Supporting spatial play in mathematics

Catherine Gripton and Emily Farran

What is spatial reasoning and why is it important?

2-year-old Ana is playing with the wooden blocks. She chooses each block carefully, making sure they are the same shape as the first block that she chose. Looking closely at the tower she is constructing, she reaches out for another block and quickly looks at it when it feels different to the others. Realising it is longer than the other blocks she pushes it away and finds one that is the shape she wants. She stacks each block on top of the previous one (realising that they need to be stacked flat rather than on the shorter side). Ana stretches further to reach the top as she places each block on the top of the previous one. She makes sure that the corners line up and turns a block if it does not line up with the rest. Ana shows a sense of satisfaction as her tower grows taller.

Ana is engaging in spatial reasoning (sometimes called spatial awareness or spatial thinking). Ana notices the spatial properties of the blocks, selecting blocks with the same shape. Ana also moves and turns the blocks so that they are in the same orientation (the same way around). She is aware of the changing height of her tower. Spatial reasoning in mathematics involves spatial features of objects (size and shape) and spatial relations in our environment, such as between objects or in relation to our bodies (space). Ana uses both as she builds. Ana selects blocks that are the same size and shape as well as turning them to fit and reaching up to place them as her tower grows.

Ana's early spatial reasoning, developed through her play, is preparing her for her future. Spatial reasoning is a 21st century skill that we use in our daily lives from following a route on our mobile phone, putting our shoes on, parking a car or packing a shopping bag. Recently, research has shown that spatial reasoning helps children do better in mathematics throughout their education. Being good at spatial reasoning also makes it more likely that they will get a job in Science, Technology, Engineering and Mathematics (STEM) as an adult. It is equally important in the present, supporting children to navigate their environment, recognise familiar objects, make patterns, interpret pictures and fit objects (and themselves) into spaces.

Recent research has demonstrated the benefit of deliberate focus on developing children's spatial reasoning skills. These studies use structured spatial activities involving blocks, Duplo, jigsaws, symmetry games, matching games (using rotation, mirror images, shape and size) and spatial visualisation games (eg Bower et al, 2020; Hawes et al, 2017). Using concrete resources is essential when we are seeking to support children's spatial reasoning development. Hawes et al, (2022) recently reported that using concrete resources to support and develop children's spatial reasoning (as opposed to computer-based activities) leads to the biggest improvement in number and maths. In primary and early years, practitioner time spent on supporting children's spatial reasoning is well worth it. Positive effects of spatial activities on young children's understanding of number and of mathematics overall have been found by research (eg Schmitt et al, 2018; Bower et al, 2020). This continues into primary school where

focussed and deliberate efforts to support children's spatial reasoning development is often equivalent to half their typical annual learning gain in mathematics (Hawes et al, 2022). The positive impact of spatial reasoning development suggests that it is an important 21st century mathematics skill, in early years and beyond.

Pedagogies which support spatial reasoning development

In order to develop spatial reasoning, children need a wealth of spatial experiences. Recently, we have been working with practitioners from a range of early education settings (birth to seven years) through surveys and focus groups. This work shows that we, as practitioners, regularly use a range of spatial play activities in our practice and recognise the spatial learning within these activities. So, there is much that we already use in our practice that supports spatial play.

Providing spatially stimulating and varied indoor and outdoor spaces provides a strong foundation for effective practice. Such spaces include opportunities for children to sit, lie and stand whilst playing. They provide children with opportunities to follow varied paths or routes through the environment as well as smaller, more enclosed areas to fit inside and play within. Beyond the spatial learning opportunities within the environment, we provide toys and activities which are particularly rich in spatial learning possibilities. Playing with blocks, small world toys, jigsaws, treasure baskets, dens, loose parts and climbing frames all support early spatial development and are staple resources in early years practice.

To further enhance our support for spatial learning, research suggests some supportive pedagogies which are likely to aid children's spatial reasoning development. We have summarised three key pedagogies here:

Provide time, space and opportunity for movement

Spatial reasoning develops alongside physical development. As babies become more mobile, they become increasingly skilled at judging distances, navigating around obstacles and fitting inside spaces, for example. We can encourage children to explore using their whole bodies. As they become increasingly mobile, we can encourage them to navigate different routes around their environment (sometimes with our commentary on the directions they take). This affords the opportunity to view objects and places from different perspectives, estimate distances and the size of objects/spaces as well as gain a feel for where objects/places are in relation to one another.

Supportive practice begins with careful observation of how children enjoy moving, where they look or pause and the movements or spaces they find fascination in. If welcomed, we might join them in their exploration by moving in similar ways, pointing out perspectives, spaces or features of interest and sensitively encouraging new ones.

From space to wriggle and explore how your body moves when you are a baby to running, climbing and balancing as a much older child, children need time, space and opportunity for movement to support important spatial reasoning development.

Use spatial language and gestures

To help children to understand spatial concepts, we can draw their attention to the spatial elements in what they are doing using spatial words and gestures. We can say "turn" whilst rotating our hand and "over" with an arched hand. Further examples include "up", pointing upwards with our finger, and "edge" whilst tracing the edge of a jigsaw piece with our finger. The posters in the spatial reasoning toolkit (Gifford et al, 2022) provide examples of spatial words which adults can use when playing with children. When children hear the word or see a gesture being used, it emphasises that spatial idea, helping them to form a secure, specific understanding of the spatial concept which they then use to help them to think spatially.

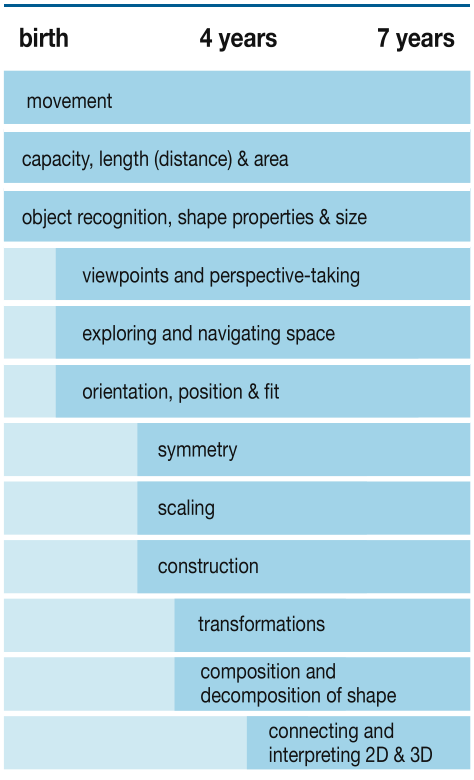
Use knowledge of child development in spatial reasoning to guide your interactions with children

Spatial reasoning draws upon a range of spatial skills. As children develop, the suite of spatial skills available to them expands. 12 areas of spatial reasoning were identified and included in the Early Childhood Mathematics Group (ECMG) spatial reasoning toolkit from their earliest stages. These are listed in Figure 1 which shows how spatial skills diversify as they develop.

Broad knowledge of how spatial reasoning typically develops supports practitioners. It helps us to provide opportunities for children to develop the full range of spatial skills and to ensure that our expectations are developmentally appropriate. In the ECMG toolkit, indicative ages are provided for guidance but are not expectations for individual children. The sequence is what is important. This is because knowing what often follows from the spatial reasoning that children currently enjoy can inform the suggestions we make or thinking we model when engaged in spatial play with children. Because this knowledge of child development is in our heads, as practitioners, we can use this flexibly within our professional judgement. We can ensure that spatial reasoning development is sensitively and appropriately integrated in holistic learning experiences that are meaningful and authentic to the child.

To summarise, we can draw out the spatial learning in play by providing time, space and opportunity for movement. We can use spatial language and gestures during play, alongside using knowledge of spatial reasoning development. This knowledge helps shape provision and interactions during play by helping us to identify and build upon the spatial reasoning that we observe children engaging in. The Spatial reasoning toolkit (Gifford et al, 2022), from the Early Childhood Mathematics Group, is intended to support practitioner knowledge. It provides a learning trajectory which maps out the key elements of spatial reasoning that children tend to develop at earlier and later stages. Learning trajectories are designed to be flexible. They

Figure 1. Areas of spatial reasoning development in the ECMG learning trajectory

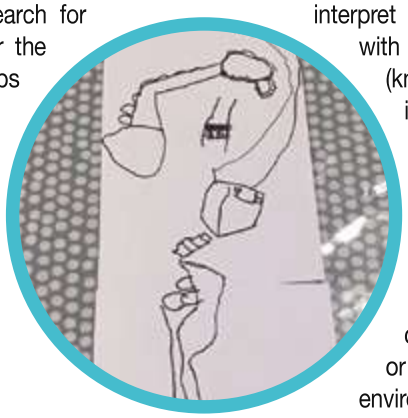


build from the individual child, considering natural child development as well as being mindful of long-term learning goals (they are not a list of prescribed small steps to be taught). Learning trajectories also include activities or advice for specific practices matched to the different stages in the natural developmental progressions (Clements & Sarama, 2021). Next, we provide a few examples of such activities.

Activities which support spatial reasoning development

Using shape sorters and posting toys (typically with babies or toddlers)

Fitting an object through a hole requires a range of spatial skills. Children judge the size and shape of both the object and the hole, as well as rotating (and sometimes flipping) shapes to get them to fit. With experience, children begin to predict fit and ignore shapes that are clearly too large. They select shapes for a specific hole or search for the right shaped hole for the piece in their hand, perhaps visualising the shape of the hole they need for this piece. They may begin to turn the shape in their hand before it gets to the hole, realising that it cannot fit through the hole in its current orientation.



Using toy cars and figures with construction (typically from 2 to 3 years)

Adding in toy cars and figures to construction and block play provides opportunities for adults to use direction as well as position language ("above", "near", "under"), modelling this for children and drawing their attention to dynamic ("through") as well as static ("next to") spatial concepts. It also affords adults the opportunity to model moving around and viewing the construction from different viewpoints. By talking about what blocks (shapes) look like from different perspectives and how this is different depending on the position you are viewing from, encourages children to notice these differences. This supports children to develop perspective-taking skills which help them to interpret what they see as they move around their environment and is most helpful in navigation and finding your way around.

Using home-made jigsaws (typically around 3 or 4 years, depending on the complexity of the jigsaw)

Cutting up the front of a cereal box or used greetings card can create a simple jigsaw puzzle. This resource has the added benefit of being an image that the child is familiar with and has a connection to. To begin with children may enjoy putting halves of several cards together but these can develop over time to puzzles with more pieces. Additional challenge can come from covering the final piece and talking about what shape it could (and could not) be, encouraging important visualisation and prediction skills. Jigsaws support composition and decomposition of shape which is an important area of spatial reasoning. Block play also supports this as new shapes are made by combining or separating blocks. Cutting up food also draws upon these skills and encourages prediction of what the food will look like when sliced, perhaps in different ways.

Making maps of the local area (typically begins around 4 or 5 years)

As children develop perspective-taking and navigation skills they become more able to interpret basic maps. This begins with spatial searching abilities (knowing where an object is in relation to one or two key landmarks or objects, to locate it quickly). It develops to remembering a series of landmarks or directions on a familiar route. We can support children by drawing plans or maps of the setting environment with just a few key familiar objects on there. This may be a plan of the corner of a classroom with the sand tray (rectangle), bookcase (three lines) and dough table (circle) indicated, for example. Children can use these three familiar landmarks to locate a toy buried in the sand tray or hidden on the bookcase. With experience, children can draw their own maps of familiar places, including their route to the setting which can be enhanced with a series of photographs, showing the sequence of the journey. Families often enjoy getting involved with these early map-making activities and point out the directions and landmarks when they walk this route with their child.

Cath Gripton is an Assistant Professor in the School of Education at the University of Nottingham. Emily Farran is a Professor of Cognitive Development and Director of the Cognition, Genes and Developmental Variability (CoGDeV) lab in the School of Psychology, University of Surrey. Both were part of the team that launched the Spatial Reasoning toolkit, a collaboration with the Early Childhood Mathematics Group.

Further information

The Early Childhood Mathematics Group's (ECMG) spatial reasoning toolkit is available at: https://earlymaths.org/spatial-reasoning/. It contains:

- a guidance document for practitioners working with children birth to 7 years
- a learning trajectory with suggestions for what adults might do and what the environment might include
- short videos which can be used by individuals or teams for professional development
- a set of posters which can be displayed in settings.

References

Clements, D.H. & Sarama, J. (2021). *Learning and teaching early math: The learning trajectories approach* (3rd ed.). New York: Routledge.

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, 686. http://dx.doi.org/10.1037/dev0000899

Gifford, S., Gripton, C., Williams, H., Lancaster, A., Bates, K.E., Williams, A.Y., Gilligan-Lee, K.A., Borthwick, A. & Farran, E. K. (2022). *Spatial reasoning in early childhood*. DOI: 10.31234/osf.io/jnwpu

Hawes, Z.C., Gilligan-Lee, K.A. & Mix, K.S. (2022). Effects of spatial training on mathematics performance: A meta-analysis. *Developmental Psychology*, 58(1), 112. DOI: 10.1037/dev0001281

Hawes, Z., Moss, J., Caswell, B., Naqvi, S. & MacKinnon, S. (2017). Enhancing children's spatial and numerical skills through a dynamic spatial approach to early geometry instruction: Effects of a 32-week intervention. *Cognition and Instruction*, 35(3), 236-264. DOI: 10.1080/07370008.2017.1323902

Schmitt, S.A., Korucu, I., Napoli, A.R., Bryant, L.M., & Purpura, D.J. (2018). Using block play to enhance preschool children's mathematics and executive functioning: A randomized controlled trial. *Early Childhood Research Quarterly*, 44, 181-191. https://doi.org/10.1016/j.ecresq.2018.04.006