8 PAGE INSERT ELEMENTARY MATH

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SPATIAL REASONING WITHIN NUMBER SENSE AND NUMERATION CONTEXTS

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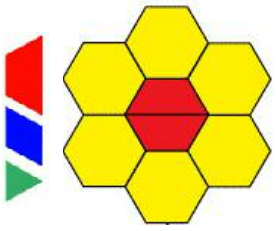
MARY LOU KESTELL works on K to 12 mathematics professional learning at the provincial level. She has spent more than 30+ years working in all aspects of Ontario mathematics education and is a past-president of both OAME and OMCA.



KATHY KUBOTA-ZARIVNIJ currently focuses on K to 6 mathematics professional learning at the provincial level. She is a long-time OAME board member and OAME past president. In relation to her work in mathematics education, she uses complexity thinking to interpret mathematics teaching and learning for students and teachers.

Number sense in the early grades is more than matching a numeral to a quantity. It is about having a "feel" for how numbers compare to one another. It is the basis for how we differentiate quantities that are reasonable from those that are unreasonable. Such number reasonableness or number sense is derived from a spatial understanding of number.

What type and number of pattern blocks could cover this pattern block flower?



Determining the area relationships between the hexagon, trapezoid, rhombus and triangles is achieved through spatial reasoning; that is how the area of one pattern block relates to another pattern block.

For example:

- 6 triangles, 3 rhombus or 2 trapezoids cover 1 hexagon
- 1 trapezoid, 1 rhombus and 1 triangle cover 1 hexagon
- 3 trapezoids, 3 rhombus and 3 triangles cover 3 hexagons

Solutions	hexagon	trapezoid	rhombus	triangle
1	7	0	0	0
2	0	14	0	0
3	0	0	21	0
4	0	0	0	42
5	1	12	0	0
6	?	?	?	?

For this problem, spatial reasoning (and proportional reasoning) is used to discern these number and measurement relationships:

- the larger the pattern block, the fewer number of pattern blocks
- the smaller the pattern block, the greater the number of pattern blocks

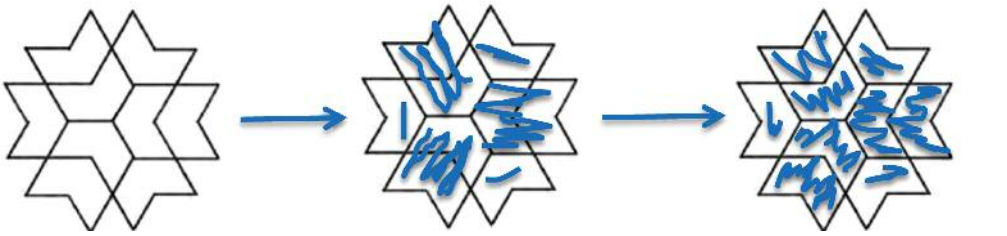
In this issue, the Research Summary and problems (with multiple solutions) focus on the use of spatial reasoning within number sense contexts. The problems we provide are designed for use with a three-part problem-solving lesson structure.

RESEARCH SUMMARY – SPATIAL REASONING WITHIN NUMBER SENSE AND NUMERATION CONTEXTS

Children use imagery in their thinking and the properties of images will have consequences on children's concepts and reasoning (Piaget & Inhelder, 1971). For example, students who have a well-developed spatial sense tend to solve tasks in more meaningful ways, not just as rote learners (Reynolds & Wheatley, 1997). Wheatley (1998) reports that students develop the capacity to solve problems in multiple ways, as their network of mental imagery for mathematical concepts and relationships develops. Consider this problem that relates spatial organization and quantity.

How many same and different size hexagons comprise this shape

Challenges like this, called Quick Draw (Wheatley, 2007) provide learners with experiences in making direct connections between spatial reasoning and number concepts. In this example, students select a particular size shape in the drawing that is repeated.



Original shape (3 large + 3 small) hexagons 3 x 2 + 3 = 9 small hexagons

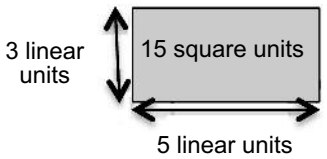
Though number reasoning tasks or problems are predominately viewed as numerical in nature, evidence is emerging that spatial attention plays an important role in preschool and kindergarten children's ability to successfully complete number naming, numeration and symbolic magnitude comparison tasks. For example, Ansari et al. (2003) reported visual spatial abilities account for children's response to cardinality tasks and to questions like, "How many?".

Some studies examined mental representations or imagery in arithmetic and revealed differences between high and low achievers (Pitta & Gray, 1996; Gray, Pitta & Tall, 1997). Low achievers had a tendency to highlight surface details and emphasized the concrete qualities within situations (focused to the descriptive qualities of numbers). Mathematically high achievers focused their attention on the relationships and abstract qualities of numbers (Pitta & Gray, 1996). According to Gray, Pitta and Tall (1997), different perceptions of these objects are at the heart of different cognitive styles that lead to success and failure in elementary arithmetic.

Spatial reasoning for numbers enable the capturing of a mathematical concept or relationship as some form of representation, such as diagrams, graphical displays and symbolic expressions. Representations or models illuminate particular aspects of a mathematical concept or relationship. For example, Mowat and Davis (2010) explain that understanding of number as a "position in space" is the spatial component of understanding number as movement along a continuous measurement scale. Numbers 4, 9 and 15 are located as points or positions on the number line. These numbers also have a linear unit value; that is, number 4 has a length of 4 linear units.

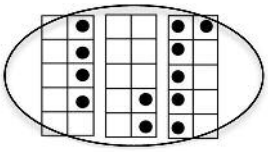
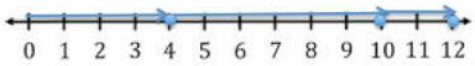
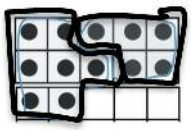
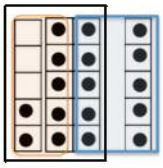
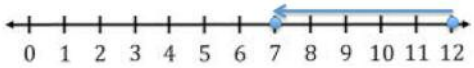
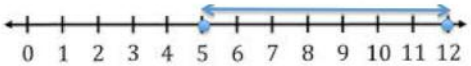
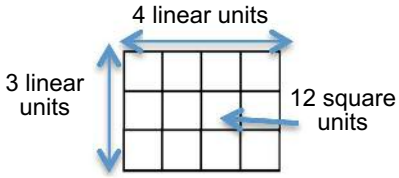
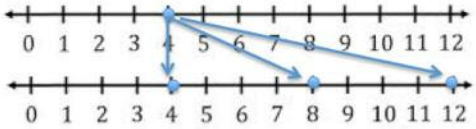
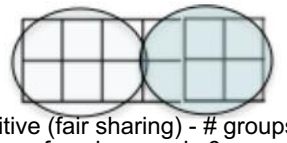
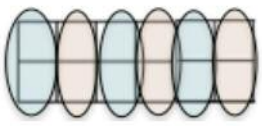
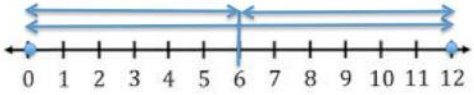
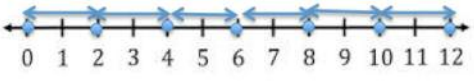
Newcombe (2010) explains that "space provides a concrete grounding for number ideas, as when we use a number line, use base-10 blocks, or represent multiplication as area. (p. 34).

3 linear units x 5 linear units = 15 square units



Representations can help students organize their mathematical thinking and make mathematical ideas more concrete and available for reflection. As students' develop their mathematical knowledge, they develop an increasingly large repertoire of mathematical representations, as well as knowledge of how to use them productively. Such knowledge includes choosing and moving between representations and learning to ask such questions as, "Would a grid or number line model provide greater clarity than a set of symbolic calculations to solve this problem?"

LINKS TO MANIPULATIVES: USING GRIDS AND NUMBER LINES

Number Operation	Grid	Number Line
Addition Joining or Combining of 2 or more addends; Sum = addend + addend + addend 12 = 4 + 6 + 2	 Join 3 quantities, 4, 2 and 6 to make 1 quantity, 12	 start at 4, add on 6, then 2, end up at 12
Subtraction *Separation* (1 whole separated into 2 parts) OR *Comparison* (comparing 2 wholes for same and difference; comparing subtrahend to minuend (referent) Minuend – subtrahend = difference 12 – 5 = 7	 Decomposing 1 whole, 12, into two parts, 5 and 7 minuend subtrahend  Comparing 2 wholes, 12 and 5; same is 5, difference on minuend is 7	 start as 12 and separate 5, the result or difference is 7  mark 12, 5 show difference of 7
Multiplication *Area of rectangle* *Scalar* (1 to many correspondence) Multiplicand x multiplier = product 4x1=4; 4x2=8, 4x3=12	 4 linear units 3 linear units 12 square units Area of a rectangle with known side lengths and unknown area (product)	 4 is the multiplicand; multiplier is 1, 2, or 3 which maps on to the products of 4, 8 or 12
Division *Fair Sharing* (Partitive – number of groups known, size of each group unknown) or *Grouping* (Quotative – size of 1 group known, number of groups unknown) Quotient – result of division Dividend ÷ divisor = quotient 12 ÷ 2 = 6	 Partitive (fair sharing) - # groups is 2, size of each group is 6  Quotative (grouping) – size of each group is 2 and # of groups is 6	 Partitive (Fair Sharing) - 12 divided into 2 groups, size of each group is 6  Quotative (Grouping) – size of each group is 2, so # of groups is 6

LESSON LEARNING GOALS

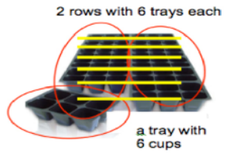
Identify the curriculum expectations (MOE, 2005) grade-before and grade-after the grade specific learning goal, in order to:
- see the development of mathematical knowledge, skills, and strategies across grade levels
- determine the mathematical focus of the problems chosen for Before (activation), During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

Grade 4	Grade 5	Grade 6
-multiply two-digit whole numbers by one-digit whole numbers using a variety of tools, student-generated algorithms and standard algorithms	-multiply two-digit whole numbers by two-digit whole numbers, using estimation, student generated algorithms and standard algorithms	-solve problems involving the multiplication ... of whole numbers (four-digit by two-digit) using a variety of tools and strategies

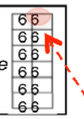
BEFORE (Getting Started) – 5 to 10 minutes

- 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.

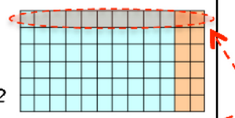
Planting Trays Problem:
Garden plants are sold in flats. Two trays with 6 cups each are attached side by side and 6 rows of them are joined to form a flat.



Solution 1
1 tray with 6 cups, 6 times, twice
6 x 6 x 2 = 36 x 2 = 72



Solution 2
12 rows x 6
(10 + 2) x 6
= 60 + 12 = 72



Solution 3
6 cups and 12 trays in a flat

Tray Number	1	2	3	4	5	6	7	8	9	10	11	12
Number of cups	6	12	18	24	30	36	42	48	54	60	66	72

***Picture** or **Visualize** equal size groups in rows and columns:*
- *12 equal size groups of 6*
- *6 equal size groups of 10 and 2 (or 12)*

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.

Flowers Problem:
The social committee needs about 250 to 300 flowers for decoration. Boris orders 12 groups of 24 flowers. How many should be delivered?

What information are we going to use to solve the problem?
- *Ordered 12 groups of 24 flowers*
- *Needs 250 to 300 flowers*
- *How many flowers should be delivered?*

AFTER (Consolidation) – 20 to 25 minutes

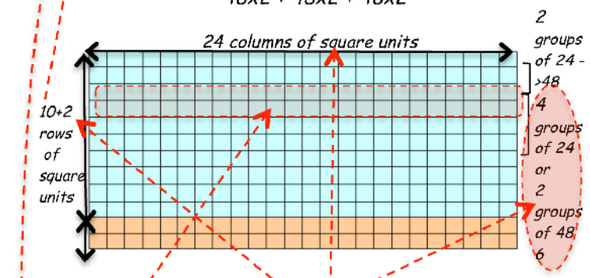
- Teacher selects 2 or more solutions for class analysis and discussion in a sequence (1st, 2nd, 3rd, etc.) based on mathematical relationships between the solutions and the lesson learning goal.
- Students (authors) explain and discuss their solutions with their classmates; co-construction of success 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.

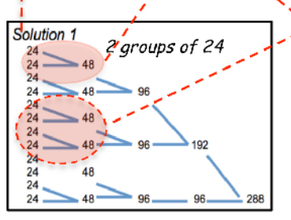
288 = 24 x 12

product *result of multiplication number of square units* — ***multiplicand*** *size of the group # of columns* — ***multiplier*** *# of groups # of rows*

distributive property *(decomposing factors into 10s, 1s)*
→ 24x12 = 24 x (10+2) = 24x10 + 24x2

288 = 24 x 12
24x2 + 24x2 + 24x2 + 24x2 + 24x2 + 24x2
48x2 + 48x2 + 48x2





Solution 2
24 x 10 = 240
24 x 2 = 48
24 x 12 = 288
They will have enough flowers at 288.

Adding Doubles Or Pairs of Same Size Numbers

Distributive Property
Decompose Multiplier into 10s, 1s

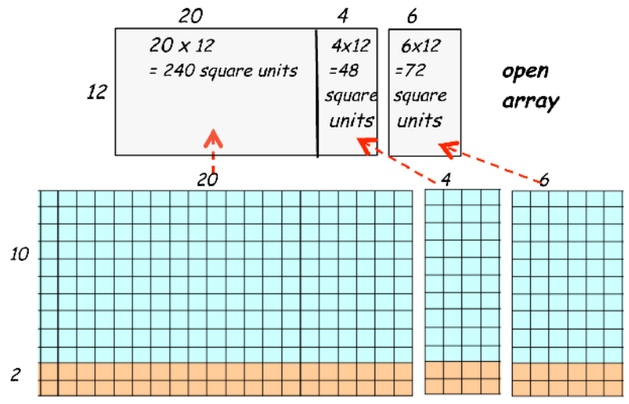
How does the table of values relate to multiplication?

Number of Groups	Number of Flowers in 1 Group	*Multiplicand size of group* *multiplier number of groups*	Number of Flowers
1	24	24 x 1 = 24	24
2	24	24 x 2 = 48	48
5	24	24 x 5 = 120 (24x2+ 24x2 + 24x1 = 48+48+24)	120
10	24	24 x 10 = 240 (24x5+24x5=120+120)	240
12 = 2+10	24	24 x 10 + 24 x 2 = 240+48 = 288	288

- *number of groups -> term number*
- *number of flowers -> term value*
- *number of flowers in group X # groups = # flowers*
- ***multiplicand x term number (multiplier) = term value***

Array → # rows x # columns = multiplicand X multiplier

12x20 < 12x24 < 12x30



- *Under calculated to 20 groups, needed to add 4 more groups*
  12x24 = 12x20 + 12x4 = 12x2x10 + 48 = 240 + 48 = 288
- *Over calculated to 30 groups, needed to subtract 6 groups*
  12x24 = 12x30 - 12x6 = 12x3x10 - 72 = 360 - 72
  = 360 - 60 - 12 = 300 - 12 = 288

Solution 3
12 x 20 < 12 x 24 < 12 x 30
12 x 2 = 24; 12 x 3 = 36
12 x 4 = 48; 12 x 6 = 72
12x20 =12 x 2 x10 = 24 x 10
= 24 tens = 240
need 4 more groups of 12
12 x 4 = 48

Compensation (Area Model)

Solution 4
number of flowers = number in 1 group x number of groups
24 flowers in 1 group
number of flowers = 24 x number of groups.

Number of groups	Number of flowers
1	24
2	48
5	120
10	240

48 + 240 = 288

distributive property 24x12 = 24 x (10+2)

Size of Group, # of Groups (Table of Values)

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

Highlights/Summary:

288 = 24 x 12 = 24x10 + 24x2

product result of X # square units = # of columns X # of rows — *multiplicand group size* — *multiplier # of groups* — *distributive property decompose factors to 10s, 1s* — *array (# rows x # columns)*

Represent the multiplication of 2-digit by 2-digit whole numbers by:
- *Distributive Property – decomposing one or more of the factors into 10s and 1s*
  (24x12 = 24x(10+2) = (24x10) + (24x2) = 240+48 = 288
- *Compensation – under or over calculating the product to closest 10s then adjusting by adding or subtracting*
  24x12 = 20x12 + 4x12 = 240 + 48 = 288
  24x12 = 30x12 - 6x12 = 360 - 72 = 360-60-12 = 288
- *Table of Values –*
  multiplicand x term # (or multplier) = term value

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.

Trash Problem :
62 people picked up at least 15 pieces of trash at the BBQ. At least how many pieces of trash were picked up?

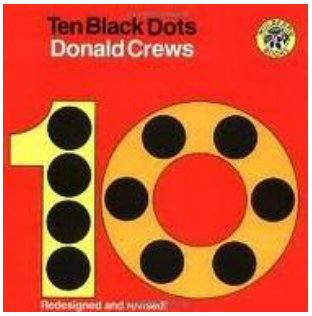
Solution 1
62 groups of 15 pcs trash
15 pcs trash x 62 people
= 15 x 20 = 300
+ 15 x 20 = 300
+ 15 x 20 = 300
+ 15 x 2 = 30
15 x 62 = 930
15 pcs trash x 132 people
= 930 pcs trash

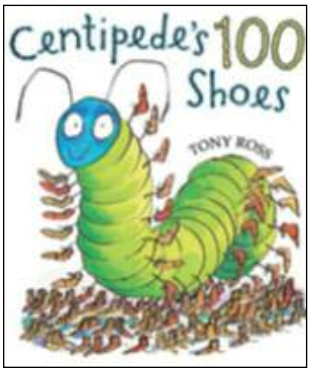
Solution 2
Size of group is 15 (trash pc)
# of groups is 62 (people)

Number of people	Pieces of trash
1	15
2	30
10	150
20	300
60	900
62	900+30

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.

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.





LINKS TO LITERATURE:

Ten Black Dots by Donald Crews provides a spatial representation of numbers in different ways (e.g., rows and columns of black dots). It illustrates how numbers can be decomposed and re-composed. "five buttons can make buttons on a coat…" shows five dots as a column of black dots, while the next page, "…or the portholes on a boat" Five is decomposed into horizontal rows of two and three dots.

- Read Ten Block Dots as an introduction to using quick images with dot cards, ten frames.

Centipede's 100 Shoes by Tony Ross is about a centipede (with 42 legs) that buys 100 pairs of shoes and realizes the next morning that he bought too many shoes. So, he sells them along with 42 socks.

- Represent the shoes and socks that were sold to the beetles, wood lice, grasshopper, spiders and worms. Use ten frames, 10x10 square grid or array of dots.

LET'S DO MATH – APPLE PROBLEMS

Before (Getting Started)

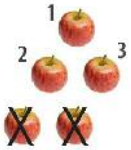


Apple Problem A:

Johnny Appleseed saw 5 apples in the bowl on the kitchen counter. He took 2 apples. How many apples were left in the bowl?

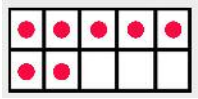
Solution 1

I pictured the apples and I took 2 away. I counted those left and there were 3.



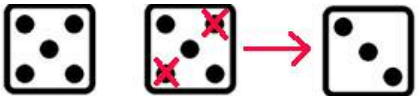
Solution 2

I showed 5 dots in to top of a 10-frame. Then I showed 2 dots in the bottom. When I compared the numbers the difference was 3.



Solution 3

I thought of the 5 apples and saw the 5 on the die. Taking 2 dots off makes the number 3.



During (Working On It)

Apple Problem B:

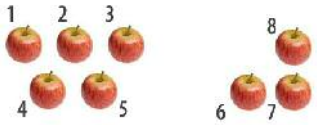
Jani Appleseed noticed 5 apples in a bowl on her kitchen counter. How many apples would there be once she added 3 apples to the bowl?



After (Consolidation)

Anticipating Student Responses:

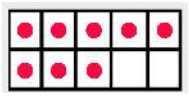
Solution 1



I saw the apples in my head and I counted them 1, 2, …5, 6, 7, and 8.

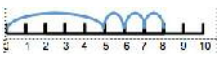
Solution 2

Put each apple in 10-frame and saw 2 less than 10 or 8.



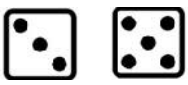
Solution 3

Start at 5 and jump 3 more to 8



Solution 4

Each dot is an apple
5 apples + 3 apples = 8 apples.



Coordinating Discussion for Student Learning:

Why might solution 1 be chosen first for student discussion followed by solution 2, 4, and 3?

- *Solution 1* – counting each object using one-to-one correspondence, stable order and cardinality
- *Solutions 2 and 4* – using an organized space (i.e., 10-frame, dice faces) to represent quantity and join them to determine the sum
- *Solution 3* – using number line

LET'S DO MATH – PROBLEMS



Before (Getting Started)

Ticket Problem 1:

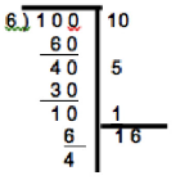
Six people give out tickets for door prizes. 100 tickets are shared equally among 6 people. How many tickets did each person get?

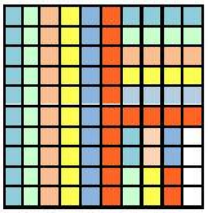
Solution 1

I imagined the 6 hands and the 100 tickets. Then I started sharing.
10 x 6 = 60 too little
15 x 6 = 90 too little
16 x 6 = 96 and 96 + 4 = 100
So, each worker gets 16 tickets to give out and there were 4 left over.



Solution 2





So 100 = 16 x 6 + 4
Each of 6 people get 16 tickets each with 4 left over.

During (Working On It)



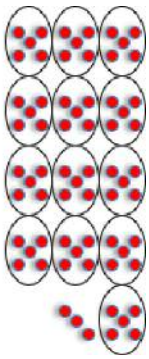
Flowers Problem 2:

The garden centre donated 68 flowers to the community centre. The flowers are bundled in groups of 5 to decorate tables. How many tables could be decorated?

After (Consolidation)

Anticipating Student Responses:

Solution 1



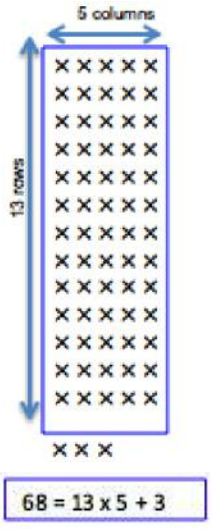
I put 68 counters in groups of 5 and got 13 groups with 3 left over. So we can decorate 13 tables with 5 flowers each and have 3 extra flowers.

Solution 2

Number of Groups	Number of Flowers
0	68
1	63
2	58
3	53
4	48
5	43
6	38
7	33
8	28
9	23
10	18
11	13
12	8
13	3

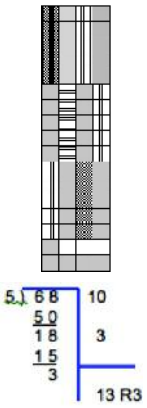
So 68 ÷ 5 = 13,
3 flowers left over so cannot make another group, so 3 left over.

Solution 3



68 = 13 x 5 + 3

Solution 4



68 flowers can make 13 groups of 5 and there will be 3 left over.

Coordinating Discussion for Student Learning:

Problem 1 is a division by sharing problem and 2 is a division by grouping problem.

Why might solution 1 (for Problem 2) be chosen first for student discussion, followed by solution 3, 2 and 4?

- *Solution 1* – counters represent 68 flowers, grouped 13 times with 5 in each group and 3 left over.
- *Solution 3* – the dimensions for 13 groups of 5 flowers in an array (i.e., 5 flowers in each row; 13 in each column; 65 of the flowers are accounted for and there are 3 left over)
- *Solution 2* – Shows skip counting starting with the 68 flowers and subtracting 5 flowers at a time as each table is decorated. When there are 13 groups, there are 3 flowers left so that cannot make another group and there will be 3 left over.
- *Solution 4* – model repeated subtraction; know that 10 groups of 5 means 50 of the flowers will decorate 10 tables; the remaining 18 flowers make 3 groups of 5 with 3 flowers left over.

NEXT STEPS FOR YOUR PROFESSIONAL LEARNING

Application to Your Classroom

- Consider how these number sense problems include visual-spatial reasoning in relation to proportional reasoning.
- To suit your students' learning needs, begin designing number reasoning tasks or problems that are relative to the grade specific curriculum expectations in the Number Sense and Numeration strand, being mindful of the models of representation (e.g., area, set, linear, graphic, number) of different types of numbers and number operations.
- Provide problems that have students represent number relationships and operations using models of representation, such as the area model (e.g., square unit grids), set model (e.g., groups of same and different objects organized in rows and columns, equal size groups, 2x10 and 10x10 rekenreks, five and ten frames), table of values and linear model (e.g., 1x100 rekenrek, metre stick, open or unitized number lines).
- Incorporate spatial reasoning daily for practice, such as Quick Images. Quick images materials include dot patterns, ten frames, dominoes, coloured squares that the learner views for a few seconds to decide on the quantity presented.
- Practise noticing the different strategies and the breadth of the mathematics your students use to solve number reasoning tasks or problems, such as, decomposing or composing numbers using proportional shapes, like pattern blocks, square tiles, base ten blocks.
- Think ahead of the kinds of mathematical annotations you will record on and around the student solutions to make explicit spatial reasoning strategies for number representations and concepts like addition as combining, multiplication as equal size groups in an array or division as fair sharing or equal size grouping.

SUGGESTED READINGS

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

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CLOSING

Our next issue will focus on spatial reasoning within measurement contexts. 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 learning and teaching mathematics within a three-part problem solving lesson framework.

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