SPATIAL COGNITION TO ENHANCE MATHEMATICAL LEARNING

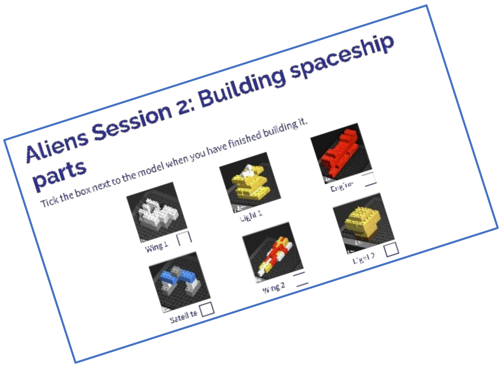
Year 2 Mathematics Curriculum and Spatial Reasoning

Contents

What is the evidence that children’s mathematics skills are improved by working with LEGO®?

Studies have shown that children’s block construction skills and mathematics skills are related, meaning that children who are more skilled with toys such as LEGO tend to be better at mathematics activities. Block construction and mathematics tasks both draw on similar spatial skills. For example, holding visual and spatial information in mind during problem solving, visualising and manipulating objects in the mind’s eye, estimating and comparing the size and length of objects, and identifying shapes embedded within complex patterns. These spatial skills help children solve geometry and arithmetic problems. They are important for numerical skills such as understanding how symbols are arranged in equations and understanding place value, and for mathematical reasoning such as visualising mathematics word problems.

Research has also shown that children’s spatial and mathematics skills can be improved with spatial training. In the SPACE programme children recreate models from instructions using physical Lego bricks, i.e., they practice their spatial skills via block construction. We expect that our training programme will lead to benefits in spatial ability, spatial language (e.g., understanding of words like “between”, “symmetrical”) and mathematics competence in children.



How does the SPACE program relate to the Year 2 Mathematics Curriculum?

By engaging in the SPACE program children have many opportunities to improve both their knowledge of mathematical content areas, such as geometry, and their skills in problem solving, fluency, reasoning and spoken language through specific spatial and mathematical dialogue. This section outlines how SPACE relates to the Programme of Study (PoS) for KS1 Mathematics which sets out the statutory requirements and non-statutory guidance[1]. Teachers should refer to the PoS in order to be clear on its specific content. What follows is consistent with the PoS but does not attempt to distinguish between requirements and guidance; rather it provides an integrated commentary on how SPACE supports children's learning in mathematics in line with the overall aims of the National Curriculum as they begin their journey to:

- "become fluent in the fundamentals of mathematics …."
- "reason mathematically by following a line of enquiry …"
- "solve problems by applying their mathematics to a variety of routine and non-routine problems …"[2]

Children's development across KS1 is supported by SPACE activities through:

- working with concrete objects to explore numerals, mathematical operations and language, including words related to spatial concepts such as "between", "parallel", "left" and "next to"); and
- developing their ability to recognise, describe, draw, compare and sort different shapes using the related vocabulary.

In particular, SPACE activities relate closely to the geometry requirements of the mathematics programme of study so that children:

- **build on their work in Y1 relating to**:
  - *properties of shapes:* recognising and naming common 2-D (e.g. rectangles, including squares, circles and triangles) and 3-D (e.g. cuboids, including cubes, pyramids and spheres) shapes*;*
  - *position and direction*: when they describe position (left, right, top, bottom, middle), direction and movement (whole, half, quarter and three-quarter turns; clockwise and anticlockwise);

- **explore and consolidate their Y2 work, for example:**

[1] National Curriculum in England: mathematics programmes of study. Updated 28th September 2021
[2] Page 1, National Curriculum in England: mathematics programmes of study. Updated 28th September 2021

- *properties of shapes*: comparing and sorting common 2-D and 3-D shapes and everyday objects;
- and handling and naming shapes while using vocabulary (such as sides, edges, faces) precisely;
- *position and direction*: ordering and arranging combinations of objects in patterns and sequences;
- and using mathematical vocabulary to describe position, direction and movement in practical contexts.

- **prepare for their work in Y3, for example:**
  - *properties of shapes*: drawing 2-D shapes and making 3-D shapes using modelling materials;
  - and recognising 3-D shapes in different orientations and describe them;
  - and recognising angles as a property of shape or a description of a 'turn';
  - and identifying 'right angles' as well as horizontal and vertical lines and pairs of perpendicular and parallel lines.

The value of spatial reasoning and the SPACE activities, however, is not restricted to the 'geometry' sections of the Programme of Study. As presented in the following section, spatial reasoning touches on nearly all aspects of the maths curriculum:

- Number (addition, subtraction, multiplication and division)
- Place value
- Fractions
- Measurement

Importantly in helping to develop spatial reasoning, SPACE activities provide opportunities for children to develop and practice spatial skills. These spatial skills can be usefully applied to practical mathematics opportunities, for example when putting mathematical operations (addition, subtraction etc.) into practice. Furthermore, spatial skills can be applied when children are provided with concrete contexts for developing problem solving and reasoning skills so that children:

- **build on their work in Y1 relating to, for example**
  - *Number and place value*: identification and representation of numbers using objects and pictorial representations including the number line, and use the language of: equal to, more than, less than (fewer), most, least;
  - *Number – addition and subtraction*: solve one-step problems that involve addition and subtraction, using concrete objects and pictorial representations, and missing number problems such as: 7 = 9 - ?;
  - *Number - addition and subtraction*: children discuss and solve problems in familiar practical contexts, including using quantities. Problems should include the terms: put together, add, altogether, total, take away, distance between, difference between, more than and less than, so that pupils develop the

concept of addition and subtraction and are enabled to use these operations flexibly;

- **explore and consolidate their Y2 work to, for example:**
    - *Number – addition and subtraction:* solve problems with addition and subtraction: 1. using concrete objects and pictorial representations, including those involving numbers, quantities and measures, 2. applying their increasing knowledge of mental and written methods;
    - *Number – multiplication and division*: solve problems involving multiplication and division, using materials, arrays, repeated addition, mental methods, and multiplication and division facts, including problems in contexts.
    - *Measurement:* choose and use appropriate standard units to estimate and measure length/height in any direction (m/cm);

- **prepare for their work in Y3 to, for example:**
    - *Number – multiplication and division*: solve simple problems in contexts, deciding which of the four operations to use and why. These include measuring and scaling contexts, (for example, four times as high, eight times as long etc.) and correspondence problems in which 'm' objects are connected to 'n' objects.

Spatialising the Year 2 Mathematics Curriculum

On this page, you can find a reminder of the six spatial skills that we refer to in SPACE, and their definition.

On the following pages, you will find examples that demonstrate how these spatial skills connect the Year 2 Mathematics curriculum. You can use this knowledge to spatialise how you teach the mathematics curriculum.

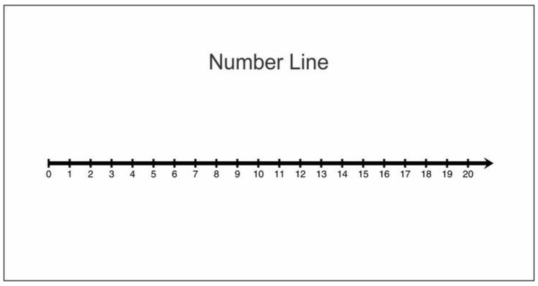
Spatial skills	***Definition***
Visualisation	*Imagining and manipulating spatial information in the mind's eye, involving memory and prediction.*
Visual and spatial memory	*The ability to maintain an image in memory for a small amount of time.*
Composing and Decomposing	*Understanding of structure, parts, and wholes.*
Spatial Scaling	*Working between different size versions of the same thing. Understanding the spatial relationships represented by diagrams of real objects.*
Perspective Taking	*Things appear differently depending on where we are (position) and what we can see from where we are (visibility).*
Representation	*Representations help children to make sense of spatial and mathematical structures and relationships, for problem solving. Examples include gesture, language, physical manipulatives, graphs, and diagrams.*

Number and place value

A number line is a spatial *representation* of the linear number system.

Number lines represent the ordinal relationships between numbers, spatially. This helps children to build spatial awareness of how numbers relate to each other.

Example 1

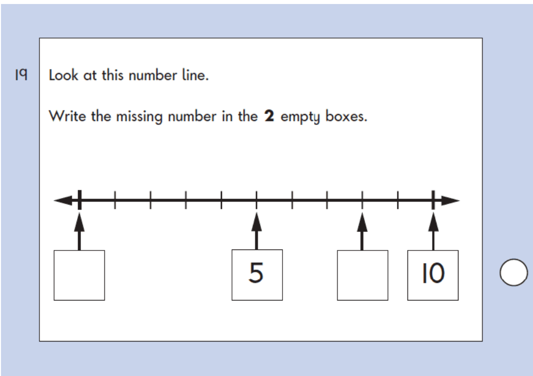


Q1. “Can you imagine where the number 17 goes on a 0-20 number line? Is it closer to 10 or to 20?”

Q2. “Can you see 15 and 5 on a number line in your head? Which has a bigger value?”

Asking a child to imagine a number line in their head involves prompting the use of *Visualisation* as a spatial skill. Visualisation can be supported by asking children to check their predictions on a physical number line.

Example 2



For this number line, we need to recall the order of numbers. The child needs to understand the position of numbers on the number line – for example, whether 5 comes before or after 0, and whether 10 comes before or after 5.

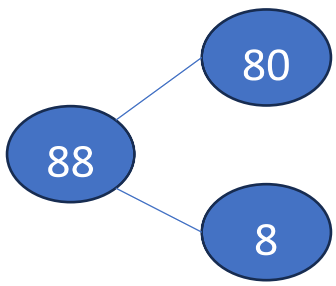
When children need to recall the order of numbers, they use *Visual and Spatial memory* as a spatial skill.

You can find more examples here.

Addition and Subtraction

Part- whole models as spatial tools.

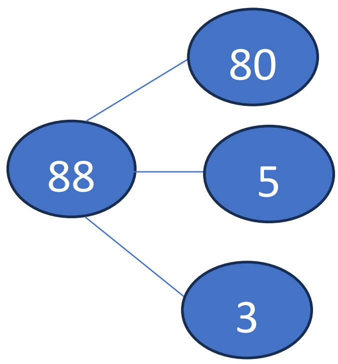
Example 1



□ + 8 = 88

88 - □ = 80

Example 2



□ + 5 + □ = 88

For Addition and subtraction children use various spatial skills, such as *Composing and Decomposing*, *Visual and Spatial memory* and *Visualisation*.

Before children use part-whole models they need to understand that every number can be split into two or more parts. Using a part–whole model requires children to be able to use *Composing and Decomposing* as a spatial skill, i.e., children recognise that a whole can be divided into parts. Below the part-whole models are addition and subtraction problems with missing numbers. For this type of problem-solving, children need to use *Visual and Spatial memory* as spatial skills because they may recall patterns or configurations they have seen before, facilitating the retrieval of relevant information stored in their memory. Also, children could solve these problems using *Visualisation* as a spatial skill. That is, children could mentally manipulate the terms in their mind's eye. For example, __+ 8 = 88 can be manipulated to become __= 88 -8

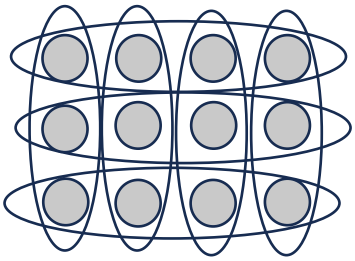
Some more examples to practice *Composing and Decomposing* spatial skill here and here.

Multiplication and Division

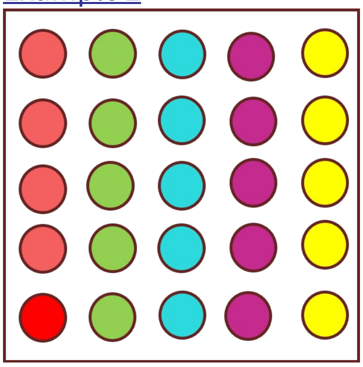
For solving multiplication and division problems children rely on a range of spatial skills. These include *Composing and Decomposing*, *Spatial Scaling* and *Perspective Taking*.

Example 1

Using arrays is one way to explore the commutative property of multiplication questions. Children can use arrays to explore commutativity with multiplication. In the example below children might notice there are 4 groups of 3 which equal 12 and also 3 groups of 4 which equal 12. This draws on a form of *Perspective Taking* as a spatial skill. In a 3x4 array, children need to understand the spatial relationships between the rows and columns. Recognizing that the same set of objects can be viewed as either 3 groups of 4 or 4 groups of 3 requires them to mentally reorient their viewpoint of the array. Also, Perspective taking requires cognitive flexibility, enabling children to shift between different viewpoints. By considering both 3 groups of 4 and 4 groups of 3 within the same array, children develop the ability to flexibly navigate through different representations of multiplication.



Example 2



A child has 25 counters. We can ask questions like: "Can you separate your counters into 5 groups? How many are in each group? How else can you partition in counters?" these questions require children to use *Composing and Decomposing* as a spatial skill.
When we ask the child to separate the 25 counters into 5 groups, we are asking them to decompose the counters into distinct groups.

You can find some interesting examples here.

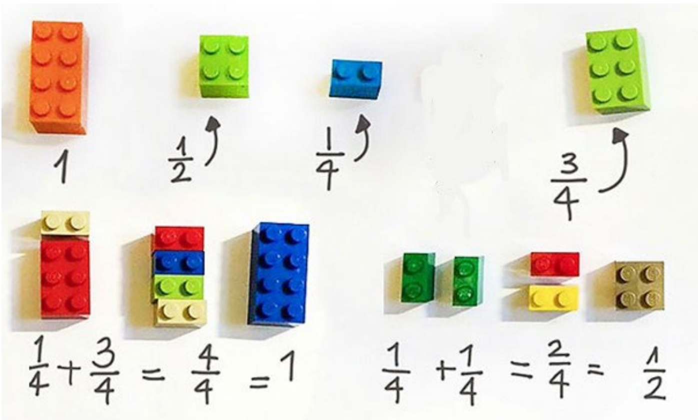
Fractions

Prior to comprehending fractions, children must first grasp the concept of parts and wholes. In dealing with parts and wholes, children use *Composing and Decomposing* as a spatial skill, as we previously mentioned.

Example 1

When children have a set of different shapes and are shading in half of each shape. We can ask: “How many different ways can you shade half of the shape? How will you know that you have shaded half of the shape?”. This will draw on *Representation* as a spatial skill. When we ask children how many different ways, they can shade half of a shape they need to *visualize* and *represent* the different ways the shape can be divided into two equal halves. When we ask the child how they will know that they have shaded half of the shape, we are encouraging them to develop an internal *representation* of what constitutes half of a shape.

Example 2
LEGO can help with introducing fractions as shown in the image below.



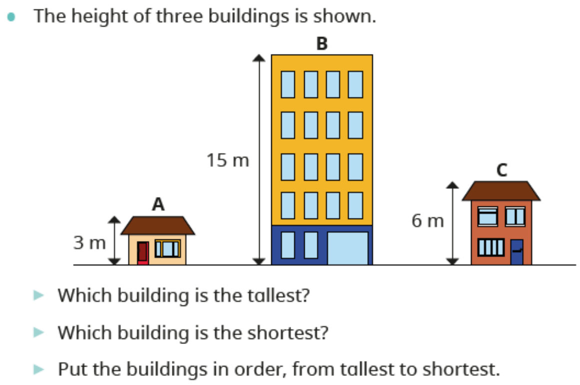
You can find more examples with fractions here, here and here.

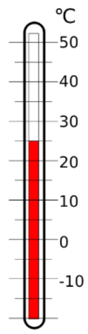
Measurement

Measurement involves using various spatial tools to measure length, height, volume, capacity and mass. The ruler, a spatial tool which is often used in the classroom, presents a spatial representation of the linear number system.

Example 1

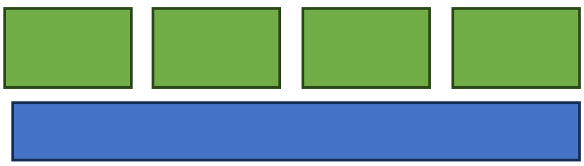
When we prompt children to compare the heights of different buildings or to measure the temperature inside and outside the classroom, children use *Visual and Spatial memory* as a spatial skill. *Visual and Spatial memory* helps children recall the temperature readings and compare them to make judgments about the temperature differences.





Example 2

If we instruct children to employ blocks, instead of a ruler, to measure the length of a ribbon, this will encourage them to use *Spatial Scaling* as a spatial skill. The child needs to understand the relationship between the length of the blocks and the length of the ribbon. So, the child can see that the ribbon is the length of X blocks (put another way, it is four times the length of one block).



You can find more activities here.

Geometry – properties of shape

The association between spatial reasoning and geometry is readily apparent to practitioners, as spatial reasoning is predominantly interconnected with the principles and concepts within geometry.

Example 1

If we ask the class to find the shapes below in the classroom, this activity will require the use of *Spatial Scaling* as a spatial skill. This activity promotes spatial reasoning skills as children analyse spatial information. They have to *visualise* the shapes and locate larger or smaller scaled versions of them within the classroom and use spatial scaling to match them to the examples.

Example 2

When children collaborate in pairs with 3D shapes and are prompted with questions such as, "How many sides and corners can you see? What can your partner see?" they are being encouraged to adopt different perspectives, using *perspective taking*. 3D shapes have multiple sides and angles. By prompting the children to discuss what they see and comparing it with what their partner sees, they are encouraged to consider different viewpoints. This process fosters an understanding that an object can look different depending on the observer's perspective.

You can find more examples here and here.

Geometry – position and direction

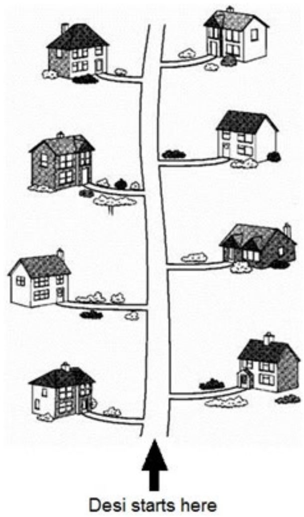
In the context of position and direction, various spatial skills can be used. If we look at the example below where children need to find Desi's house, children need to be able to distinguish between left and right directions ("2nd on the left"). Looking at the map children will need to *visualise* in their mind the position of the Desi's house. To reach the solution, children need to compare the instructions to the map and back again using *visual and spatial memory*.

<u>Example 1</u>

Look at this map.

Desi's house is the **2nd** on the **left.**

Tick (✓) it.



You can find more examples <u>here</u> and <u>here</u>.

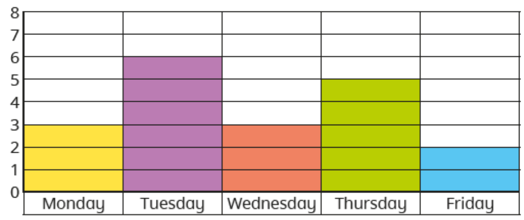
Statistics

Tables, diagrams, tally charts, and pictograms serve as spatial *representations* of information. Engaging in such activities also prompts children to use *Visual and Spatial memory* as part of their cognitive processes. Children need to visually interpret and understand the information presented in tables and diagrams. *Visual and Spatial memory* is crucial for retaining key details, patterns, and relationships between elements represented visually. That is, holding visual aspects of the information in mind helps them make sense of the data. Tally charts and pictograms use symbols or icons to *represent* quantities or categories. Children need to remember what each symbol represents and apply this knowledge when reading or creating these visual representations.

<u>Example 1</u>

The block diagram, table and tally chart show how many children went to after-school club each day. Some of the question that we can ask children are: “How many children went to after-school club on Monday?”, “Which day had the most children?”. These examples Illustrate that the same data could be presented using a variety of *representations*.

- The block diagram shows how many children went to after-school club each day.



- On Monday, ______ children went to after-school club.
- The day with the most children was ______

Days	Number of children
Monday	3
Tuesday	6
Wednesday	3
Thursday	5
Friday	2

Days	Tally
Monday	III
Tuesday	~~IIII~~ I
Wednesday	III
Thursday	IIII
Friday	II

Some more activities you can find <u>here</u> and <u>here</u>.