Symposium: Embodied Learning in Early Mathematics

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In this symposium we present some of the findings from Phase 1 of a three-phase project (2021-2024) titled *Embodied Learning in Early Mathematics and Science* (ELEMS). The project aims to translate embodied cognition research from the fields of neuroscience, psychology and education into evidence-based classroom teaching strategies, and to produce professional learning materials for teachers. The overall research design for the project is a three-phase structure, guided by design-based research principles and utilising mixed methods of data collection and analysis (Refer to Way & Ginns, 2022 for a project rationale). The underlying premise for the project is that the haptic modes (gesture, touch-tracing, body-movement and drawing) of embodied learning are under-utilised for mathematical representation, and as thinking and communicating tools in the development of mathematical understanding.

Phase 1 of the project involved a year-long collaboration with seven teachers in one NSW school, and their classes of Preschool to Year 2 children. The school has 340 students, with an additional 38 students in an attached preschool. The students come from a diverse range of cultures and 78% of students are from Non-English-Speaking Backgrounds (NESB). The researchers supported the teachers in their explorations of interpreting the research-based key ideas about embodied learning provided by the researchers, into teaching-learning activities for their students. Each of the three papers in this symposium reports a specific aspect selected from the broad range of research outcomes.

Paper 1: Connecting Mathematical Processes and Conceptual Body Movement—Katherin Cartwright & Jennifer Way

Paper 2: Finger Tracing, Noticing Structures and Drawing—Jennifer Way & Katherin Cartwright

Paper 3: Changes in Year 2 Children's Drawings of a Subtraction Story—Jennifer Way & Katherin Cartwright

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The University of Sydney research team: Dr Jennifer Way (Mathematics), Dr Paul Ginns (Educational Psychology), Dr Christine Preston (Science), Dr Amanda Niland (Early Childhood), Dr Jonnell Upton (TESOL), Dr Katherin Cartwright (Mathematics).

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(2023). In B. Reid-O'Connor, E. Prieto-Rodriguez, K. Holmes, & A. Hughes (Eds.), *Weaving mathematics education research from all perspectives. Symposium in the proceedings of the 45th annual conference of the Mathematics Education Research Group of Australasia* (pp. 57–69). Newcastle: MERGA.

Finger Tracing, Noticing Structures and Drawing

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This paper presents an initial analysis of 10 Preschool children's responses to a look-draw-trace-draw task. The findings suggest that figure-tracing helped half the children to produce a more accurate representation of the geometric figure presented to them, in their second drawing.

The development of children's mathematical drawing capabilities is largely determined by developmental factors that span several years. Natural development of drawing abilities from playful scribble to realistic representations of imaginings and external objects takes time (Machón, 2013), and is linked with both cognitive and motor factors. Hand-motor control is a crucial component of drawing skill and develops over time in young children (Cohen, Bravi, & Minciacchi, 2021). Cognitive flexibility and associated drawing flexibility (ability to adapt and change familiar figurative schemas) increases over time and with age (Ebersbach, & Hagedorn, 2011). To be able to enhance mathematical drawing of children, particularly those developing at slower rates than expected, teachers need strategies that produce positive outcomes in a shorter timeframe.

In mathematics education, children might be asked to use drawing as a representation of their thinking (an external representation of an internal representation), or to produce a record of tangible objects (external representation of an external representation). Representing a visible, external model through drawing is a different task to drawing an object from an internal image or graphic schema. To reproduce the appearance of an object, say a geometric figure (e.g., a 2D shape), the child needs to give attention to, or notice, the key characteristics of the figure. Therefore, strategies that help the child focus their attention and raise their awareness of task demands are likely enhance the child's drawing performance (Morra, 2005; Sutton & Rose, 1998). This line of thinking suggests that increasing children's 'noticing' might have an immediate effect on children's drawing reproduction accuracy, if other developmental factors are sufficiently advanced. Pointing and finger tracing techniques have been shown to increase performance in particular mathematical tasks in older children (E.g., Hu, Ginns & Bobis, 2015) and may assist children to attend to spatial or structural features of a figure. While pencil-tracing might also be helpful, finger-tracing evokes the genetically driven visual-attention response to pointing (Hu, Ginns & Bobis, 2015), and contact with the surface activates the sense of touch and hence a different part of the brain to 'looking' only.

For this paper we pose the question, what changes in the preschool children's drawings occur after finger-tracing a figure?

Method

Context and Participants

This study was imbedded within the Embodied Learning in Early Mathematics and Science (ELEMS) project which involved Preschool to Year 2 teachers and their classes in one school. Although data for this tracing-drawing study was collected from all four cohorts, only the preschool data has been tentatively analysed at this point. The 10 Preschool children (approx. 4 ½ years) with parental permission to participate are the focus of this paper.

Procedure

a) In an individual task-based interview, the child was shown a geometric figure (see Figure 1) and invited to look carefully then draw what they saw. As soon as the child began drawing, the card was turned facedown so the figure was hidden.

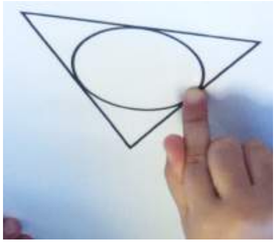


Figure 1. Child finger-tracing the geometric figure.

b) When the drawing was completed, the figure was again placed in front of the child and the interviewer asked them to trace around the shapes with their finger. To ensure the child understood the instruction, the interviewer demonstrated by pointing to the top left corner of the triangle and touch-tracing across the top of the triangle, around the corner (clockwise direction), then invited the child to trace it themselves. If the child did not automatically also trace around the circle, they were prompted to do so, again beginning the trace at the top and moving clockwise.

c) The child was then invited to draw the figure again, on a new sheet of paper, and the figure was again hidden from view.

Analysis was exploratory and open-ended and used several approaches to examine both the product (finished drawings) and process (video of drawing actions). The pairs of drawings for each child were compared for changes and annotated with arrows and numbers to indicate the drawing process. Observation notes were added to capture some key changes, features, or additional information from the videos. The pairs of drawings were grouped according to the magnitude of change between Drawings 1 and 2.

Findings

The drawings were idiosyncratic, both in process and product, with few patterns identifiable in the small sample. Some observations are:

- Half the pairs of drawings show a definite change in structure and detail in the second drawing (See Figure 2). A notable change for P107 is from drawing two separate shapes to one shape enclosed inside another. Another significant change is from a single stroke to a closed shape (P116).
- Three pairs of drawings showed minimal changes, but the first drawings were already well formed. Small changes were a slightly larger circle or slightly 'pointier' triangle corners. (See Figure 3).
- Two children produced highly idiosyncratic pairs of drawings that were very different the drawings of the other children (See Figure 4).
- All children drew a closed shape (P116 only after tracing), and most were recognisable as a triangle. Most drew a recognisable circle inside.
- No child succeeded in drawing a circle that touched all three sides of the triangle, though P103 tried to make such an adjustment in her second drawing.
- All children except P112 drew the outer shape (triangle) first using a continuous line.
- The starting point and direction of drawing varied. Although some children changed this in the second drawing, it did not seem to be influenced by the tracing sequence modelled by the interviewer.
- Two children persisted with drawing the triangle upside-down relative to the figure presented to them (P213, P109).

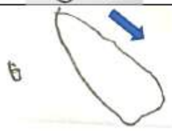
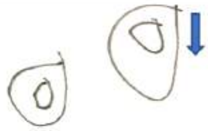
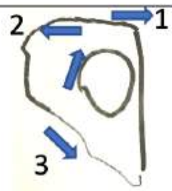
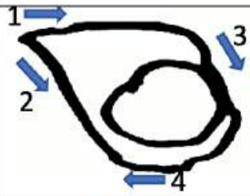
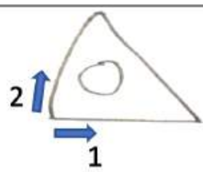
Student code	Look then draw. Drawing 1	After finger trace Drawing 2	Notes
P103			Explained scribble by saying, "I wanted it to touch".
P107			From two separate shapes to one shape enclosed by another. Continued to fill the page with the same figure,
P110			Awkward pen grip. Very slowly drew separate pieces. Orientation unclear. Inner circle enlarged.
P116			Poor pen grip. Needed coaching to trace all around. From a single stroke to a closed shape
P213			Immediately said, "It's like a triangle with a circle", but drew 4-sided shape. Changed from 4 sides to 3 sides. Incorrect orientation of triangle.

Figure 2: Before and after drawings that show change.

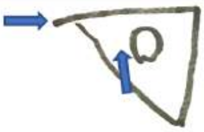
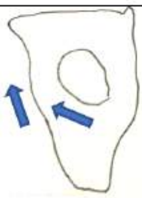
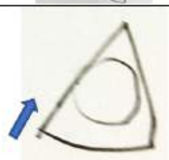
Student code	Look then draw. Drawing 1	After finger trace Drawing 2	Notes
P104			Minimal change
P108			Started in middle of left side. Drew quickly. Lack of straight lines. Change to sharper corners.
P109			Maintained incorrect orientation of triangle. Circle larger.

Figure 3. Before and after drawings with minimal change.

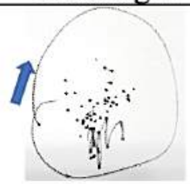
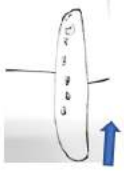
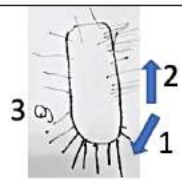
Student code	Look then draw. Drawing 1	After finger trace Drawing 2	Notes
P112			Drew circle first, then enclosed with 'triangle'. Needed prompting to trace circle, but did so anticlockwise. Quickly drew a large circle then giggled
P113			Could not follow sides of triangle all the way around when tracing. Drew large shape, then small 'curl' outside, then added strokes.

Figure 4. Highly idiosyncratic drawings.

Discussion and Conclusion

With the limitations of this small exploratory study in mind, we offer some speculative interpretations of the findings. One explanation for the minimal-change in drawings (Figure 4) is that these children held stable mental images of triangles and circles and the task evoked existing schema (Ebersbach, & Hagedorn, 2011) useful for drawing the composite figure. P110 and P116 (Figure 3) struggled with a lack of fluidity in hand movement but the role this played in how they responded to the tracing experience is unclear (Cohen, Bravi, & Minciacchi, 2021). Both P107 and P116 exhibited a remarkable change in geometric structure, in a topological sense, by moving from separate shapes to enclosed shapes, and a single line to a closed shape respectively. It seems likely that the act of tracing stimulated this change somehow. The odd second drawing produced by P112 can be accounted for as playfulness. P113 produced drawings that are classic examples of the drawing stage of exploring combinations of forms, typical around age 3 years (Machón, 2013), which suggests the child was not ready for the type of drawing task used in this study.

In conclusion, the 'self-correction' of drawings by half the children suggests that the finger-tracing may have supported these children's noticing of the structure of the figure presented to them. The preliminary findings from this small sample provide encouragement for continuing the exploratory analysis with the data from the 5- to 8-year-olds and refining the analysis techniques in preparation for further studies, in which the role of memory in 'hidden figure' tasks should be considered.

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