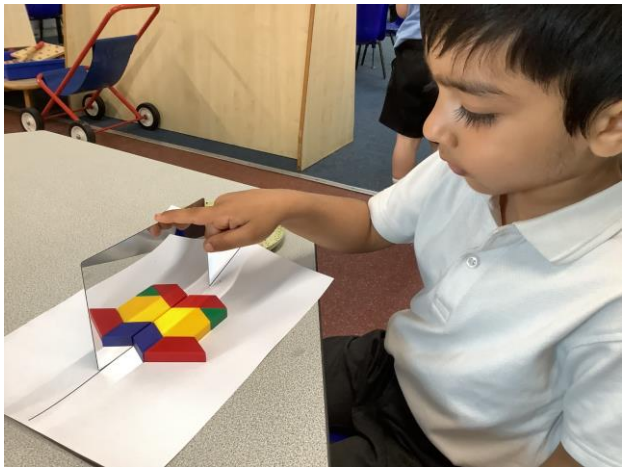
ChIPs assessments

Child Indicators of Performance
in mathematics

Spatial reasoning



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These activities are intended to enable educators to gather assessment information about young children's spatial reasoning, in order to monitor progress and to plan teaching. The activities are based on research evidence about aspects of spatial reasoning which have been shown to be predictive of children's later mathematics. If five year old children can do these activities at the start of primary school, they will have a firm foundation for spatial reasoning and wider mathematical development.
The focus is on children's recognition of spatial relations and shape properties and on visualising in order to solve puzzles and problems, e.g. which shapes might fit together, how to turn a shape to fit a gap or which way to go on a familiar route. Visualising is essential for spatial reasoning, and involves remembering experiences and imagining movement as well as static arrangements. In all the different aspects of space and shape, the progression from experience to reasoning involves representing, using visualization and also language, gesture and graphics. The development of spatial reasoning is therefore dependent on a range of practical experience, indoors and out, and activities which involve exploration, problem solving, discussion, drawings and pictures.

Aspects of spatial reasoning included in these assessment activities:

Space

Position and direction: non-verbal & vocabulary
Navigation and maps
Transformations and arrangements: rotation and reflective symmetry

Shape

2D and 3D properties
Composing and decomposing

Activities

1. **Position, direction and navigation**
   a. Where's the dinosaur? b. Obstacle course
2. **2D shape properties, transformation and composition**
   a. Outline puzzles b. Reflection challenge c. 2D shape recognition
3. **3D shape composition, orientation and properties**
   a. Building with blocks b. Copying brick models
4. **Spatial patterns**
   Copying arrangements with objects and by drawing

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It is not suggested that you have to do each activity with all children individually. In practice, you may choose activities according to children's experience, and adapt them as group activities, focusing on one or two children in a group. Or you might choose three children to assess as a sample of the class range, then identify pointers for adults to look for when all children are engaged in regular activities in the setting. The activities should help to identify areas where children need further support and provision. They should be used alongside the ECMG Spatial Reasoning Toolkit, which provides a learning trajectory from birth to 7 and suggests ways to develop children's spatial reasoning. The Toolkit also includes guidance about the different aspects of spatial reasoning with research references, as well as videos, posters and keyrings to help identify progression, and a picture books list.

The activities are presented in two columns. Column 1 describes the assessment activity (with speech in italics). Phrasing can be adapted to suit individual children and supplemented by signs and pictures as needed. There are progressive challenges and we suggest that you stop when it begins to feel difficult. There are some assessment activities in red font: these are too challenging for most five year olds. They are included in case they are needed for an individual child. Column 2 provides pointers for what to look for and note, in an approximate developmental progression. We have also provided a class observation record, which some educators find useful and may adapt. There are accompanying videos showing activities with young children's interesting responses. These can also be used for professional development and discussion with colleagues.

Resources

1.a) Four toy dinosaurs, or other toys/objects which are similar to each other (e.g. pinecones of same size)
b) Obstacle course items (e.g. hoops, cones, crates and planks), images of these, long pieces of paper, and a marker pen
2.a) Pattern blocks and outlines A & B*. You may need to make your own outlines by drawing around your pattern blocks so that they fit exactly.
b) pattern blocks, boards, marker pen, and mirror.
c) shape sheets* and pencil
3.a) Wooden unit blocks (e.g. Community Playthings or similar)
b) Lego bricks with 4,6, 8 & 12 studs (or different sizes of Duplo), 10-15 of each.
4. 20 identical counters (10 in a container), cards or boards to make patterns on, paper, and a pen.

*See appendix

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Spatial reasoning assessments

You may choose from these activities, according to children's experiences
Items in red are more challenging, for more experienced or older children.
Words for the adult to say are in italics.

What to look for in the child's responses

1. Position, direction and navigation

a. Where's my dinosaur?: Position

You will need: several toy dinosaurs or other small toys of the same kind (e.g. all sheep). Put four dinosaurs in different places in the room or outdoor area so that they are 'on', 'under', 'next to' or 'between' objects or pieces of furniture.

Responding to position words: Ask the child to: ***Get the dinosaur which is on the table*** (or other object or piece of furniture). Use a hand gesture to show 'on' when you say the word. Repeat for a dinosaur that is 'under', 'next to', and 'between', using hand gestures each time. Repeat for 'behind', 'in front of', 'above' and 'below'.

Saying position words: Put the dinosaurs in different places in the room (on, under, next to and between). Ask the child to tell you where each dinosaur is using position words: ***Where are the dinosaurs?*** Repeat 'behind', 'in front of', 'above' and 'below'.

Repeat using two descriptions, such as '*the dinosaur is on top of the cupboard and next to the pencils', or 'inside the box in front of the bookshelf'.*

Repeat for 'closer than' and 'further away than' an object or piece of furniture. Repeat for 'lower/higher than' placing the dinosaurs on shelves,

Where's my dinosaur?: Position

Position words	Responding	Saying/gesturing
on		
under		
next to		
between		
behind		
in front of		
above		
below		
closer than		
further away than		
lower than		
higher than		

For each, the child may…

- **respond to** the position word by finding the dinosaur
- **say and/or gesture** the position word to describe where the dinosaur is

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b. Obstacle course: direction

You will need: a simple obstacle course or items to create one (e.g. hoops, cones, crates and planks), images of obstacles in the course (drawn symbols or photographs), long pieces of paper, marker pen.

Responding to direction words: Using direction words, ask the child to move along the obstacle course: ***Go up the steps and down the slide, through the tunnel, along the plank.*** Use hand gestures when you say the direction words.

Saying direction words: Repeat asking the child to: ***Say what you are doing as you go along.*** Model this if needed, e.g. *I'm going over, I'm going through*...
When the child has finished a sequence of movements, ask them to recall what they did or tell another child what to do, using direction words and gestures.

[See example obstacle course videos**:**
https://earlymaths.org/mathematical-moments-3-4-5-year-olds/]

Obstacle course: direction

Direction words	**Responding**	**Saying/gesturing**
up		
down		
over		
under		
through		
along		
forwards		
backwards		
sideways		
left		
right		
diagonally		

The child may…
move without following the direction words:
- copying the movements of others (e.g. are unsure where they go first or copy an incorrect movement of another child)
- use 'there' or 'that', describing objects not directions

respond to and use direction words:
- respond to direction words by moving as described
- use their own words to indicate directions (e.g. 'in and out', 'round and round', 'like a wriggly worm')
- say and/or gesture the direction words

use a greater range of direction words:
- including forwards, backwards, sideways, left, right

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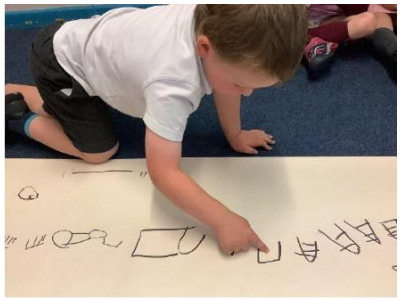
Obstacle course: navigation

Show the child the photographs or drawn symbols and name them so that the child knows which obstacle each represents.
Ask the child to: ***Put these in the right order.*** If necessary, offer prompts such as: ***Which one comes first? What did you do after you went through the tunnel?***
Ask the child to**: *Show me how you moved along the obstacle course with your finger.*** Offer prompts such as: ***What did you do first/next?***
Tracing the route with their finger helps the child to connect their memory of physically navigating the obstacle course with the symbols on the map.



Ask the child to: *Make your own obstacle course.* After they have travelled along the course a few times, narrating their route as they go along, **ask the child to: *Draw a map of the obstacle course.*** Drawing and using the map requires the child to make the connection between the small-scale representation and the life-size obstacle course.

Some children may create obstacle courses with changes of direction, perhaps creating a circuit. Invite the child to include turns on their map (e.g. using arrows). Ask: ***Can you show on your map when you turn the corner?*** Prompt them to find alternative routes by asking: ***Can you find different ways to go around the obstacles?*** You might prompt for more detail in the map by saying: ***Imagine zooming in. What could you add that is not on your map yet?***

Obstacle course: navigation

The child may…
interpret the map as a picture rather than a map:
- use words to describe the symbols (e.g. circle or squiggle) rather than the obstacle it represents

understand that the map shows the obstacle course:
- look at a specific obstacle and point to its symbol
- use their finger and/or directional words to discuss moving from one obstacle to another but miss out important steps in the sequence
- draw a map with symbols representing obstacles

sequence movements to recall a familiar route
- use their finger and/or directional words to recreate their route (as a sequence of places)
- Talk about, point to or draw the key obstacles (landmarks) in the correct order

The child may…
Indicate changes of direction on their map:
- show turns with fingers, arrows or words

Sequence movements to create alternative routes:
- draw lines or arrows to show routes
- use their finger and/or directional words to suggest a range of routes in the same area

Represent relative distances based on the real positions:
- draw symbols on the map showing relative distance and proximity to other symbols

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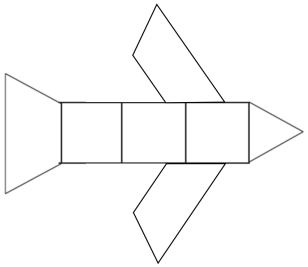
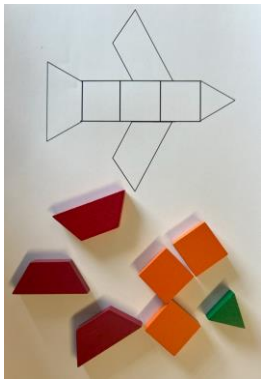
2. 2D Shape properties, transformation and composition

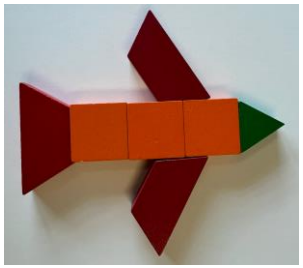
a. Outline puzzles: properties, rotation and composition

You will need: pattern blocks and outline sheets A (plane) and B (person). The easier puzzle (A. plane) has an outline for each pattern block. The harder one has just the outer outline (B. person).
NB. Pattern blocks vary by manufacturer: you may need to make your own outlines by drawing around your pattern blocks so that they fit exactly.

Give the child outline sheet A (plane) and the matching pattern blocks. Ask them to: ***Put the shapes in the right spaces to make the plane.***







A. plane

Give the child sheet B (person) and the pattern blocks that fit in it. Ask the child to: ***Put the shapes in the right spaces to make the person.***
If necessary, prompt the child to try different arrangements: ***Can you move any of the shapes so they fit better?*** Ask them to explain their choices: ***How did you know that shape went there? Why didn't you choose that shape to fit there?***

Outline puzzles: properties
The child may…
recognise some general shape properties:

- select shapes which will not fit, try and then reject them.
- choose a shape with the correct number of corners but not the correct angles (e.g. a rhombus with 30 degree instead of 60 degree corners)
- select a shape with properties which fit some of the outline but not all of it.
- select a similar shape with the wrong number of corners, which may fit between the other shapes but not the outline (e.g. triangle instead of a trapezium)

select shapes which fit:

- after trialling (or by luck)
- look for and quickly find the shape they need
- fit shapes in the outline in a different way than you expected

explain why a shape will fit:

- use gestures for the shape properties (e.g. showing the corner with their hands)
- using shape words to describe their properties (e.g. *because it has a pointy corner)*

Outline puzzles: rotation
The child may…
recognise the need to turn a shape:

- turn a shape several times before discarding it
- turn a shape several times until it fits in the outline

visualise what a shape will look like when rotated:

- confidently rotate a shape to fit
- turn a shape before fitting it into place

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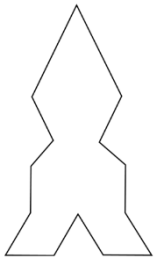
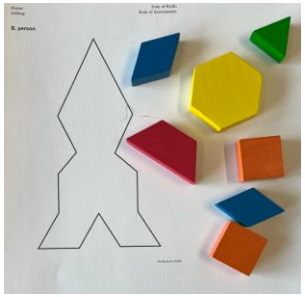
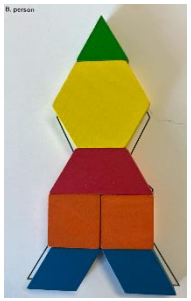
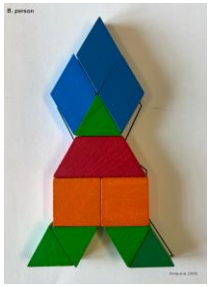
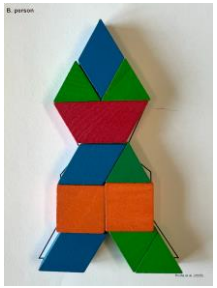
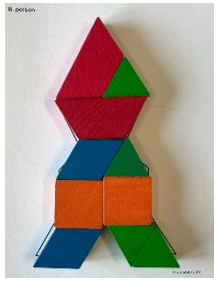
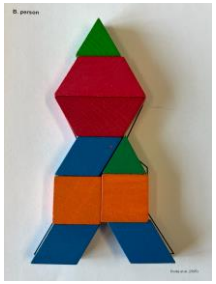




B. person

Children who can visualise which shapes will fit, and how, may show this by confidently selecting a pattern block and turning it in mid-air before placing it (rather than trying to make it fit afterwards) or they pick up two trapezia at once to fill a hexagon space. Prompt the child to visualise before they try a pattern block, asking: ***How do you know that shape will fit? Can you see which shape you need (before picking it up)? Which two shapes could you put together to make this shape?***

Ask the child to complete outline sheet B again but give them a selection of pattern blocks without any hexagons. Ask them to: ***Make the person again but this time using any of these shapes.*** This prompts them to use different combinations to make shapes.

For more outline puzzles see:
https://www.learningtrajectories.org/pages/resources

Outline puzzles: composition

Combining two or more shapes to make another shape (e.g. two squares to make a rectangle, two triangles for a rhombus or two trapezia for a hexagon).

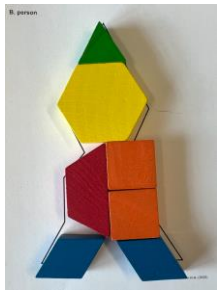
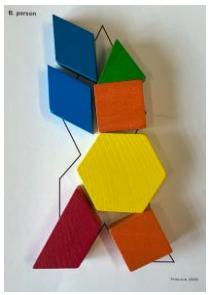
The child may…

fill part of a space with a shape:

- fit a shape into one part of the outline, leaving a space that cannot be filled

combine shapes to make new shapes:

- place one shape into the outline leaving a space which another shape will fit into
- try putting together different combinations of shapes to fit the space
- place two shapes together to make another shape, then fit them into the outline
- remove a shape from the puzzle and swap it for two or more other shapes which fill the same space

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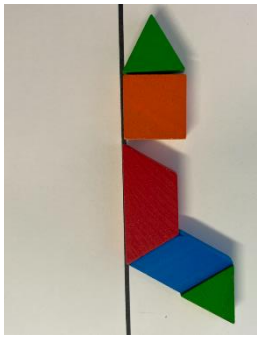
b. Reflection challenge: symmetry

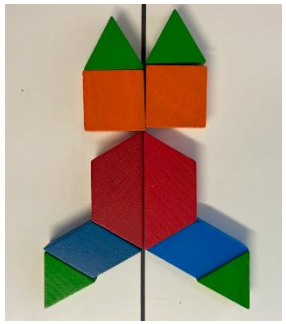
You will need: two sets of the same pattern blocks, a line taped/drawn on a card/board, a mirror.

Arrange some of the pattern blocks on one side of a horizontal line. Put the mirror on the line and show the child the reflection of the arrangement in the mirror (it may help to turn the arrangement so the child can see the reflection easily). Remove the mirror and show the child how to arrange the pattern blocks on the other side of the line to create the reflection that they just saw in the mirror. Afterwards, check it with the mirror.

Arrange the shapes like this:



Ask the child to: ***Make the other side of the pattern as you would see it in the mirror.***



Afterwards, the child can check their response using the mirror. Ask the child: ***What do you need to do if I put a shape here?*** (Place a shape away from the line on one side).

Reflection challenge: symmetry
The child may...
put the same shapes on each side of the line:

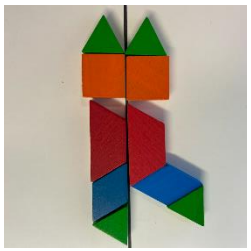
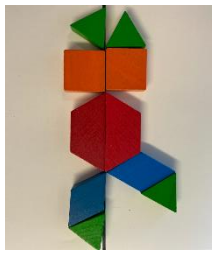
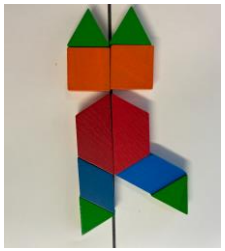
- put matching shapes on the other side of the line, but in the same arrangement (ie not reflecting the arrangement)

create a partial reflection:

- reflect shapes correctly which touch the line, but not those further away
- place all shapes in the correct order top to bottom but spacing, overlapping or bunching up the shapes
- put shapes in the correct places but rotate some incorrectly (e.g. placing them in the same orientation as on the other side of the line)

predict the complete reflection:

- self-correct when they spot an error (e.g. repositioning or turning a shape around)
- position all shapes and orientations correctly to create the vertical reflection
- position all shapes and orientations correctly to create the horizontal reflection
- position all shapes and orientations correctly to create a diagonal reflection

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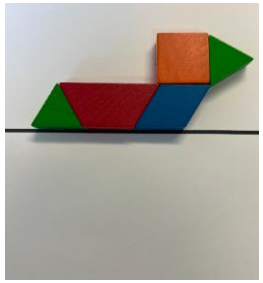
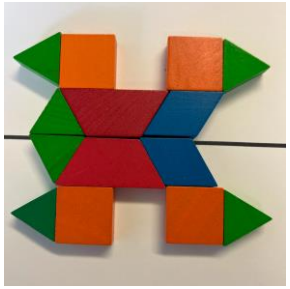
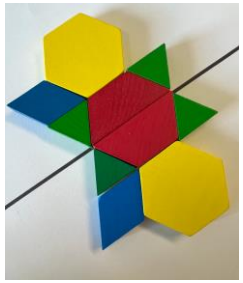
Repeat with this arrangement and a horizontal line.

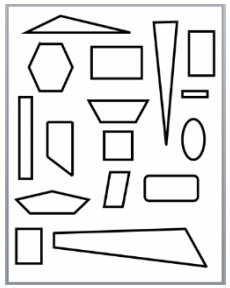
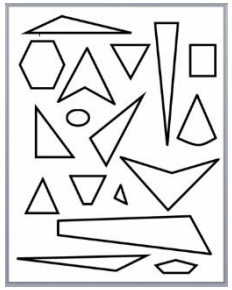
Ask the child to reflect an arrangement with a diagonal line (above).

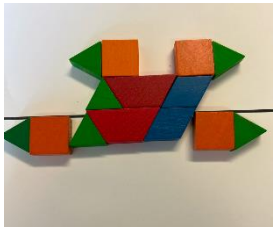
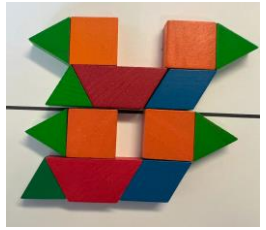
c. 2D shape recognition
A five year old child may know shape names and some properties, but not yet distinguish shapes and 'near shapes' according to shape definitions.

You will need: a pencil and the sheets of triangles and rectangles (appendix) which include a range of irregular and 'nearly but not quite' examples of the shapes.

Give the child the triangles sheet. Ask the child to put a dot or write a 'T' on all the triangles. Ask the child ***Why did you put a dot on those? Why didn't you put a dot on these?***

Repeat with the rectangles sheet (appendix).

2D Shape recognition
The child may…
recognise shapes which are regular or familiar examples of polygons, in familiar orientations:
- select equilateral and isosceles triangles when 'pointing up', but not the less familiar examples e.g. asymmetrical and 'upside down' triangles

recognise some properties of triangles (e.g. corners are not right angles, but have the incorrect number of corners):
- select all the triangles but also other shapes, such as quadrilaterals or the hexagon (e.g. any shapes without right angled corners)

recognise a triangle by its properties:
- select all and only the triangles, but not explain why

identify the properties of a triangle:
- explain why/not, using a correct definition (e.g. *It isn't a triangle because it has a curved side / four sides).*

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3. 3D shape composition, orientation and properties

a. Building with blocks: 3D shape composition and properties

You will need: unit blocks (e.g. Community Playthings or similar)

Observe a child making a construction. With experience, children make increasingly complex constructions, with enclosures, repeating units, staircases and ceilings.

Look for how they select the blocks that they need, whether they show recognition of particular properties when selecting blocks to create a structure (e.g. two blocks of equal length for the sides of a window) or in order to represent things (e.g. blocks with sloping sides for a roof).

After they have finished building, ask them to describe their construction: ***Tell me about what you have done. Why did you use these blocks?***

Children may use mathematical or informal language (and/or gestures) to identify properties e.g. *flat, curved, sides, faces, corner, sloping, roof-shaped*.

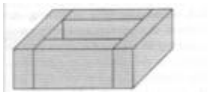
3D shape composition

The child may…

stack and line up blocks:

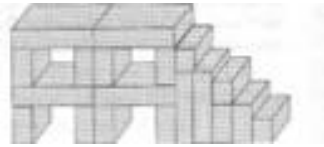
- make towers of the same block
- stack smaller blocks on top of larger ones
- make a row of blocks (end-to-end or side-to-side)

make enclosures:



- put blocks around the edge of a space or object to enclose them
- balance a block on two blocks/towers to form a ‘bridge’ (with a space underneath)

create and repeat units:



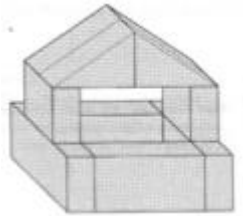
- repeat a structure/unit (e.g. tower of bridges)
- pick up several blocks together to make a unit
- make a staircase out of identical ‘bricks’
- estimate and count the number of blocks needed

visualise and plan ahead:

- collect a number of blocks together before building, predicting what they will need
- plan to make gaps in their building (e.g. windows, doorways or tunnels)

Images: Clements & Sarama (2021)

- plan dimensions for a purpose (e.g. making a house for a teddy or using a toy car to measure tunnel width)



make complex constructions

- create storeys with ceilings
- make increasing/decreasing repeated parts (e.g. staircase)

3D shape properties:
The child may…
recognise some properties of shapes:

- change blocks, realising the properties are unsuitable (e.g. remove a block with a curved face, realising they cannot build on top of it)
- select blocks by their properties, e.g. cylinders for legs, flat blocks to build on

use shape property words:

- use hand gestures to show the properties of the block they need
- get a block that fits a description, e.g. *the wedge block* or *one with a curved face*
- describe shape properties of blocks, e.g. *curved, flat, face, sloping, right-angle*

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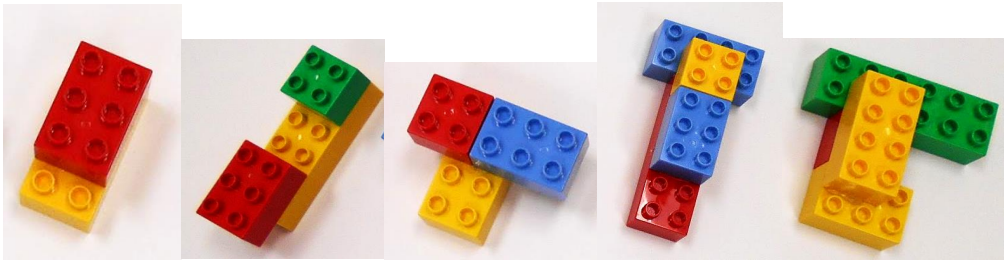
b. Copying brick models: composition and orientation

You will need: a selection of Lego bricks with 4,6, 8 & 12 studs, (or different sizes of Duplo bricks) and models 1 to 5 already made.

Show the child a model made out of three blocks, with a set of blocks to make one the same. Demonstrate making a copy of the model (using the same bricks). Ask: ***Is this one exactly the same as this one?***

Show the child model 1 and give them the same bricks to make a copy. Ask: ***Can you make a model just like this one?*** Afterwards, ask, ***Is it the same?***

Repeat with models 2 to 5 in order. The models get progressively more challenging, so stop when the child begins to find them difficult.
Look out for how often they look at the pattern they are copying and whether they self-correct any errors. If the child does not check the original model after an initial first look, then prompt them to look carefully to check: ***Does your model look exactly the same?***



Model 1 Model 2 Model 3 Model 4 Model 5

Composition and orientation

Model	size and order of bricks	alignment (ends line up/overhang)	rotation (at right angles)	bridge connection
1				
2				
3				
4				
5				

The child may…

notice the overall shape:
- bricks are on top of each other, but incorrect size
- bricks are on top of each other, but incorrectly aligned

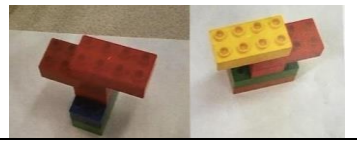
align bricks:
- bricks are on top of each other, with ends aligned
- bricks connected correctly, but not overhanging

space bricks correctly:
- bricks overhang by the correct number of studs
- gaps between bricks are the correct number of studs

recognise orientation:
- place bricks across (at right angles) where needed

recognise size, order, spacing and orientation:
- connect all pieces correctly, including a 'hidden' brick

A model with child's attempt:



right angles no right angles

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4. Spatial patterns

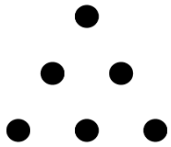
Copying arrangements

You will need: 20 identical counters (10 counters in a container), cards or boards for children make patterns on, paper and pen. It may help to stick the counters onto cards so they do not move around and you can cover and reveal the patterns.

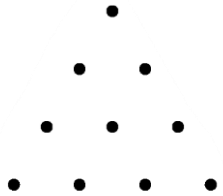
Make a 3 triangle dotty pattern using counters, then show the child and offer the child the container of counters. Ask, ***Can you copy my pattern?*** Afterwards ask, ***Is it the same?***

Look out for how often they look at the pattern they are copying and whether they self-correct any errors.

Provide pen and paper. Ask: ***Can you draw the pattern?*** Afterwards ask, ***Is it the same?***



Repeat for the 6 triangle dotty pattern.



Show the child the 6 pattern and then cover it up, so they have to make or draw it from memory. **Tell the child to: *Look closely, then I'm going to hide this and ask you to copy it.***

Growing the pattern Point to the bottom line and ask: ***What would come next here?***

Repeat the copying, drawing and growing tasks with a 10 dotty triangle.

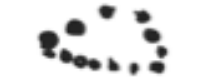
Copying arrangements

Triangles	copying	drawing	copying / drawing from memory	growing the pattern
3				
6				
10				

The child may…

copy some features of the arrangement:

- place or draw dots in random positions
- make the overall shape
- space dots equally
- include the correct number of dots



Drawing of 6 dot triangle

copy most features of the arrangement

- include the correct number of dots and space them equally, but not in the correct shape
- make the correct shape, spacing dots equally, but use the incorrect number of dots
- include the correct number of dots and make the approximate shape, but not space the dots equally

copy the pattern exactly

- use the correct number, shape and spacing of dots
- **Make or draw the pattern from memory**

Grow the pattern by increasing the bottom line

- make or draw a line of 4 dots below the line of 3 dots
- make or draw a line of 5 dots below the line of 4 dots

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References

1a. Where's my dinosaur: Position

Farran, E.K. & Atkinson, L. (2016). The development of spatial category representations from 4 to 7 years. *British Journal of Developmental Psychology*, 34(4), 555–568. doi: 10.1111/bjdp.12149

1b. Obstacle course: direction and navigation

Cohrssen, C. & Pearn, C. (2019). Assessing preschool children's maps against the first four levels of the primary curriculum: lessons to learn. *Mathematics Education Research Journal,* 33, 43-60.. doi:10.1007/s13394-019-00298-7

Farran, E. K., & Atkinson, L. (2016). The development of spatial category representations from 4 to 7 years. *The British Journal of Developmental Psychology*, *34*(4), 555–568. doi.org/10.1111/bjdp.12149

2a. Outline puzzles: 2D shape properties, rotation and composition

Learning trajectories:https://www.learningtrajectories.org/pages/resources

Pinilla, R.K., Wellberg, S., Castro-Faix, M. & Ketterlin-Geller, L.R. (2025). Analyzing children's spatial reasoning Using an existing learning progression: Insights from interviews and task performance. *Early Childhood Education Journal* doi.org/10.1007/s10643-025-01862-6

b. Reflection challenge: symmetry

c. 2D Shape recognition

DREME TE https://prek-math-te.stanford.edu/spatial-relations/shape-assessment-protocol

3a. Building with blocks: 3D shape composition and properties

Clements, D.H. & Sarama, J. (2021). *Learning and teaching early math: the learning trajectories approach.* Routledge

b. Copying brick models: composition and orientation

Verdine, B.N., Irwin, C.M., Golinkoff, R. M., & Hirsh-Pasek, K. (2014). Contributions of executive function and spatial skills to preschool mathematics achievement. *Journal of Experimental Child Psychology*, *126*, 37–51. doi:10.1016/j.jecp.2014.02.012

Bower, C., Zimmermann, L., Verdine, B., Toub, T.S., Islam, S., Foster, L., Evans, N., Odean, R., Cibischino, A., Pritulsky, C., Hirsh-Pasek, K., & Golinkoff, R. M. (2020). Piecing together the role of a spatial assembly intervention in preschoolers' spatial and mathematics learning: Influences of gesture, spatial language, and socioeconomic status. *Developmental Psychology*, 56(4), 686–698. doi.org/10.1037/dev0000899

Builder Copier game: ECMG *Mathematical Moments: 3,4 & 5 year olds, Spatial reasoning* https://earlymaths.org/mathematical-moments-3-4-5-year-olds/

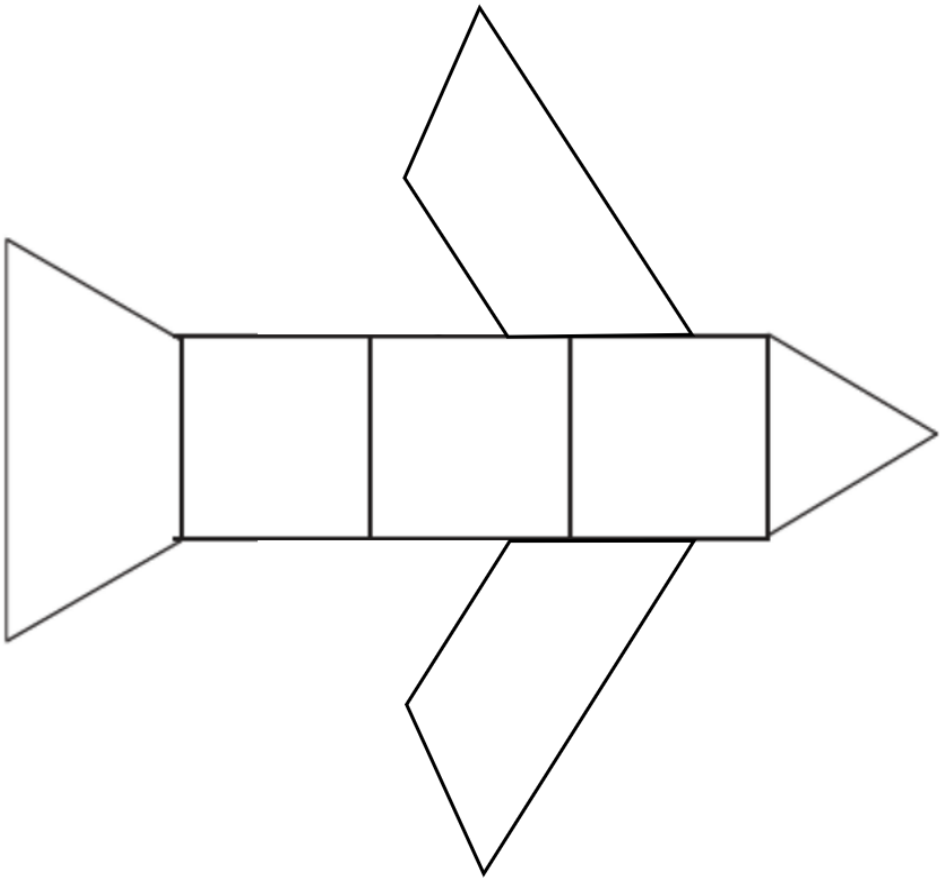
4. Spatial Patterns: copying arrangements

Papic, M., Mulligan, J., & Mitchelmore, M. (2011). Assessing the development of pre-schoolers' mathematical patterning. *Journal for Research in Mathematics Education*, 42(3), 237-268. doi:10.5951/jresematheduc.42.3.0237

Thouless, H., & Gifford, S. (2019). Dotty triangles. *For the Learning of Mathematics,* 39(2),1318.

Appendix

2a Outline templates
A. plane



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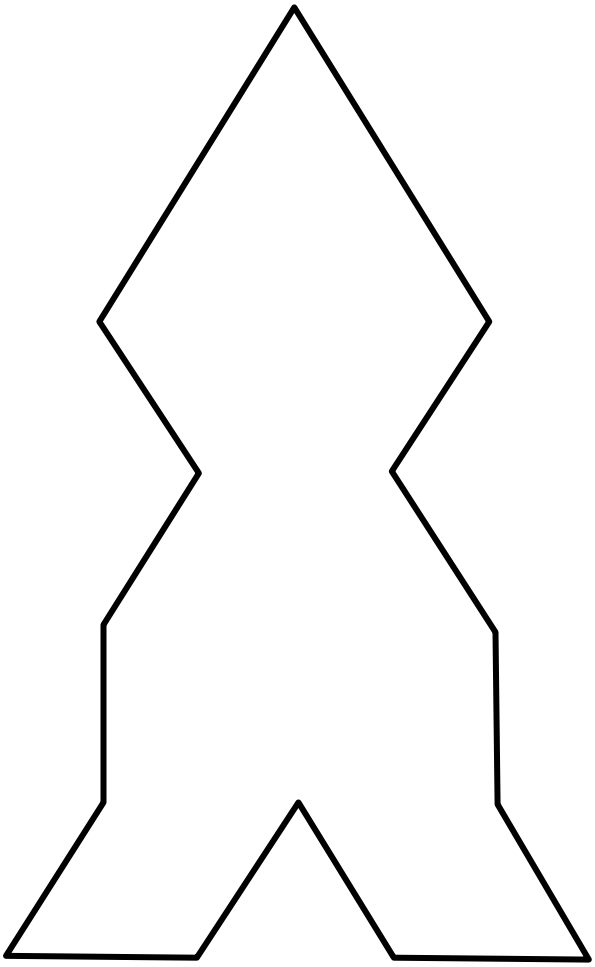
B. person



Pinilla et al. (2025)

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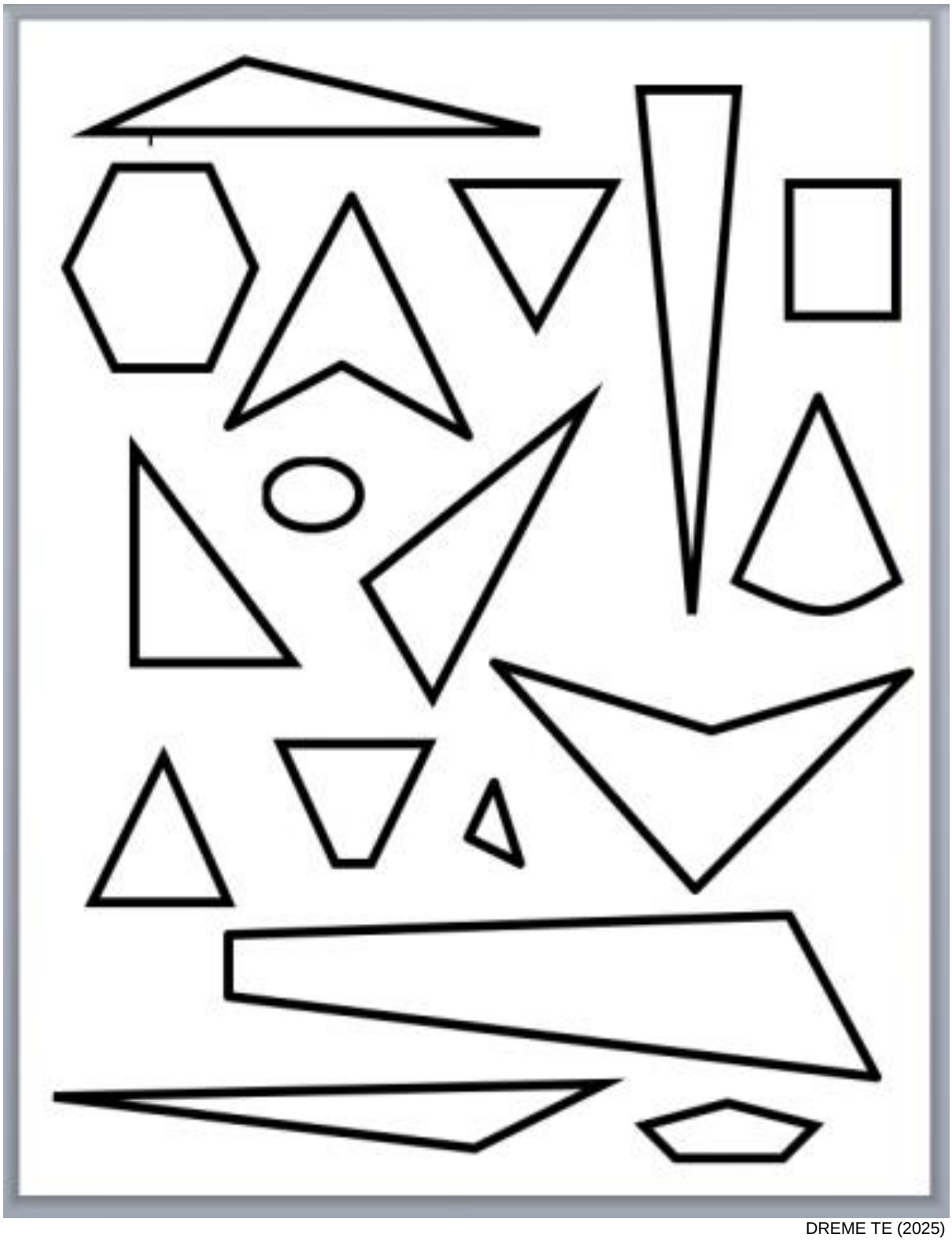
2c Shape sheets
Triangles



DREME TE (2025)

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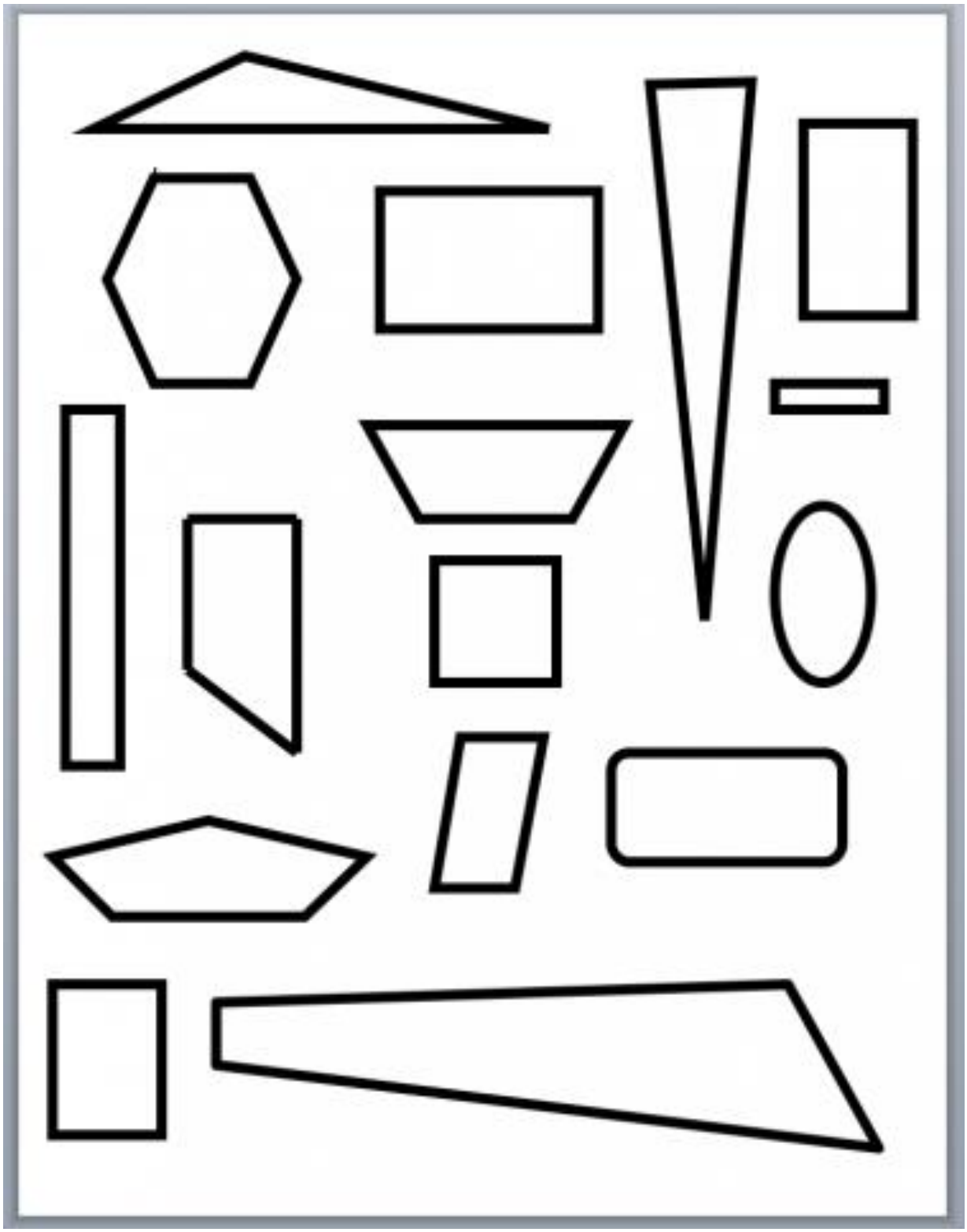
Rectangles



DREME TE (2025)

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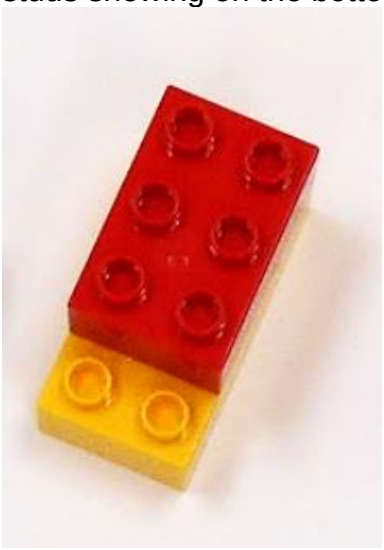
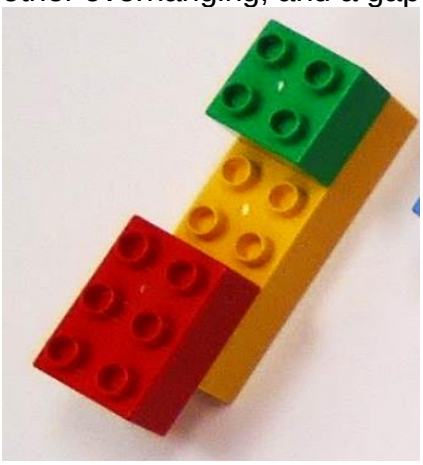
3b. Copying brick models

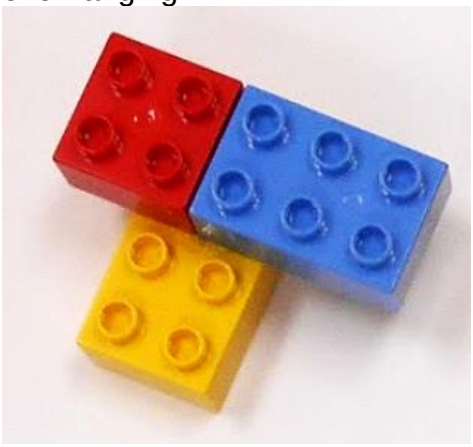
Model 1: A smaller brick placed on top of a larger brick, aligned at one end with 2 studs showing on the bottom model



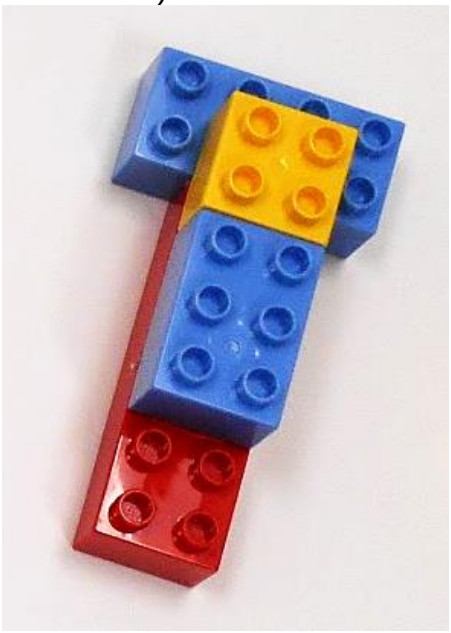
Model 2: Two smaller bricks placed on top of a larger brick, with one aligned and the other overhanging, and a gap in between them



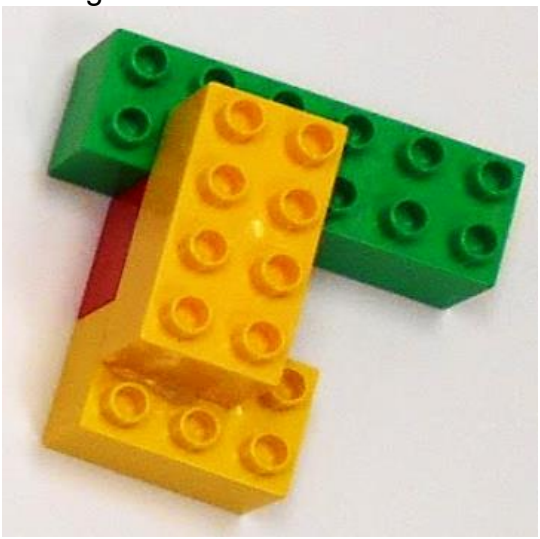
Model 3: Two smaller bricks placed across (at a right angle to) a larger brick, both overhanging



Model 4: Two smaller bricks (next to each other) placed on top of two larger bricks where one of the larger bricks is at right angles with the other larger brick. One of the smaller bricks is on top of the both of the larger bricks connecting them (a bridge connection)



Model 5: One brick is on top of three bricks, connecting all three (bridge connection), leaving one of the three bottom bricks 'hidden'.



Models from Verdine et al. (2017)
Images from Bower et al. (2020)