8 PAGE INSERT ELEMENTARY MATH

ONTARIO ASSOCIATION FOR MATHEMATICS EDUCATION

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INVESTIGATING AREA MEASUREMENT

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ABACUS CO-EDITORS

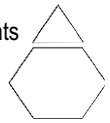


MARY LOU KESTELL works on K to 6 mathematics professional learning at the provincial level. She has spent more than 30+ years working in all aspects of Ontario mathematics education and is a past-president of both OAME and OMCA.



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.

What do you need to know about measurement and two-dimensional shapes to solve this problem?



Jan has some shapes of fabric cut out and wants to use them to make a rectangular quilt. Fabric shapes include 30 regular hexagons with side lengths of 20.5 cm on each side and 50 equilateral triangles with 20.5 cm side lengths. What are the linear dimensions of the largest size quilt that can be made, and how many of each shape will be left over?

Imagine trying to solve this problem without having strategies for measuring and calculating the area of two-dimensional shapes. What do you need to know about area measurement to solve other ordinary tasks like cleaning, painting, gardening or tiling?

In this issue, the Research Summary and problems (with multiple solutions) focus on strategies for determining area measurements using direct and indirect comparisons and non-standard and standard units. The problems we provide are designed for use within a three-part, problem-solving lesson. Consider solving these area measurement problems yourself first, before examining the solutions we provide. When we engage in solving the mathematics problems we will offer students, we are deepening our conceptual understanding of the mathematics we teach by developing a mathematical sense of the range of thinking possible. As well, we are provoked to reflect on our choices of learning materials and teaching strategies in order to develop our students' understanding of mathematics.

LINKS TO LITERATURE AND MANIPULATIVES



PAT MARGERM is an independent literacy and mathematics consultant with more that 30+ years of K to 8 teaching experience with students, in-service and pre-service teachers. She is a long-time OAME board member and works in various aspects of mathematics education.

Daily activities in the classroom have mathematical features, which can be used to set the stage for exploration and discussion about area measurement during reading and writing lessons or even when students are drawing. For example, when children use various sizes of paper and share a table top during drawing time, they conceptually "get a taste" of area and different ways to compare areas. Also, during independent reading, children estimate and choose a space in the classroom that will be suitable for reading a big book or a smaller size book from the book bin. Choosing a "space" to meet in groups in order to work on projects or to play a game at recess involves area estimation. Therefore, in this issue, grids and more real life contexts will be discussed as ways to develop students' understanding, so that they can estimate, measure, and calculate area of different 2-D shapes.

RESEARCH SUMMARY – ABOUT AREA MEASUREMENT

Area is an amount of a two-dimensional surface that is contained within a boundary and that can be quantified in some way. Small (2008) defines area as a two-dimensional attribute whereby the amount of two-dimensional (flat) space that a shape covers, or in the case of a 3-D shape, the amount of flat space that forms the surface of the shape (surface area). Area measurement assumes that a suitable two-dimensional region is chosen as a unit (usually expressed in square units), that congruent regions have equal areas, regions do not overlap, and that the area of the union of two regions is the sum of their areas. So, determining the area of a region can be thought of as tiling (or partitioning) a region with a two-dimensional unit of measure (Clements & Stephan, 2003). Baroody (1999) outlines a process for measuring area:

- determining the attribute to be measured, such as area
- choosing a unit of measure, appropriate to the size of the object - the number of units varies inversely with the size of the units (e.g., measuring an attribute of an object with a larger unit such as square metres will result in fewer units than measuring area with a smaller unit, such as square centimetres)
- comparing a unit to the object to determine the number of units - dividing a continuous quantity into countable units of measurement (e.g., for area, square units)
- reporting the number of units and the name of the unit – the number of units depends on the size of the unit, so it is essential to report the name of the unit, as well as the number of units.

Concepts Underpinning Children's Understanding of Area

There are several important concepts that underpin children's learning of area measurement. These concepts describe how children think about area as they engage in the physical activity of measuring. According to Lehrer, Jaslow, and Curtis (2003), students must conceptualize area measure as a two-dimensional region; that is, as an array composed of units of area measures, typically squares. Further, Clements and Stephan (2003) explain that such understandings are developed from at least five foundational concepts:

- partitioning – mental act of cutting two-dimensional space with a two-dimensional unit
- unit iteration – covering or tiling a region with area units with no gaps, no overlapping, and within the boundaries
- conservation – see that decomposing and rearranging shapes does not affect their area
- structuring – an array to understand that area is two-dimensional
- linear measurement – area is the product of two linear measurements of the boundary.

Stages of Area Measurement

Clements and Stephan (2003), as well as Schifter and Szymaszek (2003) outline research about a developmental sequence for area measurement in terms of structuring an array:

- little organization, coordination and structuring of a two-dimensional space; that is, difficulty covering a rectangle with tiles without overlaps or gaps
- complete covering of a two-dimensional space, but incorrect counting (e.g., cannot keep track of units counted; counts around border and unsystematically counts internal units)
- covering and counting by ones, with no row or column structuring
- incomplete use of rows or columns (e.g., counts some, but not all rows as a unit)
- structuring the rectangle as a set of rows
- iterating rows (e.g., counting each row of 4, "4, 8, 12, 16, 20")
- iterating rows in coordination with the number of square units in a column
- seeing that the rectangle's dimensions provide the number of squares in rows and columns
- relating the number of squares in rows and columns to the number of linear units (linear dimensions) and calculating area from these dimensions.

Strategies for Developing Understanding of Area Measurement

Based on the three stages of developing measurement concepts (Small, 2008), some strategies for developing students' conceptual understanding of area are as follows:

- *Definition/Comparison* – trace shoeprint or hand on paper and compare areas with other students; trace rectangular faces of different size boxes and compare and order the tracings from smallest area to largest area

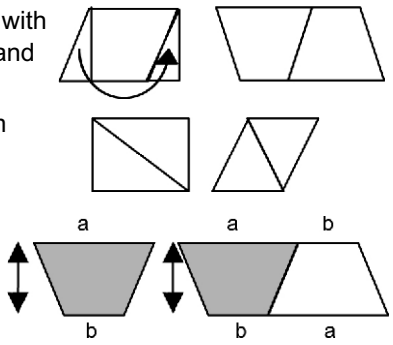
- *Using Non-Standard Units* – cut out 3 different shapes that can be covered by exactly 20 objects, such as 20 counters, 20 triangle pattern blocks, 20 hexagons; using sheets of newspaper to compare the area of two windows or two bulletin boards; measuring the same area with different units; measuring different areas with the same unit; iterating the same unit end to end, horizontally and vertically; measuring area using a transparent square grid; estimating the area of an object when it has a partial square grid for measuring
- *Using Standard Units* – associating personal referents with square centimetres, square metres, and square kilometres; measuring irregular shapes using square centimetre grid paper and transparencies, counting partial and whole square centimetre units

Applications of Area Measurement in Elementary Curriculum

For elementary mathematics, students develop and use formulas for determining the areas of rectangles, parallelograms, triangles, trapezoids, and circles. When formulas are learned as rote calculation procedures, students often do not understand the conceptual underpinnings of the formula and often apply the formula to the wrong shape or measurement attribute without knowing why this is incorrect. In addition, students often have difficulty rearranging the formula to find something other than an area, such as using the area and length of a rectangle to calculate its other length (Baroody, 1998; Clement and Stephan, 2003; Small, 2008).

Common 2-D shapes used to develop area measurements include:

- Area (rectangular array) = number of rows x number in each row = number of rows x number of columns
- Area (rectangle) = length x width = l x w = w x l
- Area (square) = side length x side length = s x s
- Area (parallelogram) = base length x height → transform a parallelogram into a rectangle with the same base length and height by cutting a triangle from one side of the parallelogram and moving it to the opposite side or creating two trapezoids that can be similarly rearranged.
- Area (triangle) = 1/2 x base x height = base x height ÷ 2 → derived from the parallelogram because every triangle, no matter what type of triangle is half of a parallelogram with the same base and height
- Area (trapezoid) = (b + a) x h ÷ 2 → viewed as half a parallelogram whereby the height of the parallelogram is the same as the height of the trapezoid and the base length of the parallelogram is equal to the sum of the two bases of the trapezoid

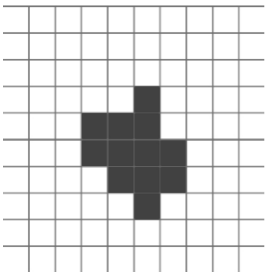


LINKS TO MANIPULATIVES: USING GRIDS

Tools for determining the area of 2-D shapes include pattern blocks templates (uniform, non-standard units) and grids (triangular, trapezoidal, hexagonal, square) made from photocopying BLMs and learning materials, like *The Learning Carpet*™. Grids allow students to use a range of mathematical strategies including counting, skip counting, repeated addition, and multiplication to determine the number of units in the area of a shape. As well, grids enable students to compose and decompose shapes to determine area by combining the areas of the smaller shapes.

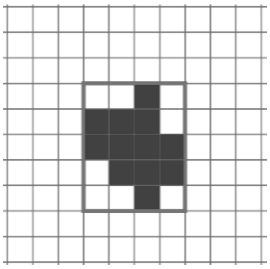
Area of Irregular Shapes

For example, cut shapes from clear plastic and place them on the grid in the Learning Carpet™ or on a photocopied square grid. Measure the area of this irregular shape.



I counted 1 then 2, 3, 4 and 5, 6, 7, 8 followed by 9, 10,11 and 12 squares. This is the same as rows of 1 + 3 + 4 + 3 + 1 = 12 squares.

I see 3 groups of 4 squares so 3 x 4 = 12 squares.



I see a 4 x 5 rectangle or 20 squares. I see that 8 squares in the rectangle are not shaded as part of the shape.

20 – 8 = 12 squares in the shape.

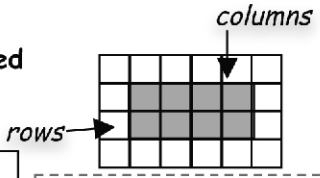
LESSON LEARNING GOALS

Identify the curriculum expectations (MOE, 2005) grade-before and grade-after the grade specific learning goal:
- to see the development of mathematical knowledge, skills, and strategies across grade levels
- to determine the mathematical focus of the problems chosen for Before (activation), During (lesson), 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 that is directly relates to the mathematics in the lesson problem.
- Includes student responses to prompt/problem to highlight key ideas/strategies.

Tile Problem A:

What is the area of the shaded rectangular tiles on the grid?



Solution 1
I counted 1, 2, 3, …, 6, 7, 8. There are 8 squares in the rectangle

Counting by 1s from left to right and top to bottom

Solution 2
I counted each column … 2, 4, 6, 8

Counting by 2s
2 + 2 + 2 + 2 = 8
2 + 2 + 2 + 2 = 2 x 4

Solution 3
I counted 4 in row 1 and 4 in row 2 for a total of 8 squares.

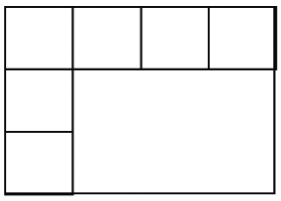
Making 2 Groups of 4
4 + 4 = 8
4 + 4 = 4 x 2

DURING (Working on It)
- 15 to 20 minutes
- Understanding the problem – Teacher asks, "What information from the problem are we using to make a plan 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 whole class discussion) in pairs or in small groups.
- Teacher circulates to record different student solutions, in addition to the ones the teacher anticipated.

Tile Problem B:

Tile the area of this rectangle using equal-sized squares.

How many square tiles are needed to cover this space?



What information will we use to solve this problem?
- *Need to cover the big rectangle with the smaller squares*
- *Use the same size squares*
- *Covering means no spaces between the squares*
- *Covering means no overlapping of the squares*

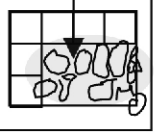
AFTER (Consolidation)
- 20 to 25 minutes
- Teacher selects 2 or more solutions for class analysis and discussion in a sequence (1st, 2nd, 3rd, etc.) based on mathematical relationships between the solutions and the lesson learning goal.
- Students (authors) explain and discuss their solutions with their classmates.
- 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 to students.

What unit of measurement are we trying use to measure the area of a rectangle?
- same size, square units

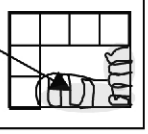
How do we use the square units to measure area of a rectangle?
- using the same size square to cover the rectangle with no overlaps or gaps

What part of the rectangle was measured for its area? → *should cover <u>both</u> the border and the inside*

Solution 1
About 8



Solution 2
About 17 squares



Counting Squares Covering Part of the Rectangle

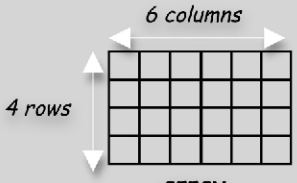
Counting Small Squares Around Border

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 3	Grade 4	Grade 5
- estimate, measure (using centimetre grid paper, arrays), and record area	- estimate and measure using a variety of tools (e.g., centimetre grid paper, geoboard) and strategies, and record the area of polygons	- determine through investigation using a variety of tools the relationships between the length and width of a rectangle and its area and generalize to develop formulas (i.e., Area=length x width)

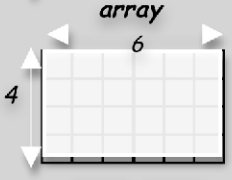
Area

total number of same size squares (or square units) that completely cover a shape (e.g., rectangle) with no spaces or overlapping



array

Area (rectangle)
= number of rows x columns
= 4 rows x 6 columns
= 24 square units



open array

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.
- Teacher lists key ideas, strategies, and models of representation separately, so the students can see how the mathematical details from their solutions relate explicitly to the lesson learning goal.

Highlights/Summary:

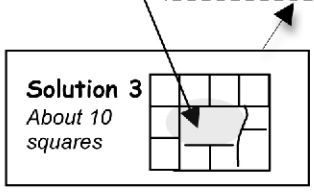
- Tile an area by using the same size shapes, like squares:
- repeating (iterating) the square unit end to end, horizontally and vertically
- with no spaces or overlaps between square units
- To measure area of rectangles -> arrange the squares in rows and columns or an array

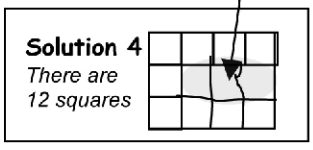
AFTER (Practice)

- 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.

How is the area of the middle part of the rectangle being measured?

Extend lines to draw from the squares on the top and side to make array



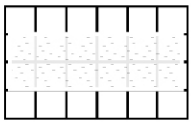


Same Size Square Units Iterated Around Border

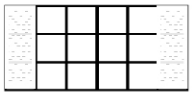
Same Size Square Units Iterated as Rows and Columns

Tablecloth Problem:

A table cloth that is 2 square units x 4 square units will cover a table top exactly. Will these cover it? How do you know?



tablecloth A



tablecloth B

Solution 1

-Table top is 2x4=8 square units or 2 rows x 4 columns
-Tablecloth A – 2 hidden rows by pattern so it is 4 (2+2) rows x 6 columns
-Tablecloth B – 2 column of 3 rows is hidden by pattern, so 3 rows x 6 (1+4+1) columns
- 2x4 < 4 x 6 ->so A covers it
- 2x4 < 3 x 6 ->so B covers it

Solution 2

B – 3 rows x 1 column hidden by pattern, so 3 rows x 6 (1+4+1) columns which is larger than 2 rows x 4 columns

Tablecloth B is smaller than A, so tablecloth A must cover it if B covers the table top.

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: PIONEER AND ABORIGINAL HOMES





In social studies, students learn about pioneer homes and Aboriginal homes. Students might read that a typical pioneer home was about 14 or 15 feet long and about 10 feet wide. A typical Aboriginal longhouse was approximately 20 feet wide and could be anywhere from 40 feet to 200 feet long. Compare the areas of a pioneer home and longhouse. Use grid paper.

Sample student responses:

- draw a model of the homes on grid paper and count the squares in each home to compare the quantities
- draw a model of the homes on grid paper and decompose into smaller rectangles (e.g., 10 x 10 squares), then 15 x 10 and 20 x 40 square units
- reason about the relationships (e.g., the width of the longhouse is double the width of the pioneer house) and compare the linear dimensions and areas (e.g., the length of a longhouse of 45 feet which would be triple the length of a pioneer house, so the area of the longhouse would be 2 x 3 = 6 times more than the area of the pioneer house).

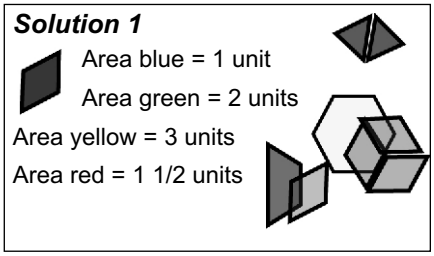
LET'S DO MATH – PATTERN BLOCK PROBLEMS

Before (Getting Started)

Pattern Block Problem A:

If the area of a blue rhombus is 1, what is the area of a yellow hexagon, a green triangle, a red trapezoid.

Solution 1



Area blue = 1 unit

Area green = 2 units

Area yellow = 3 units

Area red = 1 1/2 units

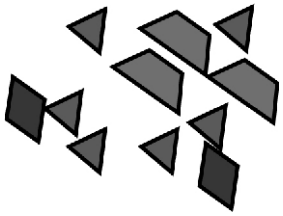
Solution 2

It takes 2 greens to make 1 blue so 1 green is 1/2. 3 blue blues are required to get a yellow so 1 yellow is 3. It takes 1 1/2 blues to get red so 1 red is 3/2.

During (Working On It)

Pattern Block Problem B:

How can you use green triangle, blue rhombus, and red trapezoid pattern blocks to build an equilateral triangle whose area is 1/3 red, 1/3 blue, and 1/3 green?



- What is the relationship between the areas of the green, blue, and red blocks?
- What do you know about equilateral triangles?
- Make an equilateral triangle using any number of blocks and write the ratios to describe the different coloured areas.
- What is the smallest collection of pattern blocks that would make a shape with equal areas of red, green and blue?

After (Consolidation)

Anticipating Student Responses:

Solution 1

My triangle is equilateral because each side is 3 units long. I have used 4 green, 1 red and 1 blue.



Solution 2

My triangle is equilateral because each side is 3 units long. Triangle area is 2/9 green, 4/9 blue, 3/9 red.



Solution 3

1 red => 3 green; 1 blue => 2 green; 2 red => 3 blue

Red	Blue	Green
2	3	6
4	6	12
6	9	18



Coordinating Discussion for Student Learning:

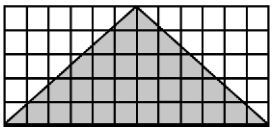
Why might solution 1 be chosen first for student discussion followed by solution 2, and then solution 3?

- solution 1 → shows an equilateral triangle but the area is 4 parts green, 3 parts red, and 2 parts blue
- solution 2 → if green is 1 part, blue is 2 parts, and red is 3 parts then the area of the equilateral triangle is 2/9 green, 4/9 blue, and 3/9 red
- solution 3 → shows an equilateral triangle with 4x3 or 12 parts red, 6x2 or 12 parts blue, and 12 parts green which is 1/3 red, 1/3 blue, 1/3 green.

LET'S DO MATH – POLYGON PROBLEMS

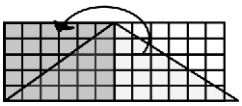
Before (Getting Started)

Polygon Area Problem A:
What is the area of the shaded part of the shape?



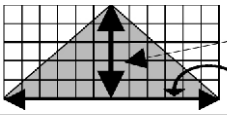
Solution 1

- Rectangle has an area 5 x 12 = 60 square units.
- Area of the triangle is 1/2 area of rectangle or 1/2 x 60 = 30 square units.



Solution 2

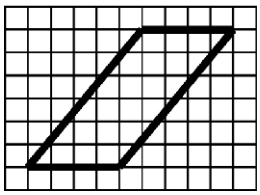
Triangle area is 1/2 x base x height
1/2 x 12 x 5 = 6 x 5 = 30 square units

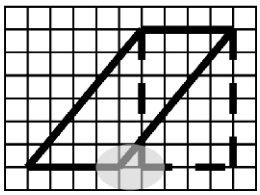


During (Working On It)

Polygon Problem B: What's the area of this parallelogram?

Note: It is not a simple matter of drawing the height line outside of the parallelogram.

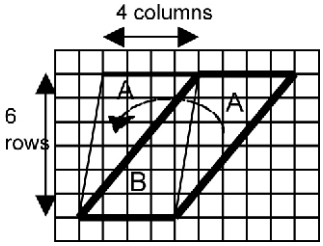




After (Consolidation)

Anticipating Student Responses:

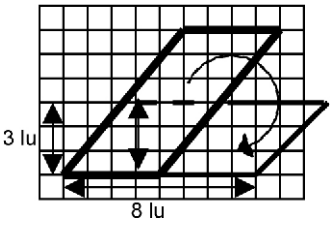
Solution 1



- problem – cannot measure height inside parallelogram
- decompose parallelogram into 2 triangles and translate one triangle 4 units left to make a parallelogram that can measure height inside it
- 6 rows x 4 columns = 24 square units

("lu means linear units and "su" means square units)

Solution 2



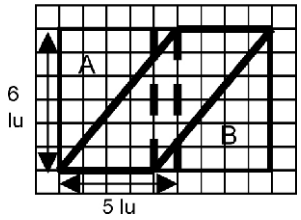
Cut parallelogram into 2 smaller parallelograms and translate it to make a longer parallelogram and can see height line inside parallelogram in 2 different ways:

Area of parallelogram

→ 4 lu x 3 lu x 2 parallelograms = 24 su

→ 8 lu x 3 lu = 24 su

Solution 3



Make a larger rectangle (6 x 9), measure area of 2 triangles, then subtract to get area of parallelogram

- area (triangle A) = ½ x 6 x 5 = 15 su
- area (triangle B) = ½ x 5 x 6 = 15 su
- large rectangle area = 6 x 9 = 54 su

Area of parallelogram
= 54 su – 15 su – 15 su
= 24 su

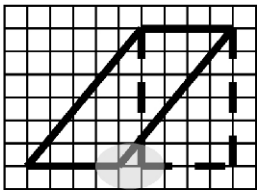
Coordinating Discussion for Student Learning:

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

- solution 1→ decomposed parallelogram into 2 triangles and composed a parallelogram that could identify the height inside the new parallelogram; counting square units by rows and columns
- solution 2 → decomposed parallelogram into 2 smaller ones in order to identify height inside the parallelogram; then calculated area by doubling the area of smaller parallelogram or making a new parallelogram with half the height and double the base
- solution 3 → made a larger rectangle, calculated area of 2 triangles and then subtracted them from the larger rectangle to get area of parallelogram

For Professional Discussion:

- How could you determine the area of the parallelogram using this drawing?
- What is the significance of the area of the triangle in between the parallelogram and rectangle?
- Are there other solutions to this problem?



NEXT STEPS FOR YOUR PROFESSIONAL LEARNING

Application to Your Classroom

- Try these area measurement problems yourself first and then with your students.
- To suit your students' learning needs, you might adjust the numbers (e.g., 1-digit, 2-digit, or 3-digit whole numbers, decimal numbers to tenths, hundredths) and the number and type of calculations needed to measure and calculate area (e.g., addition, subtraction, multiplication)
- Think about how the context of the problem evokes visual images and serves as a tool for understanding and determining area measurement (e.g., area of sandbox, classroom mat, garden)
- Provide students with non-examples of area measurement calculations. A common error is when students simply calculate the number in an area measurement without considering that they are different units of measurement. For example, Jada says that the area of a rectangle with sides 3 m and 40 cm can be calculated as (3 x 40) = 120 m. Aaron disagrees with her. What do you think? Explain using a square grid.
- Practise noticing the different strategies and the breadth of the mathematics your students use in their solutions. Take note of the number and kinds of solutions that show strategies for determining area measurement. Which strategy do students use more often? (e.g., counting square units by ones, counting rows or columns of square units, multiplying linear dimensions)
- In preparation for your class discussion of student solutions, decide which solution you will discuss first, second, and third by referring to the developmental learning sequence for determining proportional relationships to solve problems (e.g., counting square units by ones, counting by rows or columns, calculating by multiplying the length by the width of the rectangle)
- Think ahead of the kinds of mathematical annotations you will record on and around the student solutions to make explicit key mathematical ideas, strategies for determining area measurements. when the students discuss and analyze each other's solutions (e.g., relationship between the number of rows and columns with linear dimensions of 1 cm x 1 cm and the linear dimensions of the rectangle)
- Choose 4 student work samples to analyse further in terms of their mathematical details.

Suggested Readings

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

- Anderson, N. C., Gavin, M. K., Daily, J., Stone, W, & Vuolo, J. (2005). *Navigating through measurement in grades 3-5.* Reston, VA: National Council of Teachers of Mathematics.
- Baroody, A. (1998). *Fostering children's mathematical power: An investigative approach to K-8 mathematics instruction*. NJ: Lawrence Erlbaum Associates.
- Lehrer, R., Jaslow, L., & Curtis, C. (2003). In D. Clements & G. Bright. (Eds.), *Learning and teaching measurement* (2003) Yearbook) (pp. 109-118). Reston, VA: National Council for Teachers of Mathematics.
- Mulligan, J., Prescot, A., Mitchelmore, M., and Outhred, L. (2005). Taking a closer look at young students' images of area measurement. *APMC, 10*(2), pp. 4- 8.
- Randall, C. (2005). Big ideas and understandings as the foundation for elementary and middle school mathematics. *Journal of Mathematics Education Leadership, 7*(3), 9-24.
- Schifter, D., & Szymaszek, J. (2003). Structuring a rectangle: Teachers write to learn about their students' thinking. In D. Clements & G. Bright. (Eds.), *Learning and teaching measurement* (2003) Yearbook) (pp. 143 -156). Reston, VA: National Council for Teachers of Mathematics.
- Small, M. (2008). *Making math meaningful to Canadian students, K-8.* Toronto: Nelson Education.
- Small, M. (2010). *Big ideas from Dr. Small, Grades K-3.* Toronto: Nelson Education.
- Stephan, M., & Clements, D. (2003). Linear, Area, and Time Measurement in Prekindergarten to Grade 2. In D. Clements & G. Bright (Eds.), *Learning and teaching measurement: 2003 Yearbook* (pp. 3-16). Reston, VA: National Council of Teachers of Mathematics.

CLOSING

Our next issue will focus on key notions of volume and capacity, how teachers need to know these notions for teaching, as well as, ways that teachers can use these mathematical ideas and pedagogical strategies through problem solving-based teaching and learning strategies.

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