Title
Spatial Reasoning: The Role of Context in Learning

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Spatial Reasoning: The Role of Context in Learning

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Overview

Spatial reasoning is an inherent aspect of everyday life. For example, spatial reasoning supports young children playing with blocks, older children learning about positioning on a sports field, and adults navigating where they need to go. Spatial reasoning is also a critical aspect of STEM (science, technology, engineering, mathematics, e.g., Wai, Lubinski, & Benbow, 2009). For example, chemists imagine molecules rotating to compare structure, and physicists reason about the influence of invisible forces on magnetic fields.

As can be observed in the examples above, there are a wide range of spatial tasks. Spatial reasoning in real-world contexts can be complex and multifaceted (Atit et al., 2020). How individuals engage in spatial reasoning is highly context-specific, influenced by task demands, novelty of task, and prior knowledge (Uttal & Cohen, 2012).

Unfortunately, most of what we know about spatial reasoning is driven by psychological research using psychometric tasks designed to isolate specific spatial skills, independent of context (for review see Atit et al., 2020). Without examining variability across contexts, models of spatial reasoning are incomplete and limited in scope (Resnick & Stieff, in press).

In this symposium, we will explore different contexts in which spatial reasoning is learned. In doing so, we will raise theoretical questions around universal aspects of spatial cognition as well as practical considerations, such as how and when spatial learning should be included in education. This work is important because spatial reasoning can be learned and improved (Uttal et al., 2013), and improvements in spatial reasoning causally support improvements in STEM (e.g., Hawes et al., 2022; Sorby, 2009).

Although all four talks center on the role of context in spatial learning, the presenters are drawn from different disciplines, methodologies, and perspectives. Mary Hegarty will begin by characterizing the disconnect between psychological research in spatial reasoning and the spatial reasoning involved in complex STEM tasks. The next three talks unpack specific everyday STEM contexts where spatial reasoning is learned. Ilyse Resnick will present work in the learning sciences on shared book reading. David Uttal, a cognitive and developmental psychologist, will present on geographic information systems. Tom Lowrie, a mathematics education researcher, will present on the importance of embedded authentic tasks in spatial and STEM learning.

Thinking Spatially in STEM (Mary Hegarty)

Spatial ability is measured by psychometric tests of specific spatial processes (most commonly mental rotation) and is often correlated with STEM success. This has led some researchers to equate tasks such as mental rotation with spatial ability, at least implicitly, and to assume that training these specific tasks is a way of increasing STEM success. However, spatial thinking is much broader than the spatial abilities measures commonly in use, which were not developed to measure spatial thinking in STEM. Moreover, the assumption that training spatial tasks will necessarily improve STEM education (based on their correlation) is an example of the fallacy that correlation implies causality. Rather than basing our understanding of spatial ability on specific tests of that ability, and attempting to "teach to the tests", I will argue that to enhance spatial thinking in STEM we need to understand how people actually think spatially in STEM disciplines, and base our interventions and assessment on this understanding. I will draw from my collaborative work with organic chemists as a specific case.

Shared Book Reading (Ilyse Resnick)

There is strong and consistent evidence that females have lower spatial reasoning compared to males (see meta-analytic review Uttal et al., 2013). This male advantage emerges in

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preschool, and, importantly, can be accounted for by experience engaging in spatial activities (Verdine et al., 2017). Starting from a young age, females play less with spatial toys, such as blocks, puzzles, and mazes (Jirout & Newcombe, 2015), and hear fewer spatial words (Pruden & Levine, 2017) compared to their male peers. In this talk, I will present shared book reading as an innovative approach to providing equal access to spatial learning opportunities for preschool girls and boys. I will show that shared book reading leads to increased spatial talk and gesture for parent/child dyads compared to block play, which in turn leads to spatial learning. The presentation also considers a range of moderating factors, such as parental spatial skills and access to spatial toys at home.

Geographic Information Systems (David Uttal)

Geographic Information Systems (GIS) have transformed how people solve complex spatial problems. GIS facilitates computer mapping, allowing the user to construct representations of location data quickly. New maps can be constructed quickly, as needed, and as new data becomes available. We hypothesize that the emphasis on spatial thinking and problem solving can lead to long-term improvements in students' thinking. Our research (e.g., Cortez et al., 2022) has investigated the cognitive and neural consequences of taking a high school course (the Geospatial Semester) that emphasizes the use of GIS to solve real-world problems in engineering, geography, and other disciplines. Students were asked to solve a variety of tasks, including mental rotation, recognizing embedded figures, solving syllogisms, and conceptual problems that involved determining optimal locations (e.g., "How could we decide where to locate aa new wind farm?"). Students' performance across the academic year was compared to a group of students who had similar levels of achievement but did not enroll in the geospatial course. Results indicate that learning to use GIS can lead to improvements both in basic skills and spatially-based conceptual reasoning.

Embedded Authentic Tasks (Tom Lowrie)

A recent meta-analysis (Hawes et al., 2022) found that young children may have difficulty transferring spatial learning to mathematics. However, it may be the case that young children require more scaffolding within embedded, authentic tasks. This talk will present the findings from a large-scale, nationally representative randomized control trial, examining the efficacy of two play-based spatial learning programs designed for preschool children (Resnick & Lowrie, in press). In this study, we demonstrated that spatial learning led to improvements in both spatial and mathematics performance of preschool children. This presentation will focus on the key roles of spatial learning tools (e.g., gesture and sketching) and strong pedagogy in supporting transfer in young children. It also shows that children with lower spatial reasoning made the largest gains in numeracy, highlighting the importance of spatial learning in preschool mathematics.

Acknowledgments

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