Educational relevance and implications of spatial development in early childhood

Spatial skills are considered core cognitive abilities that support representation and mental transformation of object features, such as shapes, sizes, and orientation and are important determinants of general cognitive development throughout childhood. Spatial skills include spatial visualization and mental rotation (i.e., the ability to represent an object and imagine its rotational movement), form perception (i.e., the ability to differentiate between different shapes and symbols), and visual-spatial working memory relevant for navigation skills (Newcombe et al., 2013). Spatial skills are closely related to several aspects of children's cognitive development, e.g., their fluid intelligence (Weber et al., 2023), their executive functions, and their vocabulary (Bower et al., 2020).

Furthermore, spatial skills play an important role for educational and professional achievement. They are seen as gatekeepers to later careers in science, technology, engineering, and mathematics (STEM) disciplines, since individuals with higher spatial skills tend to do better in the STEM fields in school and are more likely to choose a STEM field of study or work later on (Margulieux, 2019; Uttal & Cohen, 2012; Uttal et al., 2013). In fact, spatial skills seem especially important for STEM novices, making the development of spatial skills in the early years of childhood particularly relevant and potentially critical for young learners who struggle with spatial learning. This finding is crucial considering gender differences and disparities in spatial skills due to familial background (Johnson et al., 2022; Levine et al., 2005). Therefore, early interventions targeted at improving spatial skills or spatial activities are in high demand by stakeholders in the educational landscape and may have the potential to mitigate early gender and background inequalities (Herbst et al., 2022). While many studies show that spatial skills can be fostered through everyday parent-child interactions in for example shape or block play (Borriello & Liben, 2018; Ferrara et al., 2011; Hall et al., 2022; Thomson et al., 2018; Verdine et al., 2019), research on the application of these findings to early childhood education and care (ECEC) settings has been sparse. In fact, interventions and activities supporting spatial skills in early childhood remain an understudied topic regarding (a) the implementation of these interventions and activities into ECEC, (b) the efficacy and durability of the outcomes, (c) their effect on and interaction with arising inequalities (gender differences, familial background) in spatial skills, and (d) their effect on STEM outcomes. Research on these areas can lay the foundation for designing and implementing spatial activities that are cost-efficient by using materials that already exist in preschools and ensuring that teachers feel comfortable supporting the activity. At the same time, research can provide evidence that children are getting the most out of the activity, in terms of durability of the improvements in spatial skills, mitigation of disparities related to gender and familial background, and transfer effects on their STEM skills.

In more detail, this special issue will have the potential to shed light on the following topics:

(a) **Implementation**: Studies show that spatial learning can be easily integrated into everyday parent-child activities, such as block play (Borriello & Liben, 2018). However, research on the implementation of spatial learning into more formal ECEC settings, such as kindergarten and preschool, as well as into primary schools remains an understudied topic. Studies on preschool teachers' practice found that they often feel insecure about supporting children's spatial skills (Bates et al., 2023; Schmitt et al., 2023). Finding ways to support preschool teachers to implement spatial activities and the purposeful implementation of spatial activities into ECEC remains an important topic and can be addressed in this special issue on spatial skills in young children.

(b) **Durability**: To study the durability of spatial outcomes after activities and interventions, this special issue invites longitudinal intervention studies that stretch multiple weeks to months. Several studies on spatial learning in young children employed pre-post-test designs or studied spatial learning as spatial language evoked during a video-recorded (play) session (e.g., Borriello & Liben, 2018; Bower et al., 2022; Ferrara et al., 2011). They are an excellent starting point for studying the obtained results on spatial activities and interventions in longitudinal designs.

(c) **Inequalities**: Spatial activities and interventions in ECEC take on a social equality component as well, considering that research suggests that children from low income families are in danger of falling behind on their spatial learning (Johnson et al., 2022). Moreover, there is ample research on gender differences in favour of males in spatial skills across age groups (Geiser et al., 2008; Johnson et al., 2022; Lauer et al., 2019) with substantial implications for later career paths. Johnson et al. (2022) and Margulieux (2019) even suggest that gender differences in STEM might have their origin in differences in family income as well as gender differences in spatial skills, thus highlighting the relevance of spatial skills as a potential source of later disparities. Since family background and gender differences in spatial skills as well as in careers in the STEM fields are continuously reported, engaging children in spatial activities and fostering their interest in the STEM fields before formal schooling is of particular importance (Quinn & Liben, 2008, 2014; Weber et al., 2023). This special issue invites papers concerned with fostering STEM understanding through spatial problem solving. This approach might be especially suitable for young children and other STEM novices, since improving spatial problem solving involves concrete objects rather than abstract concepts and mathematical formulas that STEM activities for older children and adults often entail (Angeli et al., 2016). Spatial interventions or activities can be a mean of fostering STEM success.

(d) **STEM**: Regarding the association of STEM and early spatial skills, most studies have focused on mathematics, relating young children's spatial skills to their later mathematical skills and achievement (Bower et al., 2020; Johnson et al., 2022; Möhring et al., 2021). These studies found that spatial skills predict mathematical achievement in young children. However, research on the interplay of early spatial skills and other disciplines in STEM such as science, technology, and engineering is widely missing. Moreover, investigating *which* spatial skills are especially important for different STEM topics, such as shape learning in mathematics, or understanding stability in physics, could advance the development and investigation of ECEC curricular and spatial activities in early childhood. Research examining the association of early spatial skills with STEM, either in relation to specific aspects or broader STEM topics, are called for in this special issue.

Early spatial learning has a societal impact and in consequence, this special issue has the potential to increase our understanding of the way spatial activities can be integrated into ECEC, ensure that they have profound and lasting effects, relate to STEM learning, and can alleviate later inequalities in the STEM fields.

Consequently, this special issue is inviting contributions from research along the following lines:

· Implementation of spatial interventions or activities into ECEC and primary school classrooms as well as in out-of-classroom settings (e.g., in museums).

· Early childhood and early primary school teachers' views and potential struggles with implementing spatial interventions or activities and ways to support teachers.

· Longitudinal studies on the durability of spatial interventions or activities.

· Interventions that specifically address sources of inequality in spatial learning, or specifically target disadvantaged groups.

· Ways to foster STEM understanding through spatial problem solving.

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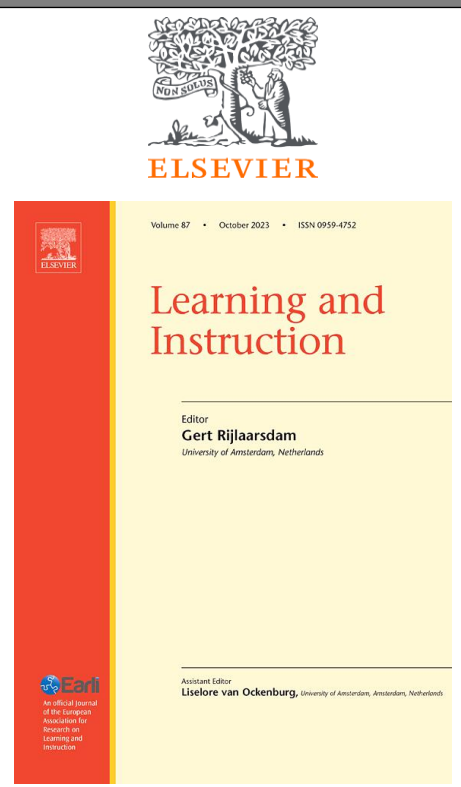

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