Refine and Evaluate a Pedagogical STEM Toolkit for Young Children's Spatial Reasoning: A Design Experiment

Spatial skills instruction is absent from most early education classrooms (Pritulsky et al., 2020), especially in Hong Kong. This hinders children's subsequent learning processes and outcomes, particularly in science, technology, engineering, and mathematics (STEM). Spatial reasoning involves active learning to allow children to interpret images, create representations, and manipulate objects to improve their STEM performance. Inadequate curriculum, teacher preparation, and learning materials contribute to the limited spatial learning opportunities in kindergartens. This project aims to address this gap by focusing on spatial reasoning as a critical facet of spatial learning for children.

Specifically, this mixed-methods project will follow the iterative cycle of design experiments aiming at refining and evaluating the effectiveness of a pedagogical STEM toolkit (P-STEM toolkit) in enhancing kindergarten children's spatial reasoning skills. Grounded in constructivist and social constructivist learning theories, the Experience-Language-Pictorial-Symbolic-Application (ELPSA) pedagogical framework (Lowrie et al., 2018) provides a logical structure for developing spatial reasoning skills, integrating pedagogical approaches and a P-STEM toolkit (built upon the PI's pilot study, ***Hu**, 2021). We will use a two-phase design experiment to complete refinement and rigorous testing. In the first phase, we will collaboratively work with two kindergartens to improve our current PSTEM toolkit for children and test 40 children across two classes. In the second phase, we will approximate a controlled experiment via *statistical matching* for large-scale testing. 162 children aged 5-6 years from eight kindergartens in Hong Kong, and 16 teachers will participate in this phase. Eight participating classes will be randomly assigned to either the experimental group (using the P-STEM toolkit) or the control group (traditional instruction). We will evaluate all the participants' spatial reasoning skills with the validated Children's Mental Transformation Task (CMTT) before and after the intervention. To test the effect of using the P-STEM toolkit, we will analyse the data with a *difference-in-differences structural equation model*. Concurrent qualitative data consisting of classroom videos and teacher interviews will be collected. It will provide a comprehensive understanding of the implementation process and outcomes of improving spatial reasoning skills for children via *statistical discourse analysis*.

The project findings will provide research-based knowledge through implementing the P-STEM toolkit, which teachers can use to integrate spatial reasoning skills effectively. More importantly, the project will build a conceptual framework to bridge the gap between theoretical knowledge and spatial reasoning skills across the kindergarten curriculum. The results will inform curriculum revisions to enhance kindergarteners' development of spatial reasoning skills.