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DIVISION OF WHOLE NUMBERS WITH DECIMAL QUOTIENT AND RATES

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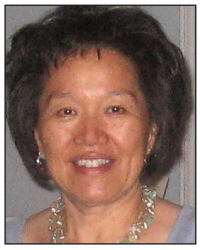
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ABACUS CO-EDITORS



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What questions could be posed using these contextual details?

- The Bakery makes 192 bagels in 5 hours.
- Eight market researchers are conducting 2 000 interviews.
- A path 35 m long is to be laid. The paving slabs are 70 cm long.



Different problems can be posed using the same contextual information. The question that you pose prompts the use of particular mathematical thinking. Which Local Bakery problems could be solved using partitive or quotative division methods? Are any of those problems representing rate (a comparison of quantities with different units)?

The Bakery makes 192 bagels in 5 hours.

(a) Which is the best buy? 5 bagels for $4; 12 bagels for $10; 18 bagels for $14

(b) About how many hours will it take to make 350 bagels?

(c) Approximately, how many bagels does the bakery make in 1 hour?

(d) If 118 bagels were sold mostly by the dozen, then about how many customers bought the bagels?

(e) Is it possible to equally divide 194 bagels among 3 restaurants? Show your work.

In this issue, the Research Summary and contextual problems (solved with different methods) focus on division of whole numbers with whole and decimal number quotients (or with remainders). Problems in this issue are designed for use with a three-part problem-solving lesson.

RESEARCH SUMMARY – WHOLE NUMBER AND DECIMAL QUOTIENTS AND RATES

Why do some numbers divide evenly into a number (resulting in no remainder), while others do not? In other words, how do you know when the quotient of two integers is an integer or a decimal number (with remainder)? Divisibility rules are used to know if a number will divide into another number without doing the division calculations.

Divisibility Rules

An integer d is a divisor of an integer N if the remainder of $N \div d$ is zero. If one integer number is divisible by another number, then the second integer is a factor of the first number. For example, since 24 is divisible by 6, then 6 is a factor of 24. Divisibility rules are methods or heuristics for determining whether one integer is divisible (or evenly divided) by another integer; that is, there is no remainder left over or the quotient is only an integer (e.g., a number is even (or divisible by 2) if its last digit is 2, 4, 6, 8 or 0).

An integer, N is divisible by:

- 2 if the last digit of N is 2, 4, 6, 8, or 0;
- 3 if the sum of digits of N is a multiple of 3;
- 4 if the last 2 digits of N are a multiple of 4;
- 5 if the last digit of N is either 0 or 5;
- 6 if N is divisible by both 2 and 3;
- 7 if subtracting twice the last digit of N from the remaining digits gives a multiple of 7 (e.g., 658 is divisible by 7 because $65 – 2 \times 8 = 49$, which is a multiple of 7);
- 8 if the last 3 digits of N are a multiple of 8;
- 9 if the sum of digits of N is a multiple of 9;
- 10 if the last digit of N is 0;
- 11 if the difference of the alternating sum of digits of N is a multiple of 11 (e.g., 2343 is divisible by 11 because $2 – 3 + 4 – 3 = 0$ which is a multiple of 11);
- 12 if N is divisible by both 3 and 4.

Why Do Divisibility Rules Work?

Why do these divisibility rules work? Any integer can be rewritten as the sum of its parts; that is, its ones, tens, hundreds and so on. For example, the integer, 3 785 can be rewritten as the sum of its parts: 3 000 + 700 + 80 + 5. There are two key ideas about divisibility.

- When each of the dividend's parts are divided by a divisor, then summing the partial quotients is equivalent to dividing the whole dividend by a divisor (e.g., $326 \div 2 = (300 \div 2) + (20 \div 2) + (6 \div 2) \rightarrow 163 = 150 + 10 + 3 \rightarrow 163 = 163$).
- When the sum of the remainders of the dividend's parts are divisible by the divisor then either: a) each of the integer's parts is evenly divisible by the divisor (the remainders sum to 0) or b) each of the integer's parts is not evenly divisible by the divisor, yet the sum of the remainders is divisible by the divisor.

Quotient Remainder Theorem

(Parker & Baldrige, 2003)

For any two whole numbers A and k with $k \neq 0$, there are unique whole numbers, q (the quotient) and r (the remainder) such that $A = (k \times q) + 4$ and $0 \leq 4 \leq k$.

When Integers are Not Divisible

Typically, when integers are not divisible, the quotient is referred to as having "remainders"; that is, the integer "left over" after dividing one integer by another to produce an integer quotient.

For example, $86 \div 8 = 10$ R6. If the dividend parts are divided by the divisor, 8, then:

- $86 \div 8 = (80 + 6) \div 8 = (80 \div 8) + (6 \div 8) = (10 + \frac{6}{8}) = 10 – \frac{6}{8}$
- $10 – \frac{6}{8} = 10 + (6 \div 8) = 10 + [\frac{6 \div 2}{8 \div 2}] = 10 + (3 \div 4) = 10.75$

The remainder, R6, represents the partial dividend (remaining from the original dividend, 86) as being divided by the divisor, 8; that is the remaining quotient is $\frac{6}{8}$ of 1. This idea emphasizes the concept of fractions as division:

$$6 \div 8 = \frac{6}{8} = \frac{6}{8} \div \frac{2}{2} = (\frac{6 \div 2}{8 \div 2}) = 3 \div 4 = \frac{3}{4} = 0.75$$

Interpreting Decimal Quotients

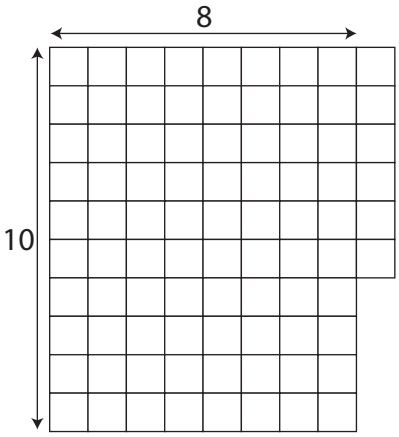
What does $86 \div 8 = 10.75$ mean using different models of division?

- Partitive Division (fair sharing) $\rightarrow$ 86 ones is divided equally among 8 groups, so that amount of each group is 10 ones and $\frac{75}{100}$ of 1 ones
- Quotative Division (grouping) $\rightarrow$ For 86 ones, one group has 8 ones, which makes about 10 groups and 0.75 of 1 group
- Rate $\rightarrow$ 86 m of walkway were raked in 8 hours, so 10.75 m of walkway was raked in 1 hour

LINKS TO MANIPULATIVES: SQUARE GRIDS AND BAR MODEL

Square Grids

Base ten blocks can represent quantity as lengths in centimetre units (cm) and area in square centimetre units (sq cm), which emphasizes the relationship between quantity and measurement units. Also, the Modelling of division equations should be accompanied with symbolic notation and explanatory labels. For example, 86 ÷ 8 = 10.75 can be modelled.



$86 \div 8$

$= (80 + 6) \div 8$

$= (80 \div 8) + (6 \div 8)$

$= (10 + \frac{6}{8}) = 10 - \frac{6}{8}$

$= 10 + .75 = 10.75$

$10 \times 8 + 6$

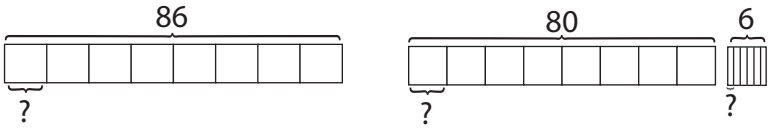
$= 80 + 6$

$= 86$ (dividend)

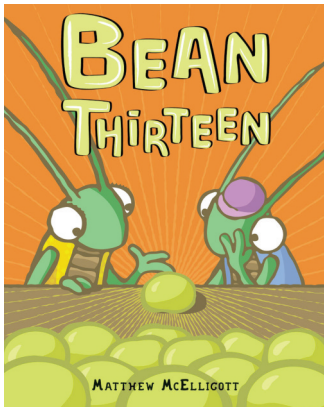
Partial dividends, (80+6) divided by divisor (8) results in the partial quotients, (10+0.75).

Bar Model

Which model of division does this bar model show? Partitive? Quotative? Rate?



LINKS TO LITERATURE: *BEAN THIRTEEN*



In *Bean Thirteen* written by Matthew McElligott, two insect friends collected 13 beans for dinner and try to fairly share the beans, but there is always one left-over. No matter what they do, they always have 'bean 13' left over. So, they have one friend over, thinking dividing the beans by three will solve the problem, but it doesn't. So, they invite more friends over, but they can't seem to escape that left-over bean.

Have the students:

- model the division of 13 beans with 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 friends
- explain how each visual model shows whole number division (dividend, divisor, quotient) and a remainder;
- explain the relationship between the divisor and quotient for each division equation for 13 beans divided among 2 to 12 friends (e.g., as the divisor increases, the quotient decreases)
- use the Divisibility Rules to discuss why 13 is not divisible by any of the divisors, from 2 to 12

LESSON LEARNING GOALS

Identify the curriculum expectations (MOE, 2005) grade-before and grade-after the grade specific learning goal, in order to:
- see the development of mathematical knowledge, skills, and strategies across grade levels
- determine the mathematical focus of the problems chosen for Before (activation), During (solving problem), and After (Practice) parts of the lesson

BEFORE (Getting Started) – 5 to 10 minutes
- Activating students' mathematical knowledge and experience using a prompt or problem, related to the math in the lesson problem.
- Includes student responses to highlight ideas and strategies.

Best Buy Bagels Problem 1

Yesterday I paid $6 for 3 buttered bagels.
Today, I paid $9 for 6 non-buttered bagels.
Which is the better buy?

Solution 1

If 1 bagel costs $??, then:
3 bagels x $_ = $6 -> 1 bagel is $2.00
6 bagels x $_ = $9 -> 1 bagel is $1.50
6x$1=$6 and 6x$0.50=$3 -> $6+$3=$9
6 non-buttered bagels better buy
$1.50 < $2.00 per 1 bagel

Solution 2

$6 for 3 bagels ÷ 3 bagels = $2.00 for 1 bagel
$9 for 6 bagels ÷ 6 bagels =
($6÷ 6 bagels) + ($3÷ 6 bagels) =
($1.00 + $0.50) = $1.50 for 1 bagel

Equivalent Ratio
$6 for 3 bagels is the same as $2.00 for 1 bagel

$9 for 6 bagels is the same as $1.50 for 1 bagel

Comparing Costs for 1 Bagel
Which is the least cost for 1 bagel?
$2.00 > $1.50

DURING (Working on It) – 15 to 20 minutes
- Understanding the problem – Teacher asks, "What information from the problem are we using to solve it? Explain." Teacher records in a list below the problem, the information that students identify.
- Students solve the problem on chart paper (landscape) with markers (visible for class discussion) in pairs or small groups.
- Teacher circulates to record different student solutions, in addition to the ones the teacher anticipated.

Best Buy Bagels Problem 2

Which is the best buy: 5 bagels for $4, 12 bagels for $10, 18 bagels for $14?

What information are we going to use to solve this problem?
- *cannot decide which prices for bagels are the best at a glance because there are different prices for different number of bagels*
- *best buy could mean the least cost for 1 bagel*
- *best buy could mean the greatest amount of bagel for $1*

` AFTER (Consolidation) – 20 to 25 minutes
- Teacher selects 2 or more solutions for class analysis and discussion in a sequence (1st, 2nd, 3rd, etc.) based on mathematical relationships between the solutions and the lesson learning goal.
- Students (authors) explain and discuss their solutions with their classmates; co-construction of success criteria towards the lesson learning goal
- During whole class discussion, solutions are organized (often re-organized) to show mathematical elaboration from one solution to the next and towards lesson learning goal.
- Teacher mathematically annotates (math terms, math symbols, labelled diagrams, concise explanations) on and around solutions to make mathematical ideas, strategies, and models of representation explicit.

Think of the quantity and number unit for each partial dividend and partial quotient

Solution 1

Compare the same number of bagels and see the cost difference

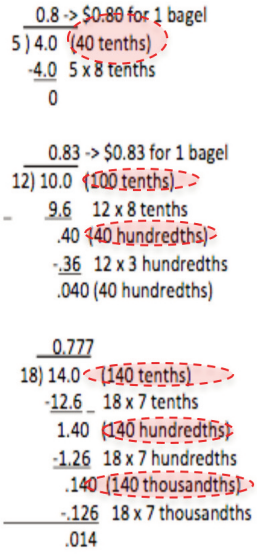
5x(3x3x2x2) = 180
3x2x2x(3x5) = 180
3x2x3x(2x5) = 180

*To compare cost of 180 bagels, m*ultiply factor that makes 180 bagels for different cost for bagels, then compare cost of 180 bagels

$4x36 -> $ 4x36=$144
$10x15->$10x15=$150
$14x10->$14x10=$140

Best buy is18 bagels for $14 (least cost)

Solution 2



18 bagels for $14 best buy; $0.78 for 1 bagel

Compare Cost of Common Whole

Compare Unit Cost Partial Quotients

Note: Mathematical *annotations* include mathematical vocabulary, symbols, elaborations of mathematical details from solutions, labels describing the method/strategy and questions to further thinking. All *annotations* are records of students' mathematical discussion.

Grade 5	Grade 6	Grade 7
-describe multiplicative relationships between quantities by using simple fractions and decimals.	-use a variety of mental strategies to solve division problems involving whole numbers -represent relationships using unit rates	-demonstrate an understanding of rate as a comparison of two measurements with different units;

Division of whole numbers can result in a quotient that is less than 1 (fraction or decimal number)

(Cost of 1 Bagel)
$4÷8 bagels = $0.50 means 4 dollars (cost) divided among 8 bagels
➔ *($4÷8) ÷ (8÷8) = $0.50 ÷ 1 = $0.50.*
cost 1 bagel

Amount of Bagel for $1
5 bagels ÷ $4 = 25/20 of 1 bagel
➔ *5 bagels ÷ $4 = (5 bagels ÷ 4) ÷ ($4 ÷4) = 5/4 of 1 bagel*

AFTER (Highlights/Summary) – 5 minutes
- Teacher and students revisit the student solutions for key ideas, strategies, and models of representation that are related to the lesson learning goal (anticipated success criteria)
- Teacher lists key ideas, strategies, and models of representation so the students can see how the mathematical details from their solutions relate explicitly to the lesson learning goal; summary of co-constructed success criteria

Highlights/Summary

Rates are a comparison of 2 quantities of different units (e.g., cost for 1 bagel; amount of bagel per $1).
Compare rates by:
- Common Whole – cost for the same amount of bagels
- Unit Cost – cost of 1 bagel for each of the prices
- Unit Amount – amount of bagel for $1

AFTER (Practice) – 5 to 10 minutes
- Teacher chooses 2 or 3 problems, similar to the lesson problem for student to solve in pairs as a scaffold and individually.
- Problems could vary by number (choice, size), problem contexts, or what is unknown or needs to be solved
- Students are asked to solve these problems using a strategy different from the one they used for the lesson problem.

Solution 3

5 bagels ÷ 4 ($4÷4=$1)
= (4+1) bagels÷4 = (4÷4) +(1÷4)
= 1 +¼ bagel = 1.25 bagels

12 bagels÷10 ($10÷10=$1)
= (10+2) bagels ÷10
= (10÷10) +(2÷10) = 1+.2 bagels
= 1.2 bagels

18 bagels÷14 ($14÷14=$1)
= (14+4) bagels ÷14
= [(14÷14) +(4÷14)} bagels
= 1+ 2/7 bagels = 1.29 bagels
(2÷7= 0.29)

(1.29 > 1.25 > 1.20) bagels
$14 for 18 bagels is best buy as get more bagel (1.29) for $1

Compare Bagel Am't of $1 Decomposing Dividend

Solution 4

How much of 1 bagel do you get for $1
5 bagels for $4
12 bagels for $10
18 bagels for $14
$4÷4=$1, 5÷4 = 5/4 of 1 bagel
5/4x5/5=25/20 of 1 bagel

I$10÷10=$1, then 12÷10
= 12/10÷(2/2) =6/5 of 1 bagel
6/5x4/4=24/20 of 1 bagel

More bagel for $1 25/20>24/20

if $14÷14=1, then 18÷14
= 18/14÷(2/2)= 9/7 of 1 bagel
25/20x7/7 = 175/140
9/7x20/20 = 180/140
More bagel for $1
180/140>175/140

Compare Bagel Am't of $1 Using Fractions

Best Buy Bagels Problem 3

After 6:00pm, the Bakery gives double the amount for the same price: 8 bagels for $4; 24 bagels for $10; 36 bagels for $14. Does 36 for $14 remain the better buy?

Solution 1

How Much Bagel for $1
10 bagels for $4
10÷4 = 2.5 bagels
24 bagels for $10
24÷10 = 2.4 bagels
36 bagels for $14
36÷14 = 2.6 bagels
36 bagels for $14 best

Solution 2

Cost of 1 Bagel
$4÷8= $0.50
$10÷24=5÷12= $0.42
$14÷36=$0.39
36 bagels for $14 is the better buy as it has the least cost for 1 bagel

Note: A classroom board is longer proportionally than these 2 pages. Due to the space constraints on these pages, the mathematical *annotations* are recorded above the solutions with arrows, rather than on and around the solutions.

LET'S DO MATH – BAGEL ORDERS

Before (Getting Started)

Four customers purchased at total of 48 bagels. Is it possible that they each purchased the same number of bagels?



Solution 1

48 bagels divided equally among 4 groups:
10 + 10 + 10 + 10 = 40 bagels
2 + 2 + 2 + 2 = 8 bagels
Each customer bought 12 bagels

Solution 2

48 bagels ÷ 4 customers
= (40 + 8) bagels ÷ 4 customers
= (40 bagels ÷ 4 customers)
+ (8 bagels ÷ 4 customers)
= (10 +2) bagels per 1 customer

During (Working On It)

Is it possible to equally divide 194 bagels among 3 restaurants?

Show your work.

After (Consolidation)

Solution 1

"What factor is multiplied by the divisor, 3, to get close to the dividend, 194?"

$$\begin{array}{r} 60+4 \text{ R2} \\ 3\overline{)\,194} \\ -180 \quad 3 \times 60 \\ \hline 14 \\ -12 \quad 3 \times 4 \\ \hline 2 \end{array}$$

Solution 2

194 bagels ÷ 3 restaurants
= (180 + 12 + 2) ÷ 3 restaurants
= (180 ÷ 3) + (12 ÷ 3) + (2 ÷ 3)
= 60 + 4 + $\frac{2}{3}$ = 64 and $\frac{2}{3}$

Two restaurants got 64 bagels and the 3rd restaurant got 66.

Solution 3

194 bagels is not divisible by 3, because the sum of its digits do not divide evenly by 3.
(1 + 9 + 4 = 14); 14 does not divide evenly by 3). But 195 bagels are divisible by 3 because the sum of the digits, 1, 9, 5 is 15 and 15 ÷ 3 = 5

Anticipating Student Responses

Coordinating Discussion for Student Learning:

Why might solution 1 be chosen first for student discussion followed by solutions 2 and 3?

- *Solution 1* – Dividing the dividend by the divisor 3, using partial quotients that include a remainder of 2 signifying that it is not possible to divide the 194 bagels equally among the 3 restaurants
- *Solution 2* – Decomposing the dividend into parts that can and cannot be divided by 3, with an interpretation of 2/3 as being 2 additional bagels so it is not possible to divide 194 bagels evenly
- *Solution 3* – Using Divisibility Rules for divisor, 3, showing that the sum of the digits for 194 is 1 + 9 + 4 = 14 is not divisible by 3, so it is not possible to equally divide

LET'S DO MATH – BAGEL TIME

Before (Getting Started)

What are all the factors of 120? How are the factors and product of 120 related to the division of 120 by its factors?

Solution 1

2 x 60 = 120; 2 x 6 x 10 = 2 x (2 x 3) x (2 x 5)

Use the associative property for multiplication to make different combinations of factors for 120

2 x (2 x 3) x (2 x 5) = (2 x 2) x (3 x 2 x 5)
= (2 x 2 x 3) x (2 x 5)
= (2 x 2 x 3 x 2) x 5 = (2 x 2 x 2) x (3 x 5)
= (2 x 2 x 2 x 5) x 3

In any combination of factors of 120, one of the factors is the divisor, while the other factor is the quotient, if 120 is the dividend

Solution 2

Dividing the dividend, 120 by a sequence of numbers, from least to greatest, which are the factors of 120

120 ÷ 2 = 60; 120 ÷ 3 = 40; 120 ÷ 4 = 30; 120 ÷ 5 = 24; 120 ÷ 6 = 20; 120 ÷ 8 = 15; 120 ÷ 10 = 12;

Factors of 120 are 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 24, 30, 40, 60.



During (Working On It) –

If 118 bagels were sold mostly by the dozen, then about how many customers bought the bagels?

After (Consolidation)

Anticipating Student Responses:

Solution 1

12 bagels x 10 customers = 120 bagels → 118 bagels

So, it must be either:
9 customers got 1 dozen bagels and the other 10 bagels were either bought by additional customers or by one or two of the 9 customers because they wanted to eat a bagel now.

Solution 2

"What factor is multiplied by the divisor, 12, to get close to the dividend, 118?"

$$\begin{array}{r} 9 \text{ R10} \\ 12\overline{)118} \\ -108 \quad 12 \times 9 \\ \hline 10 \quad \text{remainder} \end{array}$$

At the most, 9 people bought 1 dozen bagels. The extra 10 bagels could have been bought by additional customers.

Solution 3

Using Divisibility Rules, for the dividend 118, the sum of the digits is 10 (1 + 1 + 8) which is not divisible by 3, 4, so it can't be divisible by 12 either, so there will be left over.

10 customers buy 120 bagels, so a maximum of 9 customers could buy 118 bagels with 10 left over for someone else to buy.

Coordinating Discussion for Student Learning:

Why might solution 2 be chosen first for student discussion followed by solution 1?

- *Solution 1* – Uses multiplication to identify the factors, which can be interpreted as the divisor (12) and quotient (10) of the dividend, 120 bagels → 118 bagels, showing that the number of people is 9, not 10;
- *Solution 2* – Division calculation shows that the greatest whole number quotient is 9 which a remainder of 10 bagels
- *Solution 3* – Using the Divisibility Rules requires minimal calculations to determine that there are less than 10 customers who buy 120 bagels

NEXT STEPS FOR YOUR PROFESSIONAL LEARNING

Application to Your Classroom

Consider how whole number division problems develop students' understanding of the relationship between a whole number dividend and divisor that could result in a whole or decimal number quotient.

Check that the Divisibility Rules are true with student selected numbers and explain the mathematical reasoning of each Divisibility Rule.

To suit your students' learning needs, select and design whole number division problems that are relative to grade specific curriculum expectations in the Number Sense and Numeration (e.g., grade 4 focuses on 2-digit whole number dividend and 1-digit whole number divisor, while grade 5 focuses on 3-digit whole number dividend and 1-digit divisor)

Practise noticing the different methods and the breadth of the mathematics your students use to solve these division problems.

Think ahead of the kinds of mathematical annotations you will record on and around the student solutions to make explicit aspects of different methods for representing division of whole numbers with and without remainders using different models, including fraction notation (relating the remainder to a fraction of 1, relating fractions to division); explaining decomposing the dividend for division by a divisor to determine the quotient, as well as the strategic use of Divisibility Rules in solving problems.

SUGGESTED READINGS

Some readings used in the Research Summary and in the development of the problems and solutions are listed below.

Boerst, T. (2004). Division discussions: Briding student and teaching thinking. *Teaching Children Mathematics*, 233-236.

Carpenter, T., Fennema, E., Franke, M.L., Levi, L., & Epson, S. (2015). C*hildren's mathematics: Cognitively guided instruction.* (2nd edition). Portsmouth, NH: Heinemann.

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Humphreys, C., & Parker, R. (2015). *Making number talks matter: Developing mathematical practices and deepening understanding, grades 4-10.* Portland, ME: Steinhouse Publishers.

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Martin, J. (2009). The goal of long division. *Teaching Children Mathematics*, 482-487.

Parker, T., & Baldridge, S. (2003). Elementary mathematics for teachers. USA: Sefton-Ash Publishing.

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Small, M. (2009). *Big ideas from Dr. Small,* Grades K-3. Toronto, ON: Nelson

CLOSING

Our next issue will focus on division of decimal numbers and equivalent ratios, within local community applications. As well, the next issue will outline the ways that teachers need to know these notions for teaching, as well as, the ways that teachers can use these mathematical ideas and pedagogical strategies within a three-part problem-solving lesson design framework.

CALL FOR *ABACUS* SUBMISSIONS

Send your teaching strategy ideas, problems and student solutions to the *Abacus* Co-Editors via email