I. Lesson Overview

Strand	**Measurement and Geometry**
Sub-Strand	Reflection and Congruence
Specific Learning Outcome	Apply reflection and congruence to real-life situations
Grade Level	Grade 10
Duration	40 minutes
Key Inquiry Question	How would you use the concepts of reflection and congruence to improve a garden's design further? Can you think of other elements that could be added to enhance symmetry or balance? How are reflection and congruence applied in day-to-day life?
Learning Resources	CBC Grade 10 Mathematics Textbooks, graph paper, rulers, protractors, coloured pencils, printed garden layout handouts

II. Learning Objectives

Category	Objective
Know	Define reflection as a transformation that produces a mirror image across a line of symmetry. Recall that congruent figures have the same shape and size. Understand that reflected figures are congruent to their originals. Identify lines of symmetry in real-world objects and designs. Recognise that reflection preserves distances, angles, and area.
Do	Sketch a garden flower bed on graph paper and reflect it across a central pathway (mirror line). Verify that the original and reflected flower beds are congruent by measuring corresponding sides and angles. Identify the equation of the mirror line (the pathway) on the Cartesian plane. Add symmetrical elements (benches, trees, fountains) to enhance the garden design. Use coordinate geometry to plot and reflect garden features.
Apply	Design a complete symmetric garden layout using reflection and congruence. Evaluate real-world designs (architecture, art, nature) for reflection and congruence. Propose

	improvements to existing designs by adding symmetric elements. Explain how reflection and congruence contribute to aesthetic appeal, structural balance, and functionality in real-life contexts.

III. Materials & Resources

- CBC Grade 10 Mathematics Textbooks
- Graph paper (large sheets for group work)
- Rulers, protractors, and set squares
- Coloured pencils or markers (at least 4 colours per group)
- Printed handouts with the garden scenario and a blank Cartesian grid
- Tracing paper (for verifying congruence by overlaying)
- Photographs of symmetric gardens, buildings, and natural objects (optional)

IV. Lesson Procedure

Phase 1: Problem-Solving and Discovery (15 minutes)

Anchor Activity: "Designing a Garden Layout"

Scenario:

Imagine you are tasked with designing a new garden for your school. Your plan includes creating two identical flower beds positioned on either side of a central pathway. To ensure that the flower beds are congruent and reflect each other across the pathway, you must apply the concepts of reflection and congruence in geometry.

To begin, you measure the dimensions of one flower bed and create a detailed sketch. You then reflect this design across the pathway, ensuring that both flower beds maintain the same size and shape. This way, when students walk down the pathway, they will see a beautiful symmetric design that enhances the garden's aesthetic appeal.

Instructions (Work in groups):

- Step 1: On graph paper, draw a central pathway along the y-axis (the line $x = 0$). This is your mirror line.
- Step 2: On the LEFT side of the pathway, design one flower bed as a polygon. Use at least 4 vertices. Record the coordinates of each vertex (e.g., $A(-5, 2)$, $B(-2, 2)$, $C(-2, 6)$, $D(-5, 6)$).
- Step 3: Reflect your flower bed across the pathway (y-axis) to create the second flower bed on the RIGHT side. Record the coordinates of the image vertices.
- Step 4: Verify that the two flower beds are congruent by measuring corresponding sides and angles.
- Step 5: Add at least TWO more symmetric elements to your garden (e.g., benches, trees, a fountain, stepping stones). Each element must be reflected across the pathway.
- Step 6: Answer the guiding question: How would you use the concepts of reflection and congruence to improve the garden's design further? Can you think of other elements that could be added to enhance symmetry or balance?

Teacher's Role During Discovery:

- Circulate among groups, ensuring students correctly set up the mirror line along the y-axis.
- Ask probing questions: "How did you find the reflected coordinates?" "How do you know the two flower beds are congruent?"
- For struggling groups: "Remember, when you reflect across the y-axis, what happens to the x-coordinate? It changes sign! So $(-5, 2)$ becomes $(5, 2)$."
- For early finishers: "Can you add a circular fountain at the centre? What happens when you reflect a circle across the pathway? Can you add a diagonal path and reflect elements across THAT line instead?"
- Guide students to notice: reflection preserves distances, angles, and area — the reflected flower bed is congruent to the original.
- Identify 2–3 groups with creative designs to share with the class.

Expected Student Discoveries:

Observation	Mathematical Significance
The reflected flower bed has the same dimensions as the original.	Reflection preserves side lengths — reflected figures are congruent.
The x-coordinates change sign when reflecting across the y-axis.	The reflection rule for the y-axis: $(x, y) \rightarrow (-x, y)$.
The pathway (y-axis) is equidistant from corresponding points.	The mirror line is the perpendicular bisector of the segment joining each point to its image.
The garden looks balanced and aesthetically pleasing.	Symmetry creates visual harmony — this is why architects and designers use reflection.
Elements on the mirror line (e.g., fountain at origin) map to themselves.	Points on the mirror line are invariant under reflection.

Phase 2: Structured Instruction (10 minutes)

Key Takeaways:

Reflection and congruence are not just abstract mathematical concepts — they are applied extensively in real life to create designs that are balanced, functional, and aesthetically pleasing.

Properties Preserved Under Reflection:

Property	Explanation
Side lengths	All corresponding sides remain equal. If the flower bed has a side of 3 m, its reflection also has a side of 3 m.
Angles	All corresponding angles remain equal. A 90° corner stays 90° after reflection.
Area	The area of the reflected figure equals the area of the original. Both flower beds have the same planting area.
Shape	The overall shape is preserved. A rectangular flower bed reflects to a rectangular flower bed.
Orientation	Orientation is REVERSED. A reflected figure has opposite congruence (lateral inversion). This is like a mirror image.

Real-Life Applications of Reflection and Congruence:

Application Area	Example	How Reflection/Congruence Is Used
Garden & Landscape Design	Symmetric flower beds across a pathway	Flower beds are reflected across the central pathway to create visual balance. Congruent beds ensure equal planting area.
Architecture	Symmetric building facades, windows, doors	Architects reflect design elements across a central axis to create balanced, aesthetically pleasing structures.
Art & Design	Mandala patterns, kaleidoscope images, logos	Artists use reflection to create symmetric patterns. Many company logos use reflective symmetry.
Nature	Butterfly wings, leaves, human face	Many natural objects exhibit approximate bilateral symmetry — one half is a reflection of the other.
Engineering	Bridge design, aircraft wings	Engineers design symmetric structures for balance and equal

		load distribution. Both wings of an aircraft are congruent.
Everyday Life	Tiled floors, wallpaper patterns, fabric prints	Repeated congruent shapes reflected and translated create decorative patterns.

Connecting to Student Discoveries:

- Reference the anchor activity: "Your garden designs demonstrate exactly how architects and landscape designers use reflection. The pathway is the mirror line, and the flower beds are congruent reflected images."
- Emphasise the practical value: "Symmetry is not just about beauty — it ensures equal distribution. Both sides of the garden get the same amount of sunlight, water, and space."
- Connect to congruence criteria: "How would you PROVE the two flower beds are congruent? You could use SSS by measuring all three sides, or you could use the properties of reflection."
- Address the guiding question: "Adding a fountain on the mirror line, symmetric benches, and reflected tree placements all enhance the garden's balance."

Phase 3: Practice and Application (10 minutes)

Problem 1 (Worked Example): Reflecting a Garden Feature

A triangular flower bed has vertices at $A(-6, 1)$, $B(-2, 1)$, and $C(-4, 5)$. The central pathway runs along the y-axis ($x = 0$). Find the coordinates of the reflected flower bed and verify that the two flower beds are congruent.

Solution:

Step 1: Reflect each vertex across the y-axis using the rule $(x, y) \to (-x, y)$:

$A(-6, 1) \to A'(6, 1)$

$B(-2, 1) \to B'(2, 1)$

$C(-4, 5) \to C'(4, 5)$

Step 2: Calculate side lengths of the original flower bed:

$AB = |(-2) - (-6)| = 4$ units

$AC = \sqrt{((-4-(-6))^2 + (5-1)^2)} = \sqrt{(4 + 16)} = \sqrt{20} = 2\sqrt{5}$ units

$BC = \sqrt{((-4-(-2))^2 + (5-1)^2)} = \sqrt{(4 + 16)} = \sqrt{20} = 2\sqrt{5}$ units

Step 3: Calculate side lengths of the reflected flower bed:

$A'B' = |(2) - (6)| = 4$ units

$A'C' = \sqrt{((4-6)^2 + (5-1)^2)} = \sqrt{(4 + 16)} = \sqrt{20} = 2\sqrt{5}$ units

$B'C' = \sqrt{((4-2)^2 + (5-1)^2)} = \sqrt{(4 + 16)} = \sqrt{20} = 2\sqrt{5}$ units

Step 4: $AB = A'B' = 4$, $AC = A'C' = 2\sqrt{5}$, $BC = B'C' = 2\sqrt{5}$.

Therefore, $\triangle ABC \cong \triangle A'B'C'$ by the SSS criterion. The two flower beds are congruent.

Problem 2: Reflecting Across a Non-Axis Pathway

A rectangular bench is positioned at P(1, 2), Q(3, 2), R(3, 3), S(1, 3) on the left side of a diagonal pathway along the line $y = x$. Find the coordinates of the reflected bench.

Solution:

Reflection rule for $y = x$: $(x, y) \rightarrow (y, x)$. Swap the coordinates.

$P(1, 2) \rightarrow P'(2, 1)$

$Q(3, 2) \rightarrow Q'(2, 3)$

$R(3, 3) \rightarrow R'(3, 3)$ [point on the line $y = x$ maps to itself]

$S(1, 3) \rightarrow S'(3, 1)$

Verification: $PQ = P'Q' = 2$, $QR = Q'R' = 1$, $RS = R'S' = 2$, $SP = S'P' = 1$.

The bench and its reflection are congruent by SSS (all corresponding sides equal).

Problem 3: Designing a Symmetric Fountain

A circular fountain has its centre at O(0, 0) with radius 2 m. Two identical decorative arches are placed at A(−3, 0) and B(3, 0). Explain why the garden has reflective symmetry and identify the mirror line.

Solution:

The fountain centre O(0, 0) lies on the y-axis.

A circle centred at the origin is symmetric about both axes.

The arches at A(−3, 0) and B(3, 0) are reflections of each other across the y-axis: (−3, 0) → (3, 0).

The mirror line is the y-axis (x = 0).

The garden has reflective symmetry because every element on the left has a congruent counterpart on the right, reflected across x = 0.

Problem 4: Real-World Identification

Identify three examples of reflection and congruence in your school environment. For each, describe the mirror line and explain how congruence is demonstrated.

Sample Answers:

1. Classroom windows: Two rows of identical windows on either side of the classroom door. Mirror line: the door frame. Congruence: each window has the same dimensions (SSS).

2. Football pitch: The two halves of the pitch are reflections across the centre line. Mirror line: the halfway line. Congruence: both halves have the same dimensions and markings.

3. School gate: Two identical gate panels that swing open symmetrically. Mirror line: the central post. Congruence: both panels have the same height, width, and design (SSS or SAS).

Phase 4: Assessment — Exit Ticket (5 minutes)

Assessment Questions:

1. A landscape designer places a rectangular flower bed with vertices at P(−5, 1), Q(−1, 1), R(−1, 4), S(−5, 4). The central pathway is along the y-axis. Find the coordinates of the reflected flower bed and prove the two beds are congruent.

2. A school building has a symmetric facade. The left half has a window at W(−4, 6) and a door at D(−2, 0). The axis of symmetry is x = 0. Where are the corresponding window and door on the right half?

3. Explain why a butterfly's wings demonstrate both reflection and congruence. Identify the mirror line and state which congruence criterion you would use to prove the wings are congruent.

4. A garden designer wants to place four identical triangular flower beds in a pattern with two lines of symmetry (the x-axis and the y-axis). If one flower bed has vertices at (1, 1), (3, 1), and (2, 4), find the vertices of the other three flower beds.

Answer Key:

1. Reflected vertices: P′(5, 1), Q′(1, 1), R′(1, 4), S′(5, 4). PQ = P′Q′ = 4, QR = Q′R′ = 3, RS = R′S′ = 4, SP = S′P′ = 3. All corresponding sides equal → congruent by SSS. (Also, all angles are 90° in both rectangles.)

2. Reflecting across x = 0: W′(4, 6) and D′(2, 0). The window and door on the right half are at (4, 6) and (2, 0) respectively.

3. A butterfly's body is the mirror line (axis of symmetry). The left wing is a reflection of the right wing across this line. The wings are congruent because corresponding measurements (wingspan, vein patterns, colour patches) are equal. SSS criterion: all corresponding lengths on both wings are equal.

4. Reflect across y-axis: (−1, 1), (−3, 1), (−2, 4). Reflect across x-axis: (1, −1), (3, −1), (2, −4). Reflect across both: (−1, −1), (−3, −1), (−2, −4). All four triangles are congruent by SSS.

V. Differentiation Strategies

Learner Level	Strategy
Struggling Learners	Provide pre-drawn garden templates with the mirror line and one flower bed already plotted. Use the simple reflection rule for the y-axis: just change the sign of the x-coordinate. Allow students to use tracing paper to physically reflect shapes. Pair with a stronger student during the design phase. Focus on rectangular flower beds (easier to reflect than irregular shapes). Provide a checklist: (1) Plot original, (2) Reflect each vertex, (3) Connect reflected vertices, (4) Measure to verify.
On-Level Learners	Complete the full garden design with at least two reflected elements beyond the flower beds. Use the distance formula to prove congruence formally. Reflect across the y-axis and identify the equation of the mirror line. Identify real-world examples of reflection and congruence in the school environment. Attempt Problem 2 (reflection across $y = x$).
Advanced Learners	Design a garden with TWO lines of symmetry (both x-axis and y-axis), creating a four-quadrant symmetric layout. Reflect across non-standard lines (e.g., $y = x$, $y = 2$, $x = -1$) and find the equations of the mirror lines. Investigate: "If a garden has rotational symmetry of order 4, does it necessarily have two lines of reflective symmetry?" Explore tessellations: create a garden path pattern using congruent tiles that cover the ground without gaps. Calculate the total area of all flower beds and verify that reflected beds have equal areas.

VI. Extension Activity

Activity: "Design Challenge — The Perfect Symmetric Garden"

1. Design a complete garden on a large sheet of graph paper with the following requirements:

   - At least TWO lines of symmetry (e.g., x-axis and y-axis)
   - At least FOUR congruent flower beds (one in each quadrant)
   - A central feature on the intersection of the lines of symmetry (e.g., fountain, statue)
   - At least TWO additional symmetric elements (benches, trees, lamps)

• All coordinates labelled

2. For each pair of congruent elements, state the congruence criterion (SSS, SAS, ASA, or RHS) and identify the mirror line equation.

3. Calculate the total planting area of all flower beds. Verify that reflected beds have equal areas.

4. Write a short paragraph explaining how your design uses reflection and congruence to create balance and beauty. Include at least one real-world building or garden that inspired your design.

5. Challenge: Investigate the Taj Mahal gardens or the Palace of Versailles gardens. Identify lines of symmetry and congruent features. How many lines of symmetry can you find?

VII. Assessment Methods

Type	Method
Formative	Observation during group work: Are students correctly reflecting coordinates across the y-axis? Do they verify congruence by measuring? Can they identify the mirror line? Questioning: "Why does reflection create congruent figures?" "What properties are preserved?" "How does this apply to the garden design?" Peer assessment: Groups present their garden designs and classmates identify the lines of symmetry and congruent elements.
Summative	Exit ticket with 4 questions: (1) Coordinate reflection and congruence proof, (2) Identifying reflected features on a building facade, (3) Explaining reflection and congruence in nature (butterfly), and (4) Creating a four-quadrant symmetric design. Complete answer key provided for marking.

VIII. Teacher Reflection

1. Did the garden design scenario effectively engage students and make the concepts of reflection and congruence tangible?

2. Were students able to correctly reflect coordinates across the y-axis?

3. Did students understand that reflection preserves side lengths, angles, and area?

4. Were students able to prove congruence using the SSS criterion and the distance formula?

5. Did students make meaningful connections between the garden activity and real-world applications?

6. Were students creative in adding symmetric elements to their garden designs?

7. Did the guiding question generate thoughtful discussion about symmetry and balance?

8. What adjustments would improve the lesson for future delivery?