Symposium: Embodied Learning in Early Mathematics

Co-chair: Jennifer Way
University of Sydney
jennifer.way@sydney.edu.au

Co-chair: Katherin Cartwright
University of Sydney
katherin.cartwright@sydney.edu.au

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

Acknowledgements

The ELEMS project is funded by the NSW Department of Education, Strategic Research Fund (2021-2024).

We acknowledge the collaboration of the leadership team and teachers of the Phase 1 research school.

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).

References

Way, J., & Ginns. P. (2022). A call for translational research in embodied learning in early mathematics and science education: The ELEMS project. In N. Fitzallen, C. Murphy, V. Hatisaru, & N. Maher (Eds.), *Mathematical confluences and journeys. Symposium in the proceedings of the 44th annual conference of the Mathematics Education Research Group of Australasia* (pp. 538–545). Launceston: MERGA.

(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.

Changes in Year 2 Children's Drawings of a Subtraction Story

Jennifer Way
University of Sydney
jennifer.way@sydney.edu.au

Katherin Cartwright
University of Sydney
katherin.cartwright@sydney.edu.au

There is an educational expectation that children's natural drawing will develop into proficient mathematical representations and formal diagrams, yet there is little research available to guide the assessment and development of children's mathematical drawing skills. The aim of this paper is to explore how Year 2 children (approx. 7 years) chose to represent their interpretations of a simple story that is suggestive of the take-away subtraction process, and what changes occurred when the drawing task was repeated 6 months later. Analysis of 13 pairs of drawings revealed changes in what the children drew (categories of number representations) and how they drew it (style). The findings suggest that substantial change in children's representational ability can occur in within 6 months.

Children's representational competence in drawing has been linked with cognitive maturity and flexibility (Brooks, 2009), particularly regarding mathematical development. Children's drawing is also a source of evidence for internal "processes of notational competence and representational change" (Karmiloff-Smith, 1990, p. 58). Although drawing is a naturally developing ability in young children (Brooks, 1990) it can also be influenced by environmental factors including adult interactions (Malanchini et. al., 2016), making drawing development pertinent to teaching practice. Indeed, supporting children's development of drawing schemas, particularly dynamic schematisation (depicting movement and change) can enhance both drawing skill and mathematics comprehension (Poland & van Oers, 2007).

In the context of the Embodied Learning in Early Mathematics and Science project, the Pre-school to Year 2 teachers at one school explored supporting the development of children's drawing through increasing the opportunities for children to draw, discuss their drawings and experience some teacher-modelling of ways of drawing mathematical objects and processes. Pre-school to Year 2 students completed the 'Birds drawing task' in May 2022 (Time 1) as part of a larger assessment of drawing development requested by the teachers. In December 2022 (Time 2), an opportunity arose to repeat the drawing task with participating students. The 'Birds drawing task' is a very brief story used as a provocation to draw (Way, 2018), which is suggestive of a subtraction process.

This paper is focused by the questions: How do Year 2 children represent through drawing, the subtraction process implied by a simple 'take-away' story? and What changes in drawings are evident after 6 months?

Procedure

The task instructions for the 'Birds drawing task' were delivered verbally to the group of children.

> Say: 'Listen to this little story. Then I'm going to ask you to draw what happened.'
> 'Five birds sat in a row along the top of a fence. Two birds flew away.'
> Repeat the story, then ask them to, 'Draw what happened in the story'.

Only the data from Year 2 students is used in this paper, as an initial development of the analysis technique. In one of the Year 2 classes, 13 students were present for both Time 1 and Time 2 of the drawing task, and these 26 drawings are the subject of this paper.

The modelling of the 'take-away' subtraction process can be described as a sequence of three steps: 1. Represent the original quantity in a group, 2. Separate or 'take-away' the relevant number items, 3. Determine the number of items remaining. Steps 1 and 2 are dynamic—requiring movement of some type. Step 3 implies some form of acknowledgement of the result of the process.

Two approaches were used in the analysis of the drawings. The first approach involved sorting the Time 1 drawings into categories according to whether they depicted one, two or three steps in the subtraction process, or no steps. The process was repeated for the Time 2 drawings. The second approach involved comparing the two drawings produced by each student and examining the nature of changes in the style of the drawing.

Findings

The Drawing Categories

The categories are presented in order of the completeness of the depiction of the subtraction process, ranging from non-depiction of any step in the subtraction process, to depiction of all three steps.

Category 1 non-depiction. The drawing does not depict any recognisable numerical information from the 'story', nor suggest any part of the subtraction process (Figure 1).

Multiple items that do not match any of the group quantities. (2C01-Time 1)

Figure 1. Example of non-depiction.

Category 2 one step. One step of the 3-step process of take-away subtraction is drawn: the 5 original birds, or the 2 that flew away, or the 3 that remained, with sub-categories identified based on the specific number of birds depicted (Figure 2)

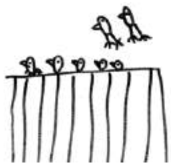
Group of 2 (2C13–Time 1)

Group of 3 (2C20-Time 1)

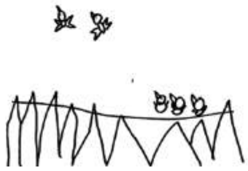
Figure 2. Examples for each sub-category of one step drawings.

Category 3 two steps. Two of three steps are drawn depiction either 5 birds and the 2 that flew away (total of 7 birds), or the group 5 birds is partitioned into groups of 3 and 2. The partitioning is typically represented by separation of the subgroups by distance but may involve crossing out of 2 birds or arrows/lines indicting movement away (Figure 3).

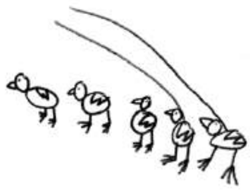
Category 4 three steps. Some drawings included a strategy for focusing on the remaining 3 birds, as well as depicting the original group of 5, and the 'taking away' of 2 birds, even though the 'story' did not mention the remaining group of three, nor ask for 'how many left?'. Three-step drawings complete the operation of take-away subtraction and could be construed as also representing the equation 5 - 2 = 3 (Figure 4).



5 birds and the 2 that flew away (2C03-Time 2)



5 birds 'partitioned' into 3 and 2 (by distance) (2C21-Time 2)



5 birds 'partitioned' into 3 and 2 (by 'arrows') (2C05)

Figure 3. Examples of two steps drawings.

"Now there is three birds"
Use of words to represent the third step
(2C04-Time 1)

A 3-part story board: 5 birds, flying away, 3 left (2C15-Time 2)

Figure 4. Examples of strategies for depicting the three steps.

Changes in Category and Style

No child drew the same drawing both times with changes in style and/or changes in the parts of the subtraction process they chose to depict (category change). Table 1 shows the distribution of students' drawings across the categories. Examining the table to match the student codes in the Time 1 and Time 2 columns reveals changes in categories by individual students. Most drawings from both Time 1 and Time 2 depicted the two steps in the story, and hence two steps in the subtraction process.

Table 1

Distribution of Students' Drawings Across the Categories, for Time 1 and Time 2

Approach Category	Sub-Category	Time 1 Drawings—May (Student codes) N=13	Time 2 Drawings—December (Student codes) N=13
Non-depiction		2C01*	
1 step	5 birds	2C14*	2C14
	2 birds	2C13	
	3 birds	2C10 2C20	
2 steps	5 and 2 (total 7)	2C05 2C06* 2C15	2C03 2C06* 2C04
	3 and 2 (partition)	2C08* 2C17 2C21*	2C01 2C08 2C13 2C20 2C05 2C10 2C17 2C21
3 steps	5 - 2 = 3	2C03 2C04	2C15

*Signifies an incorrect number of items drawn (e.g., 6 birds rather than 5).

A noticeable shift in distribution in Time 2 is towards 2-step drawings that show the partitioning of the group of 5 into subgroups of 3 and 2, rather than representing two quantities specified in the story (5 and 2), or only one of the groups from the story.

Only three students did not substantially change their style of drawing. About half the students produced changes in both category and style (For example, Figures 5 & 6).

Most changes in style involved a more mature representation of the birds, showing some distinctive characteristics such as body shape, as can be seen in Figure 5. The most striking change in style was produced by student 2C01 (Figure 6) with a change from a drawing lacking any features of the story, to a drawing that shows five birds (circles) with two crossed out.

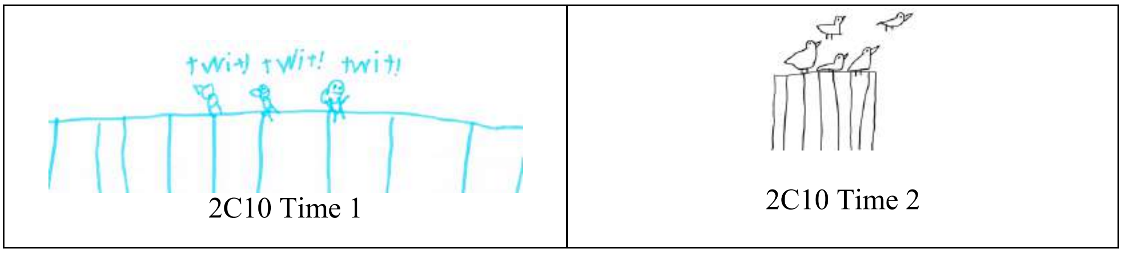


Figure 5. Example of change in both style and category.

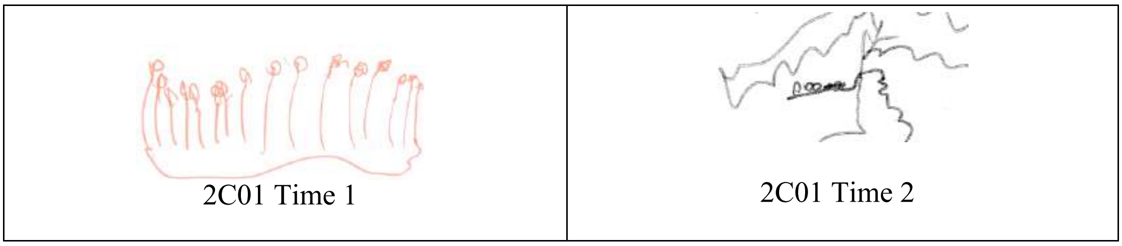


Figure 6. Example of change in both style and category.

Discussion and Conclusion

It is important to note that the story-task was not intended as an assessment of the children's knowledge of subtraction, but rather and an opportunity to study how they responded. Using the categories related to the steps in the take-way process revealed that, in 6 months, the children had an increased tendency to mathematise the story and represent the partitioning of a group of five into groups of two and three. Comparing the pairs of drawings showed a shift in representational maturity. These findings contrast with the relative stability in 'human figure' drawing over 6 months found by Malanchini et.al (2016). Although no direct claim can be made about the role played by the ELEMS project teachers' increased attention to drawing development, the results do illustrate that substantial development in mathematical drawing skill can occur within 6 months. The analysis procedure will now be applied to the full collection of Preschool to Year 2 drawings to explore age-related patterns and other relationships between Time 1 and Time 2. Further research is needed to develop drawing tasks and interpretation guidelines that teachers can use to monitor their students' drawing development and support development of mathematical drawing ability.

References

Brooks, M. (2009). Drawing, visualisation and young children's exploration of "big ideas." *International Journal of Science Education, 31*(3), 319–341. DOI:10.1080/09500690802595771

Karmiloff-Smith, A. (1990). Constraints on representational change: Evidence from children's drawings. *Cognition, 34*, 57–83.

Malanchini et.al. (2016). Preschool drawing and school mathematics: The nature of the association. *Child Development 87*(3), 929–943. DOI: 10.1111/cdev.12520

Poland, M. M., & van Oers, B. (2007). Effects of schematizing on mathematical development. *European Early Childhood Education Research Journal, 15*(2), 269–293. DOI: 10.1080/13502930701321600

Way, J. (2018). Two birds flew away: The 'jumble' of drawing skills for representing subtraction pre-school to Year 1. In Hunter, J., Perger, P., & Darragh, L. (Eds.), *Making waves, opening spaces. Proceedings of the 41st annual conference of the Mathematics Education Research Group of Australasia* (pp. 98–101). MERGA.