IMPROVING MATHEMATICS: SPATIAL REASONING TOOLKIT

BRIEFING FOR POLICYMAKERS

POLICY CONTEXT

Spatial reasoning is the ability to understand the spatial properties of objects such as their size and location, and to manipulate and visualise objects and problems in the mind.

Spatial reasoning has the potential to improve mathematical understanding, attitudes, and attainment and reinvigorate the way we teach children ALL subjects. Research has shown that spatial training also closes attainment gaps especially for children from disadvantaged backgrounds.

Despite the many benefits, spatial reasoning is not currently integrated in Early Years and English National Curricula. Doing so will significantly improve STEM outcomes, building a future workforce ready for the technological age.

KEY RESEARCH FINDINGS

The gap between established research evidence on the importance of spatial reasoning, and practical application in the classroom not only limits the potential of many children, but also costs the UK economy an estimated £1.5 billion a year.[1]

Whilst guidance exists[2], there is little emphasis on spatial reasoning in national curricula[3] and most teachers and educators are not confident enough to explain what spatial reasoning is[4]. Giving teachers, parents and carers the skills and confidence to encourage spatial activities can help to address socio-economic inequalities and revolutionise the skillset of the next generation.

"Continuing with our present [curriculum] arrangements condemns the UK to life in the slow lane"
Royal Society, 2023

Spatial Reasoning Toolkit: Resources

The Early Childhood Maths Group and University of Surrey, School of Psychology have developed a Spatial Reasoning Toolkit to address this gap in learning.

Scan the QR code to visit the Spatial Reasoning Toolkit
SCAN ME

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1. The Institution of Engineering and Technology Annual Report 2021,
2. Why Spatial Reasoning is important, UK Government
3. "Spatial thinking as the missing piece in Mathematics curricula", Gilligan-Lee et al., 2022,
4. "Practioners' perspectives on spatial reasoning in education practice from birth to 7 years" Bates et al., 2023

WHAT IS SPATIAL REASONING?

Spatial reasoning is the ability to perceive the location and properties of objects, to understand the relations between objects and oneself, and to visualise objects and problems in the mind. We use these skills day in, day out.

WHY IS SPATIAL REASONING IMPORTANT?

The value of teaching spatial reasoning to children is well established, particularly in developing abilities in Science, Technology, Engineering and Maths (STEM) subjects[5]. There are four key reasons researchers believe spatial reasoning is important for mathematical comprehension.[6]

(i) Spatial and numerical thinking activate the same areas of the brain.

(ii) Mathematics is inherently spatial, for example geometry and measurement involve numbers related to space.

(iii) Spatial visualisation supports mathematical problem solving by enabling children to think through problems in their heads.

(iv) Solving mathematics problems can be supported by representing numbers spatially, for example via number lines, rulers and graphs.

Spatial reasoning can be trained, and spatial training has a positive impact on both spatial ability and mathematics attainment.[7]

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5. Wai et al. (2009)
6. Gilligan-Lee et al. (2023)
7. Verdine et al. (2014)
8. Bower et al. (2020a)
9. Bower et al. (2021)
10. Bower et al. (2020b)

"Proficiency and confidence in spatial reasoning at a young age is a significant determinant of mathematical ability in childhood and adulthood."
Professor Emily Farran

Children from disadvantaged backgrounds typically have lower spatial skills, lower spatial language and reduced access to spatial toys. [8,9]

Research has shown that spatial training is particularly helpful in closing attainment gaps for these children. [10]

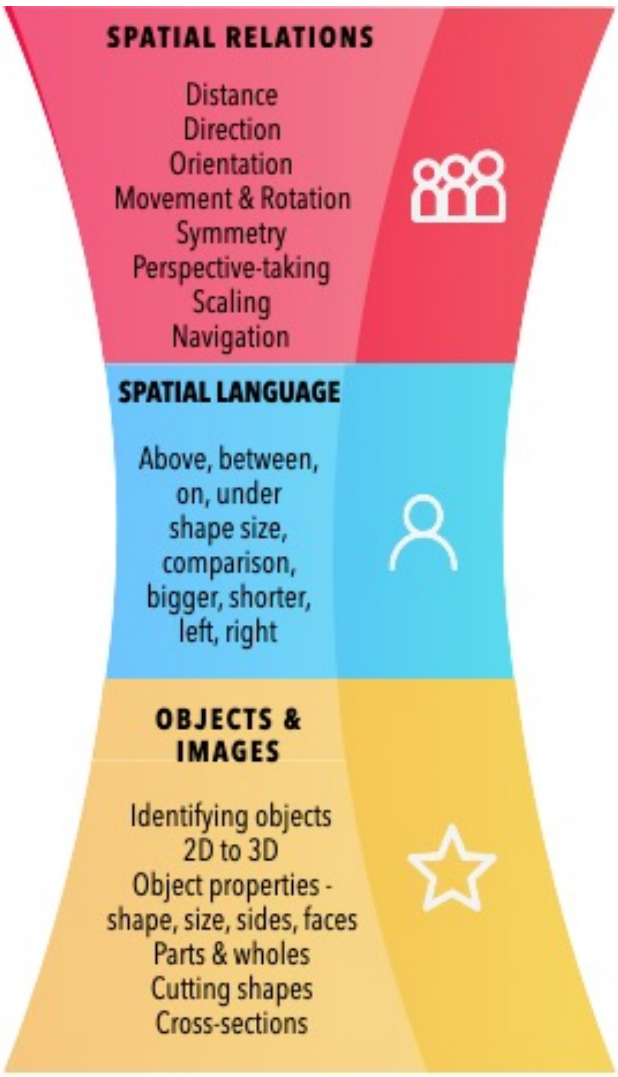

Figure 1: adapted from: Spatial Reasoning Toolkit Guidance document, pp7.

HOW CAN WE IMPROVE SPATIAL REASONING?

Encouraging the use of spatial reasoning in early childhood care and formal education has the potential to create more confident children who have a deeper understanding and appreciation of mathematics, and higher attainment. For teachers, adapting lessons does not require significant resource or difficult changes. It is about how we introduce spatial reasoning as another way to solve problems. This is illustrated by activities in the Toolkit's trajectory of spatial reasoning development.

For example, at age 4 to 5 years, **children are learning to** understand relative position, such as *between, in front of, behind, before* and *after,* where position is in relation to other things. In everyday play and routines, **adults might** encourage children to describe position and give directions, for example, in creating obstacle courses. **The environment might include** crates, tyres, planks, canes/sticks, string and logs for children to create their own obstacle courses.

The Early Childhood Maths Group and the University of Surrey have developed a Spatial Reasoning Toolkit which includes fun and inexpensive spatial activities for children aged 0-7 years. Routine use of the Toolkit offers the potential to deliver significant benefits, including accelerating improvement in maths and science abilities. The Spatial Reasoning Toolkit covers the following key areas: spatial relations; objects and images; and use of age-appropriate language and actions (Figure 1).

Children learn different skills at different ages. Figure 2 below shows the Toolkit's trajectory of spatial reasoning development. At each stage in a child's progression they can be supported by adults helping them to learn and to use age-appropriate spatial language.

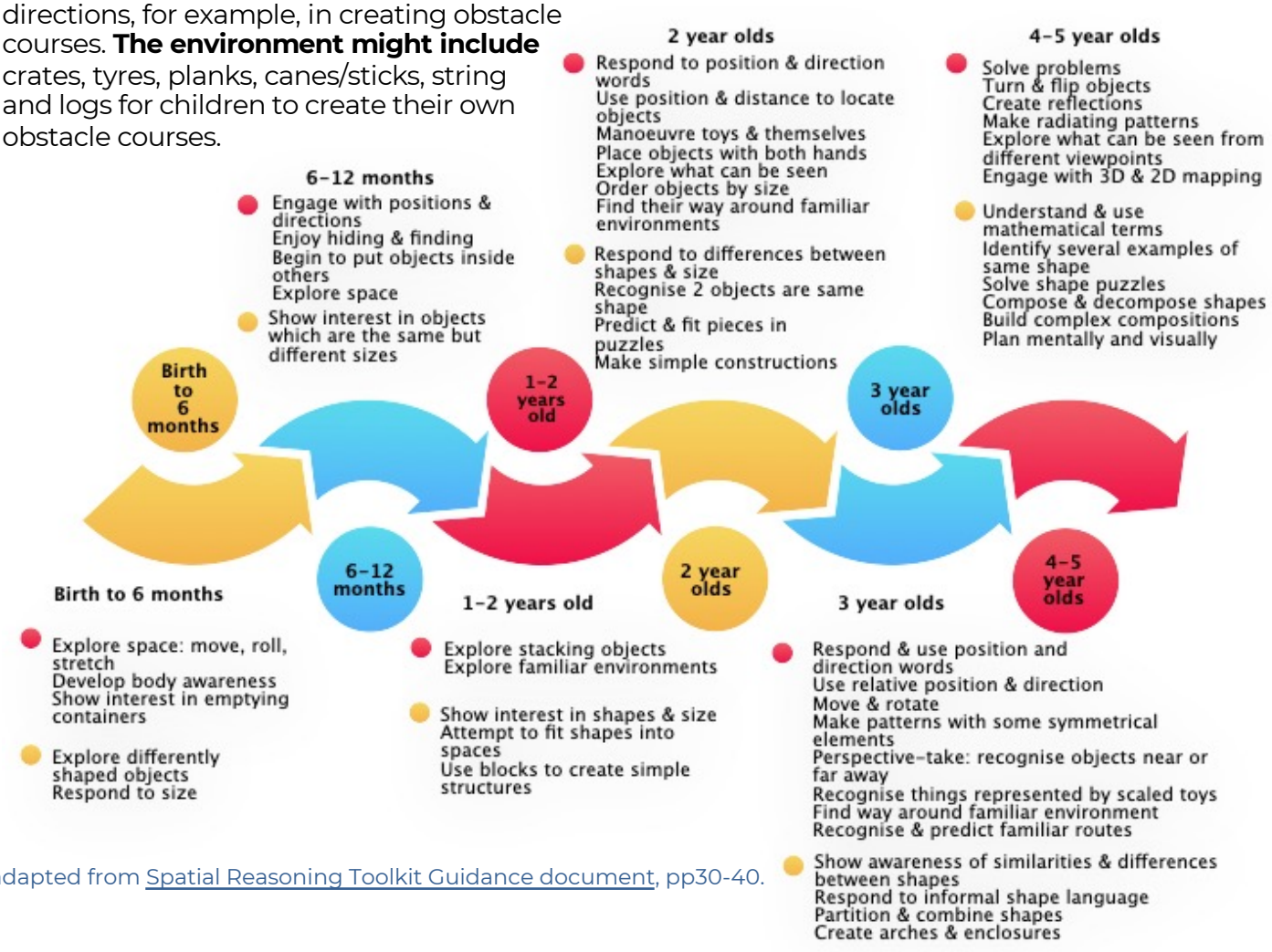

Figure 2: adapted from Spatial Reasoning Toolkit Guidance document, pp30-40.

POLICY RECOMMENDATIONS

- Integrate spatial reasoning into the learning goals of the English National Curriculum including explicit reference to spatial reasoning in the Early Years Foundation Stage statutory framework and all Key Stage national curricula, especially for mathematics. The Early Learning Goal related to "shape, space and measure" should be reinstated. [11]

- Roll out a spatialised mathematics curriculum focusing on the importance of visualisation for problem solving; spatial representation of numbers, data and relationships; and the use of spatial language and gesture. [12]

- Recognise the centrality of spatial reasoning for the current employment revolution: data is central to a broad range of occupations, and data science is becoming increasingly important. Policies on workforce development need to acknowledge and invest in the attainment of spatial reasoning skills from the youngest age. [13]

- Ensure statutory assessments do not prioritise rote retrieval and processes to the exclusion of spatial reasoning problem solving approaches. [11]

"There is robust evidence that spatial reasoning is an important foundation for the development of Mathematical and Quantitative Literacy."

Professor Emily Farran

- Highlight the importance of spatial reasoning in the Ofsted assessment framework for mathematics and STEM. Spatial reasoning should be included in the "School inspection handbook" with reference to mathematical reasoning and solving problems. [11]

- Invest in practitioners' career and professional development [11] to include Spatial Reasoning in Mathematics.

- Include spatial reasoning in the Early Career Framework (the support and development offer for teachers at the start of their career). [11]

- Fund further research, and support partnership with researchers, educators, caregivers and parents, through collective advocacy and by investing in spatial learning for babies and young children.

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11. The Value of Spatial Reasoning in the Curriculum; Recommendations for Policy Makers. Farran, Gilmore, Gilligan-Lee, December 2023
12. The Value of Spatial Reasoning in the Curriculum; Recommendations for Teachers. Farran, Gilmore, Gilligan-Lee, December 2023
13. UCL Briefing Note: Why Should we invest in Early Childhood Education and Care?, Outhwaite & Crawford, March 2023.

ABOUT THE AUTHOR

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