Research Symposium

NCTM Pre-session Proposal

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Early Years Spatial Reasoning: Learning, Teaching and Research Implications

In recent years, a wealth of research and reports have been produced that, despite coming from different fields and using different frameworks, have all reached the same conclusion: all children should have access to high quality mathematics instruction and experiences in the early years—particularly in the area of spatial reasoning. These conclusions come from different perspectives: psychological, developmental, educational, as well as the neurosciences. The productive use of these different perspectives requires not only collaboration, but a new theoretical framing that has been called "new interdisciplinarity" (Thompson, 2010), which is about bringing together diverse expertise around topics of shared interest (Klein, 2010).

For this research symposium, our topic of shared interest is the teaching and learning of spatial reasoning in the early years (pre-K to 2). Our interest in this topic stems in part from the state of current practices in Canada and the United States, where the focus of early grade mathematics teaching and learning is almost exclusively on number sense. When geometry is in focus, instruction emphasizes naming and sorting shapes, and little else (Copley, 2000). The recent NCTM Focal Points attempts to redress this imbalance in its emphasis on geometry as one of the three key curriculum focal points for early years (NCTM, 2006). Indeed, as Clements and Sarama (2011) argue, geometry should be considered as the highest priority. Further, upon closer inspection, it is clear that spatial reasoning does not occur just in geometry, but permeates the entire mathematics curriculum, as Clements & Sarama (2011) make clear: "Empirical evidence indicates that spatial imagery…is highly related to (the) ability to solve mathematical problems, especially non-routine problems" (p. 134).

We have come together as an interdisciplinary research team that aims to study naturalistic learning contexts that feature spatial reasoning. Rather than isolating analysis exclusively to student learning or teacher action, we seek to integrate the specific processes of spatial reasoning that are mediated through the teaching learning relations within the material affordances of the classroom (including tasks, tools, technologies). Our diverse perspectives include: psychological assessment of early years mathematical understanding, models of collaborative in-service teacher professional learning; cognitive developmental perspectives on early mathematics learning; instructional design; teacher's role in children's collective knowledge building of mathematics; visual reasoning practices of mathematicians; development of visual practices in pre-service teachers; impact of technology on early mathematics learning; teachers' disciplinary knowledge of mathematics;

professional development for pre-service mathematics teachers; development of children's discourse through embodiment & gestural participation. We are attempting to break down the norms of isolation between the fields (psychology, education, neuroscience, mathematics, etc.) and subfields (teacher education, cognitive assessment, learning sciences, etc.) of educational research in order to gain a robust understanding of the teaching and learning contexts that develop young children's spatial awareness and reasoning. Each contributor brings unique theoretical and methodological approaches. The synergy gained through this cross-fertilization offers a new theoretical frame for how to study mathematics teaching and learning more broadly.

Our collective methodological approach follows directly from our theoretical commitment to interdisciplinarity by pursuing a deliberate selection and analysis of a shared artifact. Since spatial reasoning is a dynamic and visual process, we privileged video data as the pivot point upon which our perspectives can converge, conflict and complement. Data come from several large projects that involve teacher professional learning in collaboration with researchers to investigate young children's spatial reasoning. These videos constitute the shared experience to which we bring our expertise and from which we deepen and enrich our conceptions of teaching and learning of spatial reasoning.

The driving questions of our interdisciplinary inquiry include:

- What spatial reasoning do young children demonstrate?
- What are the processes involved in developing spatial reasoning and how do they relate to spatial sense?
- How do we develop children's existing informal understandings of shape and space?
- What are the reciprocal relationships between *possibilities for learning* (students' informal understandings, tools and technologies, tasks, teachers) and learning trajectories?
- What are the mechanisms through which teachers can recognize and foster spatial reasoning in young children?
- What ways of communicating might be characteristic of spatial reasoning, specifically around spatially and kinetically rich language, but also around gestures, body movements and diagramming?

After viewing each of three segments of video (which have been carefully selected because they reveal the multiple dimensions of the teaching and learning process for spatial reasoning), the above questions will frame the symposium discussion with and among participants.

Sampling of Findings

Given the interdisciplinary nature of our shared work, it is not possible to provide a comprehensive summary or overview of our findings in this proposal. Three key findings follow.

(1) As predicted, our analyses of video excerpts revealed that young children have an enormous capacity for spatial reasoning.

(2) We have broadened the characterization of spatial sense and reasoning with elements that have not previously been considered in the literature. For example, we identified continuity (consistent existence) and comparing (variance and invariance) as a feature of spatial sense that was revealed through a guided exploration of parallel lines with 5 year olds using dynamic geometry software. Continuity enabled children to extend visible lines on an interactive whiteboard beyond the concrete limits of the screen in order to virtually construct (though their gestures) non-visible points of intersection.

(3) As a working definition, we identify spatial reasoning as the process of resolving a spatial quandary by imaginatively inserting oneself into the situation through recursive interactions with spatial sense.

Three categories of implications will be emphasized: (1) Possibilities for improving the teaching and learning of spatial reasoning with attention to teacher moves and close observation of students; (2) Uses of spatial reasoning as a lens for analyzing learning trajectories across the spectrum of mathematics; and (3) Benefits of interdisciplinary approaches/perspectives and methods when considering how young children learn mathematics.