language of Mathematics

2,450

thousands

+

add

>

greater

$\frac{2}{3}$

numerator

Language of Mathematics

Mathematics Vocabulary

2,45

thousands

denominator

parallelogram

$>$

skip counting

quotient

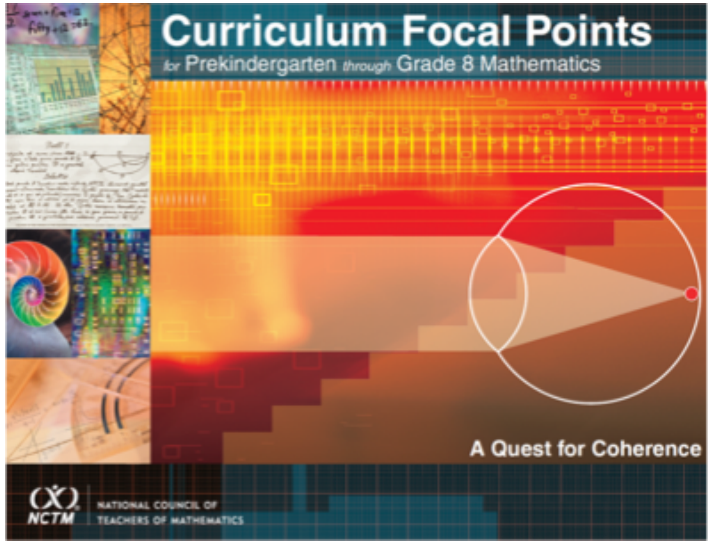
cube

ter

$\frac{2}{3}$

numerator

Mathematics Vocabulary

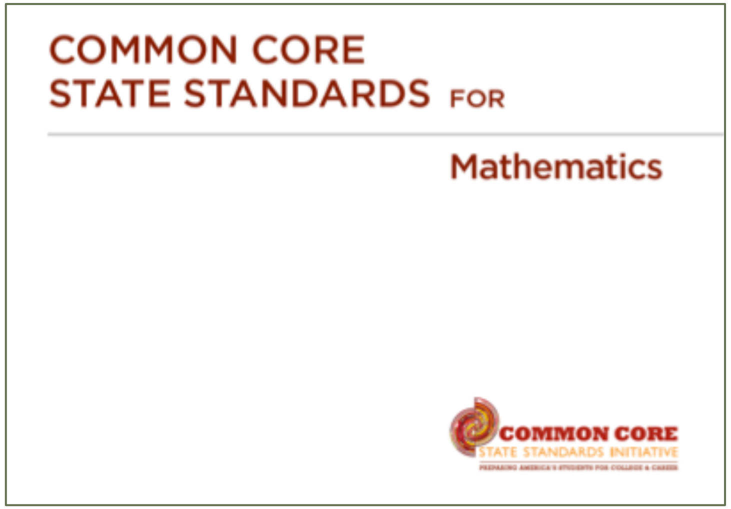


Identify, compare, and analyze attributes of two- and three-dimensional shapes and develop vocabulary to describe the attributes

Describe location and movement using common language and geometric vocabulary

Children interpret the physical world with geometric ideas (e.g., shape, orientation, sp
and describe it with corresponding vocabulary. They identify, name, and describe a va

Mathematics Vocabulary


COMMON CORE
STATE STANDARDS FOR

Mathematics

4. Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).

1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. *For example, "The ratio of wings to beaks in the bird house at the zoo was 2:1, because for every 2 wings there was 1 beak." "For every vote candidate A received, candidate C received nearly three votes."*

3. Partition circles and rectangles into two, three, or four equal shares, describe the shares using the words *halves*, *thirds*, *half of*, *a third of*, etc., and describe the whole as two halves, three thirds, four fourths. Recognize that equal shares of identical wholes need not have the same shape.

Mathematics Vocabulary

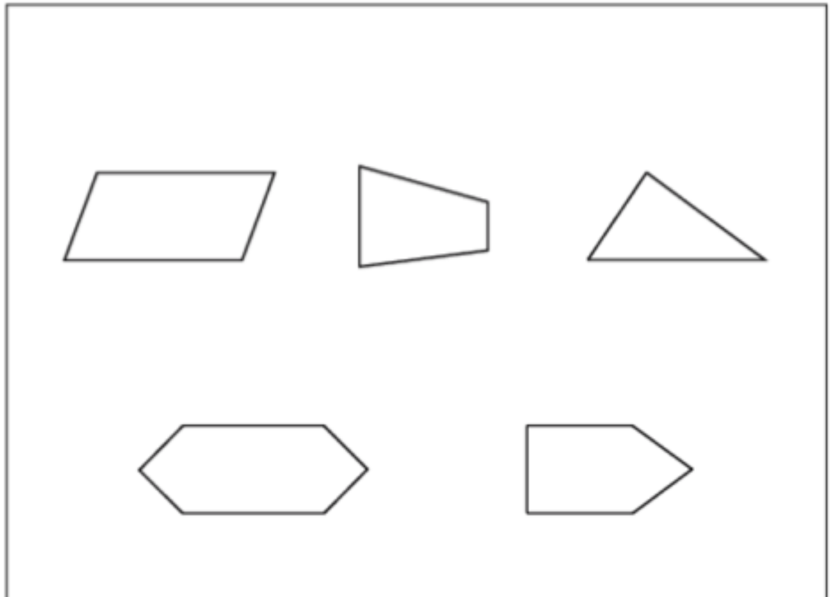
Kevin makes muffins.

- It takes 8 minutes to mix the batter.
- The muffins bake for 17 minutes.
- The muffins then cool for 5 minutes.

What is the total amount of time, in minutes, Kevin spends mixing, baking, and cooling the muffins?

2003

Click **all** of the shapes that are quadrilaterals.



Development of Measures

Grade 1

40

1. Term appeared in 2 of 3 first-grade textbook glossaries
   - *Go Math!* *enVisionMATH* *Everyday Math*

19

2. Term appeared in a textbook glossary and a standard
   - Common Core

1

3. Term was opposite of selected term
   - *longest*

4

4. Terms included to alleviate ceiling effects

Grade 1

64

19

1

4

- 31 terms appeared in kindergarten glossaries
- 45 terms appeared in second-grade glossaries

Mathematics Vocabulary (1st Grade)

Answer the questions.

1. Circle the name of each coin.

A. dime
B. half dollar
C. nickel
D. penny
E. quarter

A. dime
B. half dollar
C. nickel
D. penny
E. quarter

A. dime
B. half dollar
C. nickel
D. penny
E. quarter

A. dime
B. half dollar
C. nickel
D. penny
E. quarter

2. Circle the set with the greatest.

3. Circle the set with the least.

4. In the box, write the double of 4.

In the box, write half of 6.

5. Subtract five circles.

Add four circles.

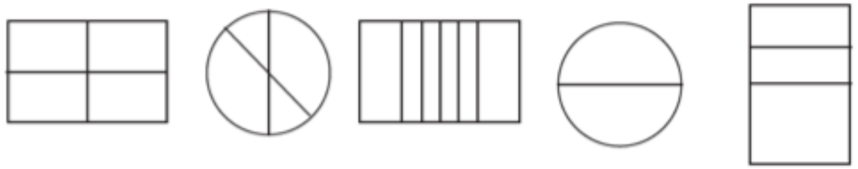
Divide into groups of three.

Multiply by two.

6. Write an odd number. Write an even number. Write a prime number.

7. Show skip counting by twos to 20.

8. Circle all that show equal shares.



9. Draw a set in the box that is equal.

10. Match each part to a word by writing a letter in the box.

5 + 6 = 11

☐ G ☐ ☐

9 – 3 = 6

☐ ☐ ☐ ☐

A. addend
B. difference
C. equal sign
D. greater than
E. minuend
F. minus sign
G. plus sign
H. subtrahend
J. subtrahend
K. sum

11. Circle all that show counting back.

8, 7, 6, 5 3, 5, 7, 9, 11 14, 15, 13, 12 21, 20, 19, 18, 17

12. Circle all that show counting on.

2, 9, 7, 4 19, 18, 17, 16 9, 10, 11, 12, 13 3, 4, 6, 5

13. Label the clock hands.

14. Draw a number line.

15. Circle the name of each shape.

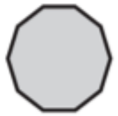
A. circle
B. octagon
C. rectangle
D. rhombus
E. square

A. decagon
B. heptagon
C. hexagon
D. octagon
E. pentagon

A. decagon
B. heptagon
C. hexagon
D. octagon
E. pentagon

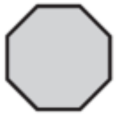
A. octagon
B. parallelogram
C. rectangle
D. rhombus
E. trapezoid

A. circle
B. octagon
C. rectangle
D. rhombus
E. square



A. decagon
B. heptagon
C. hexagon
D. octagon
E. pentagon

A. circle
B. octagon
C. rectangle
D. rhombus
E. square



A. decagon
B. heptagon
C. hexagon
D. octagon
E. pentagon

A. decagon
B. heptagon
C. hexagon
D. octagon
E. pentagon

16. Draw a triangle.

Draw a square.

Draw an oval.

Draw a line.

Draw a closed figure.

Draw an open figure.

17. Circle all that show an addition sentence.

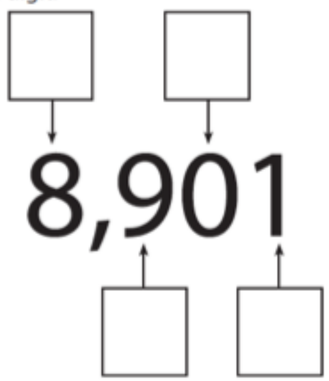
9 – 2 = 7   8 = 6 + 2   10 – 3 = 7   4 + 6 = 10   7 + 3 + 1 = 11

18. Circle all that show a subtraction sentence.

2 = 8 – 6   4 = 3 + 1   6 + 9 = 15   12 – 3 = 9   9 = 9

19. Draw circles to make ten.

20. Label the place value of each digit.



A. hundreds
B. millions
C. ones
D. tens
E. thousands

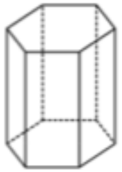
21. Draw a ball inside the box. Draw a star outside the box.

22. Circle the line that is longest.

23. Circle the line that is shortest.

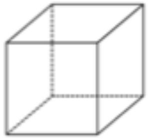
24. Circle the name of each shape.

A. cone
B. cube
C. cylinder
D. sphere
E. square

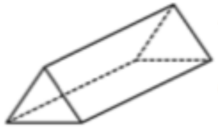


A. hexagonal prism
B. hexagonal pyramid
C. rectangular prism
D. rectangular pyramid
E. triangular prism
F. triangular pyramid

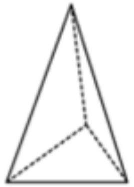
A. hexagonal prism
B. hexagonal pyramid
C. rectangular prism
D. rectangular pyramid
E. triangular prism
F. triangular pyramid



A. cube
B. cylinder
C. rectangular pyramid
D. square
E. triangular prism

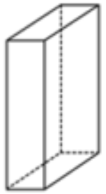


A. hexagonal prism
B. hexagonal pyramid
C. rectangular prism
D. rectangular pyramid
E. triangular prism
F. triangular pyramid

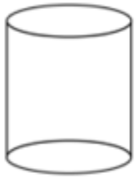


A. hexagonal prism
B. hexagonal pyramid
C. rectangular prism
D. rectangular pyramid
E. triangular prism
F. triangular pyramid

A. cone
B. cube
C. cylinder
D. sphere
E. square



A. cube
B. cylinder
C. rectangular pyramid
D. square
E. triangular prism



A. cone
B. cube
C. cylinder
D. sphere
E. square

25. Write zero.

26. Circle the set that shows more.

27. Circle the set that shows less.

28. Draw lines to break the box into unequal parts.

29. Circle the sets the show equal.

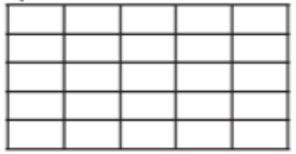
30. Draw tally marks to show 4.

31. Divide into thirds. Divide into half. Divide into quarters.

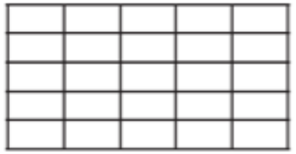
32. Separate 2 from the set.

33. Take away 4 from the set.

34. Color the bottom row with your pencil.



35. Color one column with your pencil.



Grades 3 and 5

77

1. Term appeared a textbook glossary at grade 3 and 5
   - *Go Math!*   *enVisionMATH*   *Everyday Math*

22

2. Term appeared in a textbook glossary and a standard
   - Common Core

6

3. Term in a glossary but not explicit in a standard

16

4. Term explicitly named in standards but not a glossary

12

5. Term related to previously-selected terms

Grades 3 and 5

133

22

6

16

12

- In the Common Core:
  - 22 introduced in kindergarten
  - 9 in grade 1
  - 18 in grade 2
  - 13 in grade 3
  - 14 in grade 4
  - 4 in grade 5
  - 14 in grade 6 or above

Mathematics Vocabulary

Answer the questions. Try the easy problems first, then go back and try the harder problems.

1. Identify each part. Write the letter in the box. You may repeat letters and/or not use all letters.

$5 + 6 = 11$

$24 \div 4 = 6$

$3 \times 9 = 27$

$14 - 5 = 9$

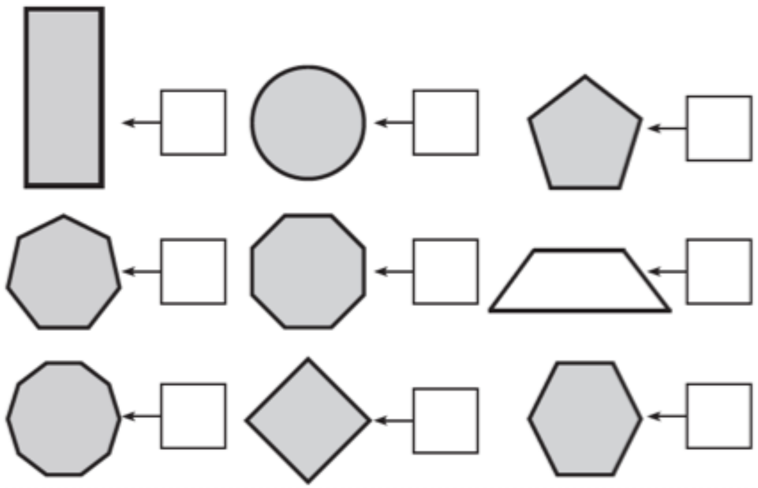
A. addend
B. augend
C. difference
D. dividend
E. divisor
F. factor
G. minuend
H. multiplicand
J. multiplier
K. plus
L. product
M. quotient
N. subtrahend
O. sum

2. Draw an acute triangle. Draw an isoceles triangle. Draw an obtuse triangle.

Draw a scalene triangle. Draw an equilateral triangle. Draw a right triangle.

3. Write an odd number. Write an even number. Write a prime number.

4. Write the letter of each shape in the box.
You may repeat letters, not use all letters, or use more than one letter.



A. circle
B. decagon
C. heptagon
D. hexagon
E. octagon
F. parallelogram
G. pentagon
H. rectangle
J. rhombus
K. square
L. trapezoid

5. Write a number with a denominator of 9 and a numerator of 4.

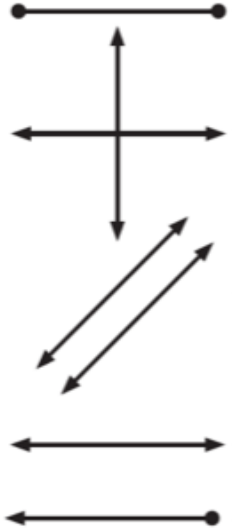
6. Draw a number line.

7. Write 537 in expanded form.

8. Write a <u>mixed number</u>. Write an <u>improper fraction</u>. Write a <u>proper fraction</u>.

Write a <u>unit fraction</u>. Write an <u>equivalent fraction</u> to 1. Write a <u>whole number</u>.

9. Identify each. Write the letter in the box. You may repeat letters and/or not use all letters.



A. intersecting lines
B. line
C. line segment
D. parallel lines
E. perpendicular lines
F. point
G. ray

10. Write the <u>reciprocal</u> of 6/5.

11. Write the name of each coin in the box.

12. Draw a <u>radius</u>. Draw a <u>diameter</u>. Draw a <u>chord</u>.

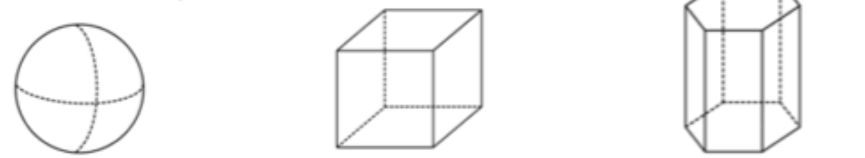
13. Write *three-hundred, twenty-five* in <u>standard form</u>.

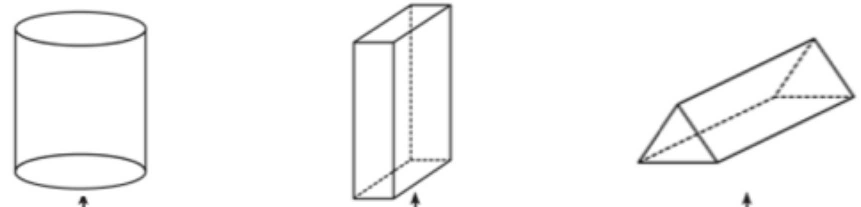
14. Write an <u>expression</u>.

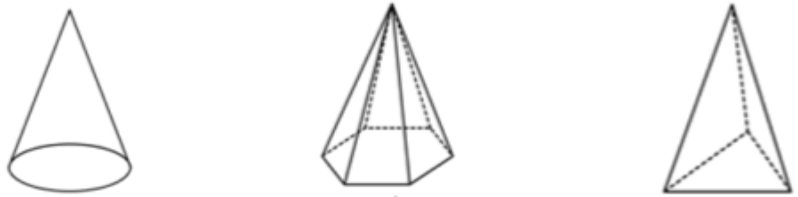
15. Write an <u>equation</u>.

16. Write an <u>inequality</u>.

17. Write the name of each shape.







18. Draw a regular polygon.

Draw an irregular polygon.

19. Label the place value of each digit.

2,568,901.347

What do the commas separate?

What is the name for the item between the 1 and 3?

What number is in the tenths place?

What number is the the ones place?

20. Write a positive integer.

Write a negative integer.

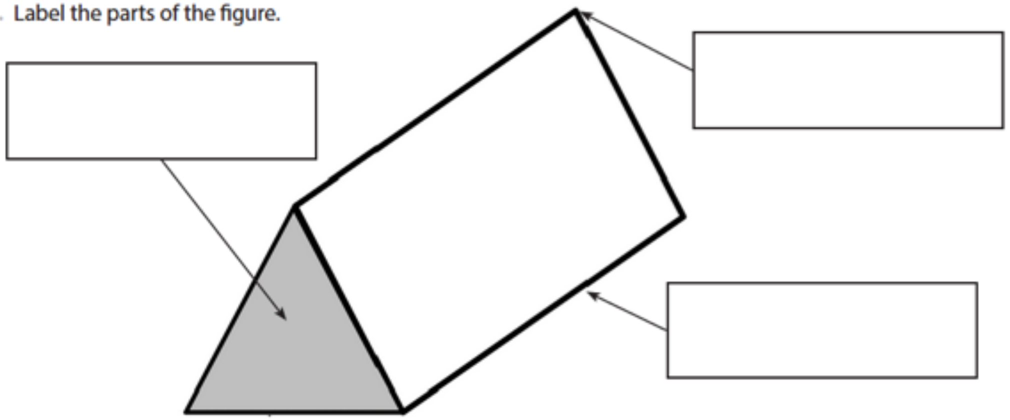
21. Label the clock hands.

22. Divide into thirds.

Divide into halves.

Divide into fourths.

23. Label the parts of the figure.



What is this figure? (Circle all options.)

Two-dimensional **Solid figure**

Three-dimensional **Open figure**

24. Subtract five.

Multiply by two.

Add four.

Divide into groups of three.

25. Show skip counting by twos to 20.

26. Draw a line around the perimeter of the shape.

Shade the area of the shape.

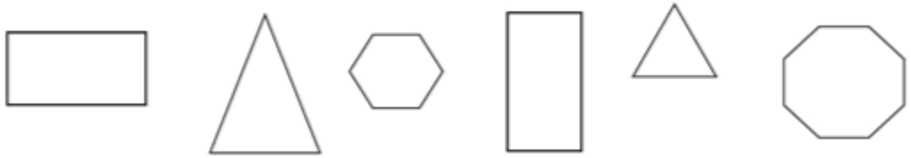
27. Draw a right angle.

Draw an obtuse angle.

Draw an acute angle.

28. Draw an array for 4 times 2.

29. Circle the two congruent shapes.



30. Complete the conversions.

1 minute = 60

5,280 feet = 1

1 gallon = 4

1 pound = 16

1000 meters = 1

2,000 pounds = 1

31.

What's the term for an approximate value?

What's the term for having the same value?

What does it mean to have to sides of a scale with the same amount?

What's the term for a number that names parts of a whole?

What's information collected to draw conclusions?

What's the term for the group with the largest value?

What's the term for the group with the smallest value?

What's the term for a set of numbers like **(6, 2)**?

Any number is ___ if it can be divided by a number without leaving a remainder.

What's the term for a closed figure made up of line segments?

What's the term for all pieces of a shape or group?

What's the largest factor of two numbers?

What's the amount left over after dividing?

32. What does more mean?

What's a prism?

What does it mean to regroup?

What does it mean to round?

What is slope?

What is a variable?

What is place value?

What does order of operations mean?

What is income?

What is a formula?

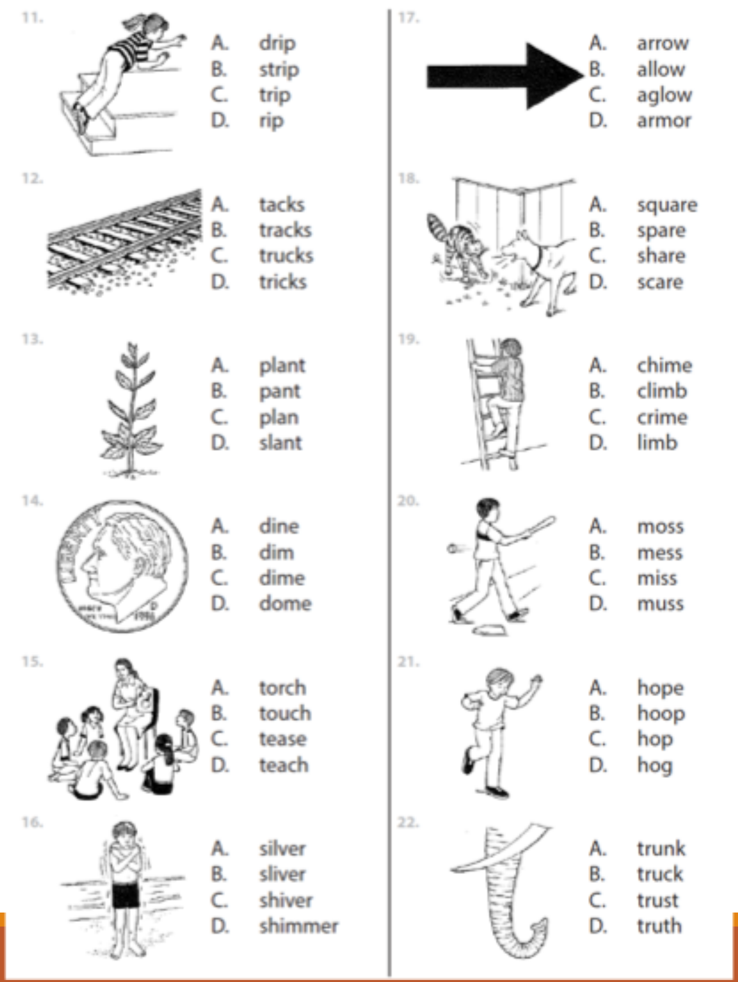
Pilot Studies

Grade 1

- 104 first-grade students from 6 classrooms

	n	%
Gender:		
Male	55	52.9
Female	49	47.1
Race/ethnicity:		
African American	12	11.5
Asian	1	1.0
White	37	35.6
Hispanic	54	51.9
English learners	1	1.0
Retained	7	6.7
Special education	3	2.9

Measures


11. A. drip B. strip C. trip D. rip

12. A. tacks B. tracks C. trucks D. tricks

13. A. plant B. pant C. plan D. slant

14. A. dine B. dim C. dime D. dome

15. A. torch B. touch C. tease D. teach

16. A. silver B. sliver C. shiver D. shimmer

17. A. arrow B. allow C. aglow D. armor

18. A. square B. spare C. share D. scare

19. A. chime B. climb C. crime D. limb

20. A. moss B. mess C. miss D. muss

21. A. hope B. hoop C. hop D. hog

22. A. trunk B. truck C. trust D. truth

1 + 1	3 + 0	2 − 2	4 − 2	1 + 2	3 − 3	0 − 0	0 + 3	2 − 1	4 + 2
0 + 5	3 − 1	6 + 1	4 − 4	5 − 0	1 − 1	1 + 6	5 + 3	4 − 1	5 + 2
3 − 2	1 + 5	6 − 3	2 + 2	1 + 7	4 + 4	8 + 1	4 − 3	2 + 7	1 + 4
5 − 2	8 − 1	5 + 4	3 + 3	10 − 2	6 + 3	7 − 2	8 + 2	1 + 3	9 − 4
6 − 2	6 + 4	3 + 9	8 − 6	5 + 7	10 − 10	6 + 2	5 − 3	6 − 6	4 + 3
5 + 5	8 + 3	5 − 1	0 + 8	7 − 4	9 + 1	10 − 6	4 + 8	8 + 6	9 − 9
1 × 1	5 − 4	7 + 7	3 × 2	10 − 5	2 × 1	2 + 3	8 + 8	5 + 9	1 × 5
7 + 3	4 × 1	9 − 2	8 + 9	3 × 3	6 + 5	2 × 2	9 − 3	1 × 3	6 + 6

Grade 1 Mathematics Vocabulary

- $\alpha = .85$
- Item-by-item analysis for reliability
  - Deletion of only five terms would have increased α by .02
  - Opted to keep all terms for analysis

Grade 1 Mathematics Vocabulary

	Raw Score		Correlations	
Variables	*M*	*SD*	WD	MF
GMRT WD	27.57	8.56	–	–
WJ-III MF	31.17	14.29	.526	–
Mathematics Vocabulary	36.30	8.10	.697	.586

Grade 1 Mathematics Vocabulary

- Range: 15 – 55
- No significant differences based on gender or retained status
- Significant differences:
  - For English learner ($n = 1$)
  - Students with disabilities < students without disabilities
  - African American < Hispanic < Caucasian

Grade 1 Mathematics Vocabulary

Predictor	*B*	*SE B*	*β*	*t*	*p*	R^2	ΔR^2
Model 1:							
Intercept	18.088	1.940		9.325	<.001		
GMRT word decoding	.661	.067	.697	9.826	<.001	.486	
Model 2:							
Intercept	16.779	1.844		9.157	<.001		
GMRT word decoding	.509	.074	.538	6.874	<.001		
WJ-III math fluency	.172	.044	.304	3.881	<.001	.553	.067

Grade 1 Mathematics Vocabulary

- Accuracy by item introduction:
  - Kindergarten **67.1%**
  - First grade **48.8%**
  - Second grade **29.2%**
- Accuracy by category:
  - Technical **42.0%**
  - Subtechnical **56.4%**
  - General **91.1%**
  - Symbolic **54.5%**

Grades 3 and 5

Variable	Grade 3 (n = 65)		Grade 5 (n = 128)		Overall sample (N = 193)	
	n	(%)[a]	n	(%)[a]	n	(%)
Gender						
Female	26	(40.0)	61	(47.7)	87	(45.1)
Male	39	(60.0)	67	(52.3)	106	(54.9)
Race/ethnicity						
African American	4	(6.2)	15	(11.7)	19	(9.8)
Caucasian	20	(30.8)	47	(36.7)	67	(34.7)
Hispanic	41	(63.1)	55	(43.0)	96	(49.7)
Other	0	(0.0)	11	(8.6)	11	(5.7)
School-identified disability	12	(18.5)	8	(6.3)	20	(10.4)
English learner	17	(26.2)	24	(18.8)	41	(21.2)
Retained	8	(12.3)	5	(3.9)	13	(6.7)
	M	(SD)	M	(SD)	M	(SD)
GMRT vocabulary[b] (standard score)	98.94	(13.98)	97.65	(11.25)	98.09	(12.22)
WRAT Math Computation (standard score)	113.92	(12.97)	107.66	(14.23)	109.77	(14.10)
Mathematics vocabulary (raw score)	35.57	(14.02)	57.51	(20.61)	50.20	(21.32)

Measures

11. They should display it.
    A. show
    B. play with
    C. go around
    D. look at

12. a sore knuckle
    A. back of the neck
    B. shoulder
    C. tip of a toe
    D. part of a finger

13. a big jug
    A. container
    B. cork
    C. jumble
    D. drink

14. She was active.
    A. lazy
    B. noisy
    C. doing things
    D. tired

15. a good excuse
    A. note
    B. reason
    C. movement
    D. example

16. It might rise.
    A. bloom
    B. go fast
    C. ride away

17. the good waxing
    A. waltzing
    B. polishing
    C. rocking
    D. answering

18. The others peered at it.
    A. looked closely
    B. smiled
    C. pecked
    D. made loud noises

19. They might discuss it.
    A. discover
    B. decide on
    C. talk about
    D. be upset about

20. It may vibrate.
    A. come loose
    B. break open
    C. inflate
    D. shake

21. the important mission
    A. homework
    B. thing that is lost
    C. task
    D. session

22. They can weave.
    A. make cloth
    B. say good-bye
    C. paint

1. $1 + 1 =$ ____	2. $\begin{array}{r} 5 \\ -\ 1 \\ \hline \end{array}$	3. Write the missing number: 28, 29, ___, 31, 32	4. $8 - 4 =$ ____	5. $2 + 7 =$ ____
6. $\begin{array}{r} 9 \\ +\ 3 \\ \hline \end{array}$	7. $8 -$ ____ $= 5$	8. $\begin{array}{r} 32 \\ 24 \\ +\ 40 \\ \hline \end{array}$	9. $\begin{array}{r} 36 \\ -\ 15 \\ \hline \end{array}$	10. $3 \times 4 =$ ____
11. $\begin{array}{r} 68 \\ +\ 23 \\ \hline \end{array}$	12. $6 \div 2 =$ ____	13. $\begin{array}{r} 33 \\ -\ 17 \\ \hline \end{array}$	14. $\begin{array}{r} 229 \\ 5{,}048 \\ +\ 63 \\ \hline \end{array}$	15. $\begin{array}{r} 17 \\ \times\ 4 \\ \hline \end{array}$
16. $\begin{array}{r} 724 \\ -\ 597 \\ \hline \end{array}$	17. Round 357 to the nearest ten. Answer ____	18. $\frac{15}{5} =$ ____	19. $\frac{1}{3} + \frac{1}{3} =$ ____	20. $2\frac{1}{2} + 1\frac{1}{2} =$ ____

Grades 3 and 5 Mathematics Vocabulary

- α = .92 at Grade 3
- α = .96 at Grade 5

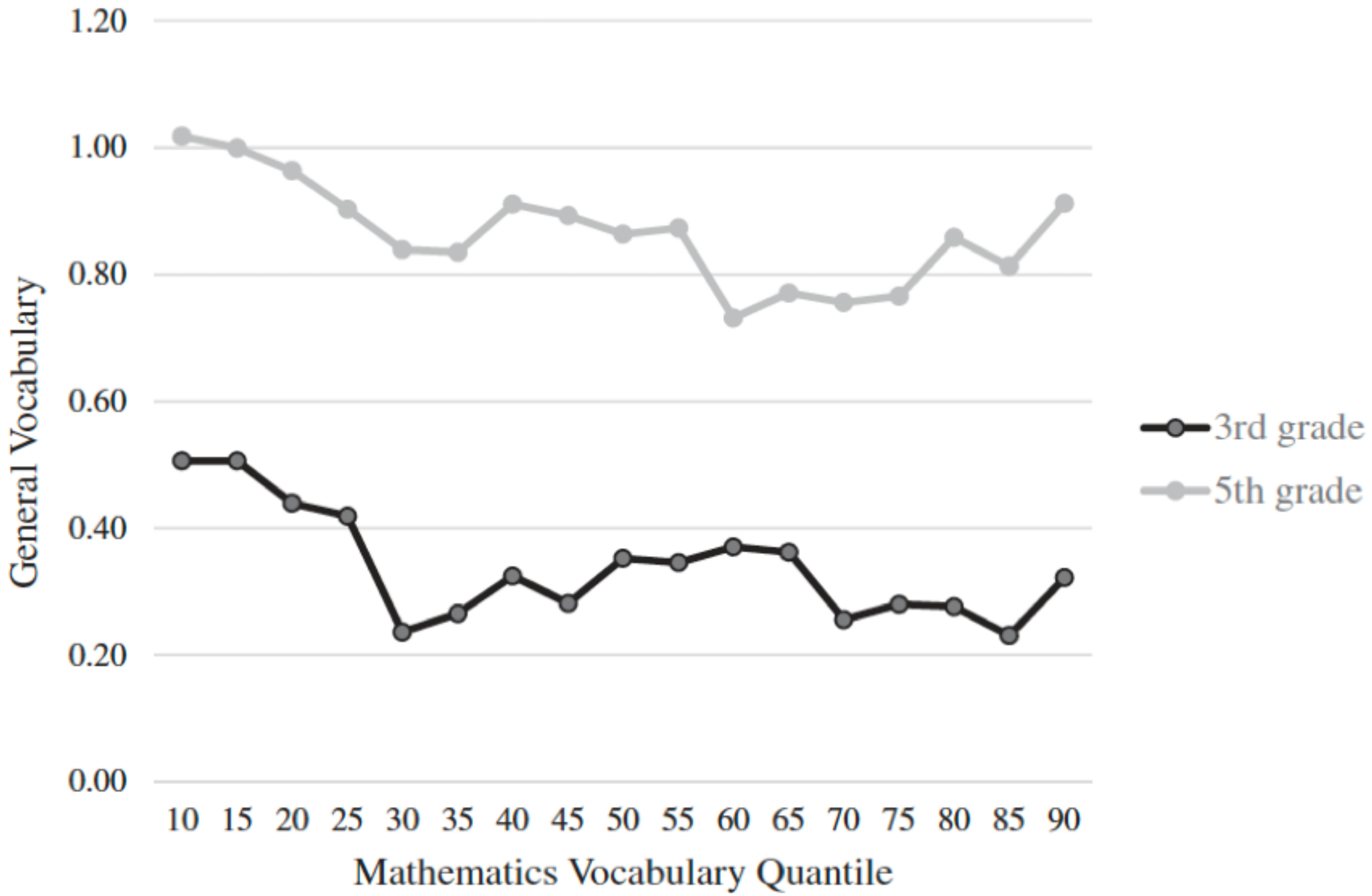
Grades 3 and 5 Mathematics Vocabulary

Measure	Grade 3			Grade 5		
	GMRT[a]	WRAT	MV	GMRT[b]	WRAT	MV
1. General vocabulary (GMRT)	–			–		
2. Math computation (WRAT)	0.573*	–		0.372*	–	
3. Mathematics vocabulary (MV)	0.606*	0.669*	–	0.659*	0.626*	–

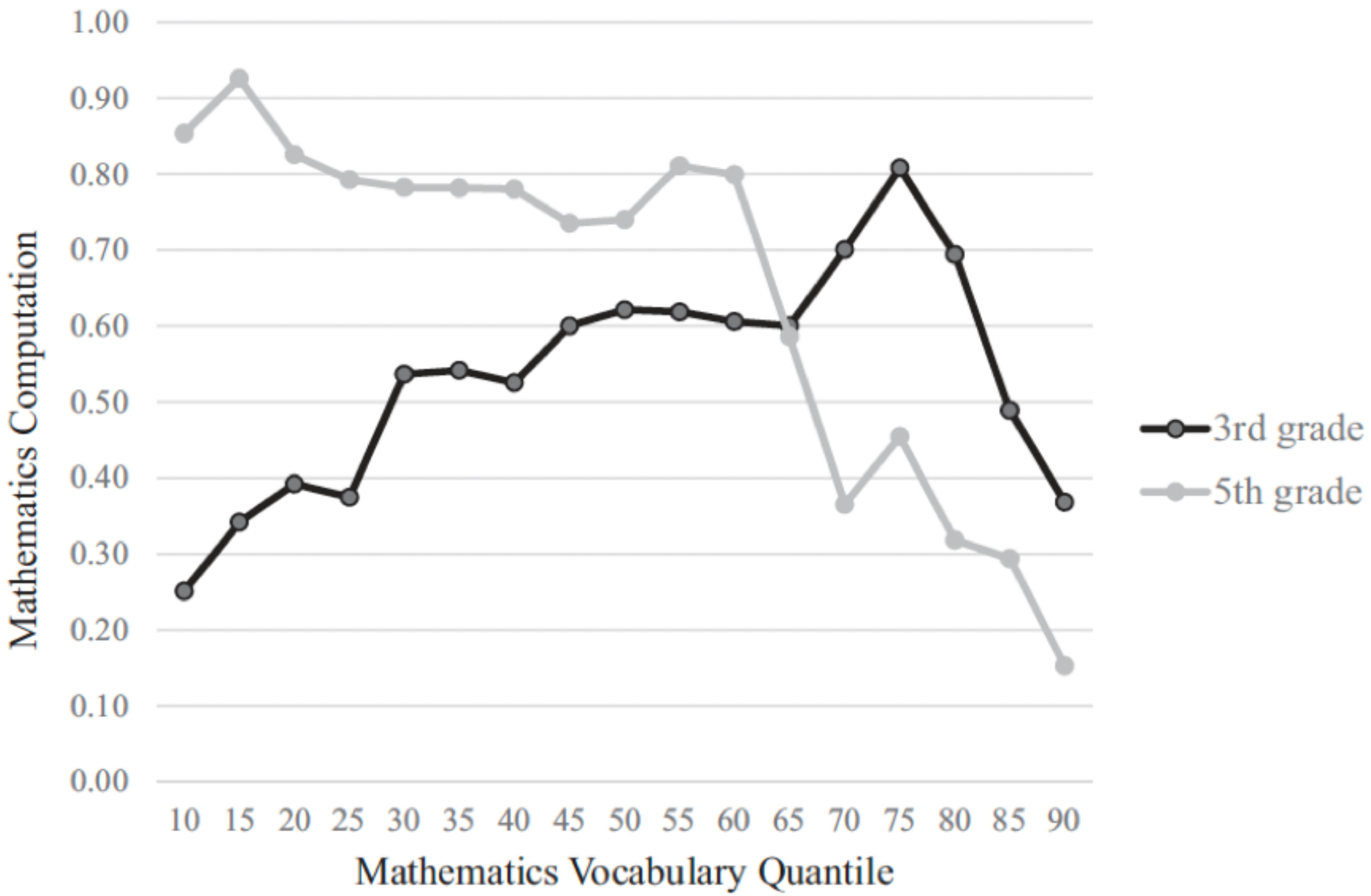
Grades 3 and 5 Mathematics Vocabulary

- Grade 3
  - Range = 6 – 68
  - *M* = 35.57 (14.02)
- Grade 5
  - Range = 5 – 100
  - *M* = 57.51 (20.61)
- No significant differences based on gender or retained status

Grades 3 and 5 Mathematics Vocabulary



Grades 3 and 5 Mathematics Vocabulary



Grade 5 Mathematics Vocabulary

	Typical (n = 70)		*MD-only (n = 16)*		*RD-only (n = 18)*		*MDRD (n = 10)*		*Excluded (n = 14)*	
Variable	*n*	*(%)*	*n*	*(%)*	*n*	*(%)*	*n*	*(%)*	*n*	*(%)*
Gender										
Female	35	(27.3)	6	(4.7)	8	(6.3)	7	(5.5)	5	(3.9)
Male	35	(27.3)	10	(7.8)	10	(7.8)	3	(2.3)	9	(7.0)
Race										
African American	6	(4.7)	4	(3.1)	1	(0.8)	3	(2.3)	1	(0.8)
Caucasian	30	(23.4)	4	(3.1)	5	(3.9)	2	(1.6)	6	(4.7)
Hispanic	28	(21.9)	5	(3.9)	11	(8.6)	5	(3.9)	6	(4.7)
Other	6	(4.7)	3	(2.3)	1	(0.8)	0	(0.0)	1	(0.8)
English learner	12	(9.4)	3	(2.3)	6	(4.7)	1	(0.8)	2	(1.6)
Retained	0	(0.0)	1	(0.8)	1	(0.8)	0	(0.0)	3	(2.3)
Special education	0	(0.0)	1	(0.8)	2	(1.6)	3	(2.3)	2	(1.6)
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
WRAT Math Computation	40.14	(3.22)	32.50	(1.79)	38.61	(2.06)	31.60	(2.46)	36.93	(2.27)
GMRT Vocabulary	29.46	(5.33)	23.19	(4.17)	13.50	(3.05)	15.10	(2.13)	21.64	(3.10)
Mathematics Vocabulary	68.13	(15.12)	46.00	(19.37)	46.56	(16.10)	21.90	(10.37)	57.07	(13.27)

Grade 5 Mathematics Vocabulary

Typical > MD = RD > MDRD

MD > MDRD	ES = 1.41
RD > MDRD	ES = 1.67
Typical > MDRD	ES = 3.12
MD < Typical	ES = 1.37
RD < Typical	ES = 1.40

AN INVESTIGATION OF THE MATHEMATICS-VOCABULARY KNOWLEDGE OF FIRST-GRADE STUDENTS

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ABSTRACT

Competency with mathematics requires use of numerals and symbols as well as an understanding and use of mathematics vocabulary (e.g., *add, more, triangle*). Currently, no measures exist in which the primary function is to gauge mathematics-vocabulary understanding. We created a 64-item mathematics-vocabulary measure for first grade and piloted the assessment with 104 first-grade students. We also administered standardized measures of general word knowledge and mathematics fluency to investigate the validity of the mathematics-vocabulary measure. Results indicated a wide variability in how first-grade students interpret mathematics-vocabulary terms but strong reliability for the mathematics-vocabulary measure.

IN mathematics, students solve problems by manipulating numerals and interpreting symbols, but an understanding of mathematics requires more than knowledge of numerals and symbols. Mathematics also requires a language-based vocabulary component. Educators and students use language to teach and learn about mathematics, and this oral and written language is filled with vocabulary terms specific to mathematics (e.g., *sum, octagon*) and vocabulary terms from everyday language that have mathematical meaning (e.g., *more, quarters*). Furthermore, the majority of standardized mathematics tests require interpretation of written

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An analysis of the mathematics vocabulary knowledge of third- and fifth-grade students: Connections to general vocabulary and mathematics computation[☆]

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ABSTRACT

To read mathematics textbooks, answer questions on mathematics assessments, and understand educator a
student communication, students must develop an understanding of the academic language of mathematics.
primary aspect of academic language is vocabulary. In this study, we focused on the mathematics-vocabula
performance of students in 3rd and 5th grade. We designed and implemented a measure of key mathemati
vocabulary in the late elementary grades, and we compared performance on this measure to scores from gene
vocabulary and mathematics computation measures. Student performance at both grades was variable, with
62-point range at 3rd grade and a 95-point range at 5th grade. General vocabulary and mathematics comp
tation were significant predictors of mathematics vocabulary, but the influence of these predictors differed
mathematics-vocabulary performance levels.

1. Introduction

On mathematics assessments, students are regularly prompted to read words and sentences to solve mathematics problems. In order to provide appropriate mathematics instruction to all students, it may be necessary to consider the reading and language demands in mathematics, above and beyond mathematical concepts and procedures. In this study, we administered an assessment of mathematics vocabulary, along with assessments of general vocabulary and mathematics computation. We explored how students in the late elementary grades respond to mathematics-vocabulary items and aimed to understand the connections, if any, among general vocabulary, mathematics computation, and mathematics vocabulary.

In this introduction, we describe the language and reading demands on mathematics assessments. Then, we discuss the construct of academic language as it relates to mathematics, and describe why mathematics vocabulary is a component of academic language. Finally, we describe the purpose and research questions of this study.

1.1. Language and reading demands on mathematics assessments

All school-age students take mathematics assessments designed to measure mathematics competency. Results from such assessments ha
assisted educators in deciding promotion from one grade level to the ne
(Maggio & Sayler, 2013) and whether students were prepared to enroll
upper-level mathematics coursework in high school (Spielhagen, 200
Performance on mathematics assessments has also been related to t
number of college acceptances for a student (Lee, 2012) and whether
student would graduate from college (You & Nguyen, 2012). Important
data from a longitudinal survey showed that scores from a set of math
matics assessments (i.e., arithmetic reasoning and mathematics know
edge) given in high school were stronger predictors of adulthood o
comes than scores from a set of reading assessments (i.e., word knowled
and paragraph comprehension; Dougherty, 2003). In a comprehensi
study, Ritchie and Bates (2013) learned that both mathematics a
reading assessments at age 7 predicted higher economic outcomes at a
42, with mathematics scores having a slightly stronger influence. Th
collection of research demonstrates how performance on mathemat
assessments is important for success during school and beyond.

The difficulty with using a mathematics assessment as a determ
nant for mathematics competence is that mathematics assessme
rarely assess the single construct of mathematics. For example, t
National Assessment of Educational Progress (NAEP; U. S. Departme

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Differences in the Mathematics-Vocabulary Knowledge of Fifth-Grade Students With and Without Learning Difficulties

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The purpose of this pilot study was to explore the impact of mathematics and reading learning difficulties on the mathematics-vocabulary understanding of fifth-grade students. Students ($n = 114$) completed three measures: mathematics computation, general vocabulary, and mathematics vocabulary. Based on performance on the mathematics computation and general vocabulary measures, students were categorized with no learning difficulty (i.e., typical), mathematics difficulty without reading difficulty (MD-only), reading difficulty without mathematics difficulty (RD-only), and combined mathematics and reading difficulties (MDRD). On the mathematics-vocabulary measure, students with MD-only or RD-only scored significantly lower than typical students, and students with MDRD demonstrated significantly lower performance than students with MD-only or RD-only.

INTRODUCTION

In the United States, federal legislation requires annual accountability testing to measure student progress and mandates that schools use evidence-based practices to mitigate performance gaps among student groups (Every Child Succeeds Act, 2015; Individuals with Disabilities Education Improvement Act, 2004). Many students, however, continue to fall behind their peers, failing to meet minimum standards on high-stakes assessments, even when receiving evidence-based instruction. One reason for persistent failure on mathematics assessments may be that students with learning difficulties, with or without a diagnosed disability, struggle with the mathematics language used for classroom instruction, in textbooks, and on assessments.

In this pilot study, we explored how students with mathematics difficulty without reading difficulty (MD-only), reading difficulty without mathematics difficulty (RD-only), and combined mathematics and reading difficulty (MDRD) performed on a measure of mathematics-vocabulary terms. This measure included mathematics vocabulary terms frequently encountered on high-stakes assessments throughout the elementary grades. We compared the performance of students with MD-only, RD-only, and MDRD to students without difficulty in mathematics or reading. In this introduction, we discuss the language of mathematics encountered in classroom learning and on high-stakes assessments. We then describe the difficulties that students with MD-only, RD-only, and MDRD encounter when answering questions on such assessments. Finally, we state the purpose and research questions of this study.

Requests for reprints should be sent to Suzanne R. Forsyth, University of Texas at Austin. Electronic inquiries should be sent to sr-forsyth@austin.utexas.edu.

The Language of Mathematics

Most preschool language and vocabulary skills are learned through oral interactions, and by the time children enter elementary school, significant differences in vocabulary acquisition and language comprehension are apparent (Beck, McKeown, & Kucan, 2013; Hart & Risley, 1999). Knowledge of specific mathematics language (i.e., quantity and spatial words) influences early numeracy development (Purpura, Hume, Sims, & Lonigan, 2011; Toll & Van Luit, 2014). These early numeracy skills are more predictive of later academic outcomes in both mathematics and reading than attention-related, behavioral, social, and early reading skills (Duncan et al., 2007).

As students progress through elementary school, linguistic skills relate to the ability to master a variety of mathematics skills, including numeration, calculation, geometry, measurement, number line concepts, and magnitude comparison (Krajewski & Schneider, 2009; LeFevre et al., 2010). At the third-grade level, Vukovic and Lesaux (2013) determined that phonological skills and general language abilities were more strongly correlated to calculation and word-problem skills than working memory and visuospatial processing, respectively. By late elementary school, oral language skills also impact fraction competence (Chow & Jacobs, 2016; Seethaler, Fuchs, Star, & Bryant, 2011).

Mastering mathematical language has been compared in difficulty to learning a second language (Wakefield, 2000). Conceptual meaning in mathematics is constructed using several systems of communication: (a) symbolic notation, (b) visual representations, and (c) oral and written language (Schleppegrell, 2007). The symbolic notation itself requires knowledge about written numbers, symbols, and their placement (Monroe & Panchyshyn, 1995). For

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