



HAL
open science

A collective approach to embodied learning in early years mathematics (ELEMS Phase 1)

Jennifer Way, Katherin Cartwright, Paul Ginns

► **To cite this version:**

Jennifer Way, Katherin Cartwright, Paul Ginns. A collective approach to embodied learning in early years mathematics (ELEMS Phase 1). Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13), Alfréd Rényi Institute of Mathematics; Eötvös Loránd University of Budapest, Jul 2023, Budapest, Hungary. hal-04420789

HAL Id: hal-04420789

<https://hal.science/hal-04420789v1>

Submitted on 26 Jan 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A collective approach to embodied learning in early years mathematics (ELEMS Phase 1)

Jennifer Way¹, Katherin Cartwright¹ and Paul Ginns¹

¹University of Sydney, Sydney School of Education and Social Work, Australia

jennifer.way@sydney.edu.au

The aim of this paper is to illustrate how collaboration between researchers and teachers in naturalistic classroom settings can translate previous research findings on embodied learning into mathematics curriculum-connected pedagogy to enhance children's learning and cater for diversity in learning needs. The paper presents a brief overview of a three-phase design-based research and development project in Australia but focuses on the 'collective approach' that evolved during Phase 1 across 2022. Three scenarios are used to illustrate the collective approach and present three associated translative outcomes.

Keywords: Embodied learning, early years, mathematics.

Introduction

A substantial body of studies with children has established that learning can be enhanced through the purposeful use of embodied approaches such as gesture, pointing, tracing, body movement and drawing. Children's mathematics learning can be supported by observing various types of teachers' gestures, but children also learn through their own spontaneous or prompted gesturing. (E.g., Goldin-Meadow, 2015; Martinez-Lincoln et al., 2018). There is also evidence that conceptual body-movement by learners reflects the dynamic nature of mathematical and scientific phenomena and can enhance learning. (E.g., Dackermann et al., 2017). Similarly, attending to the development of children's mathematical and scientific drawing can enhance their learning and increase achievement. (E.g., Poland & van Oers, 2007; Thom & McGarvey, 2015). However, much of the published research has been experimental in nature and appears in research journals in formats not readily accessible to teachers. A growing number of classroom-based studies have produced valuable insights into potential impacts on student engagement and learning, but these studies have tended to be narrowly focused and have typically been researcher-directed enquiries.

With the accumulation of research findings now pointing towards the learning benefits of embodied learning approaches in education, a foundation exists for translational research projects to transform the findings into pedagogical knowledge and practice (Way & Ginns, 2022). To our knowledge, no studies have worked collaboratively with teachers to produce a broad set of teacher-friendly embodied learning principles supported by evidence of children's progress towards achieving a range of learning outcomes in mathematics and science in the early years of schooling.

Project overview

The *Embodied Learning in Early Mathematics and Science* (ELEMS) project (2021-2024) has been designed as a step towards addressing the current lack of translational research. The aim of the project is to develop an evidence-based, curriculum-linked, classroom-ready professional learning resource

for teachers that empowers them to implement pedagogy that uses a child's full repertoire of representational modes - emphasising the under-utilised haptic and drawing modes.

Design-based research provides the ideal methodological framework for the whole project, with its emphasis on improving learning outcomes through authentic collaboration with practising teachers, and the dual goals of theory building and practical products (Reimann, 2010). The iterative nature of design-based research supports a three-phase project structure, with each phase informing the next, over three years.

- Phase 1, 2022: *Exploring*: Collaborative exploration of proposed embodied teaching/learning approaches derived from previous research.
- Phase 2, 2023: *Testing*: A mixed-methods study featuring a year-long quasi-experimental design to test student learning outcomes from experiencing embodiment-rich pedagogy.
- Phase 3, 2024: *Upscaling*: Refinement and online delivery of a professional learning package.

Theoretical and conceptual perspective

Our theoretical stance for the project is a representational view of mathematics (and science) knowledge and learning. This view is concerned with the development of each child's 'cognitive architecture' or sets of interrelated *internal* representational systems, such as language, imagery, symbols and touch/kinaesthetic, and is focused on the interplay between internal and external representations in teaching practice (Goldin, 1998). We place particular emphasis on the touch/kinaesthetic representational system and draw on embodied cognition theory to elaborate the learning experiences of children 4 to 8 years and the relationship between internal and external representation. We interpret 'embodied cognition' broadly to capture the processes of communicating, thinking, and knowing that rely to some extent on one or more modes of embodiment (Kersting et al., 2021), and include movement of the body itself and the interactions between the body and the external environment (Hutto et al., 2015). We prefer to use the term 'embodied learning' to better reflect the learning intention behind applying embodied approaches in educational settings. Embodied learning in mathematics places emphasis on representation through embodied modes including gesture, pointing, touching, tracing, and larger body movements. The close relationship between drawing and gesture warrants the inclusion of the action of drawing in investigations of embodied learning (de Freitas & Sinclair, 2012). The active engagement with a variety of movements assists the child to notice and attend to the essential properties, structures and relationships of the mathematical and scientific ideas, beyond what 'looking', 'talking' and retrieving mental images can achieve alone (Alibali & Nathan, 2012; Ginns, Hu, Byrne, & Bobis, 2016).

From the synthesis of previous embodied learning research relevant to the mathematics (and science) learning of children aged approximately 4 to 8 years, we derived a set of 13 key ideas to inform teaching practice to use as a basis for our work with teachers. Several of these key ideas are stated in the Illustrative Scenarios section of this paper.

Phase 1 Methods

The project team includes researchers with expertise in mathematics education, science education, educational psychology, early childhood education and learning English as a second language and

cultural diversity in education, together with teacher volunteers at one school during Phase 1. Complementary Accounts methodology (Clarke, 2001) was used to guide the design of Phase 1 of the project. Complementary Accounts creates rich integrated sets of data, includes the reflective voices of the teacher (and sometimes the students), and utilises the complementary yet diverse areas of expertise of the research team to increase the reliability of interpretations. Central to the research design is the establishment of a genuine collaboration between the researchers and the teachers.

Collective approach

Two main strategies were employed to establish mutual respect and open the flow of communication between the research team and the teachers.

- a) The scheduled professional learning sessions were exchanges of information and ideas between the researchers and the teachers (Olin, Almqvist & Hamza, 2021). These sessions were always a combination of input of new information from the researchers (often in response to teachers interests and expressed needs) and sharing/reflecting sessions of scenarios (including film clips) from the teachers' classrooms.
- b) At least one of the research team was present in the school every week to observe, answer questions, discuss lesson ideas, collect data, and sometimes team-teach. This level of presence and support was considered important because the teachers were asked to explore how the key ideas from the research could be applied in their classrooms rather than provided with pre-prepared activities to implement (Fleet, De Gioia & Patterson, 2016).

The school and participants

The primary school of 340 students is in an outer suburb of a major city in Australia. An additional 38 children attend the attached preschool. Aboriginal and Torres Strait Islander students make up 7% of the student population, 82% of students have a language background other than English with Arabic, Samoan and Vietnamese making up the largest language groups. A significant number of students come from low socio-economic backgrounds. Seven Preschool to Year 2 teachers participated in Phase 1 of the project. While all students in their classes experienced the lessons, data were only directly collected from students with parental permission to be study participants (N=102).

Data sources and analysis

Multiple data sources were used to address our broad aim of exploring how the key ideas derived from research can be integrated into daily teaching practice, and to address multiple sub-questions designed by team members. In summary, data were collected at three levels:

- a) Child level – in-class observations of focus-children (including informal conversations, video, photos, work samples); several individual task-based interviews of 102 participants.
- b) Class level – lesson observations, video, artefacts (e.g., drawings).
- c) Teacher level – pre & post questionnaires & semi-structured interviews, online journals entries in *Seesaw*, photos/videos of lesson moments and episodes, researcher field notes.

The exploratory nature of the research necessitated responsive and flexible methods of working with the data. Continuous preliminary analysis was conducted to allow timely feedback to both teachers

and researchers, to feed reflection and planning cycles. The dominant approach to analysis was driven by inductive methods including open-ended sorting and coding to search for categories or themes and involved at least two researchers to increase reliability. Emerging interpretations of the data were discussed at multidisciplinary team meetings. Deeper and more detailed analysis of various aspects and combinations of data is still in progress using more rigorous techniques. However, the purpose of this paper is not to present specific findings from particular data sets, but rather to focus on the productivity of the ‘collective approach’ to translational research.

Illustrative Scenarios

In line with the aim of the paper, this section presents three sequences of events (scenarios) to illustrate how collaboration between researchers and teachers in naturalistic classroom settings can translate previous research findings into pedagogy to cater for diverse learning needs. The scenarios were purposefully selected to meet the following criteria: a) a variety of the research-based key ideas are covered and hence a range of embodied modes, b) the sequence demonstrates the growth of an embodied-learning teaching strategy over time, c) the productive exchange between researchers and teachers is crucial, d) at least one unexpected outcome is included, e) the sequence resulted in an inclusion of embodied learning activity in the Phase 2 Teaching Guide.

Scenario 1 – Finger tracing and drawing

a) In the first round of ‘baseline’ classroom observations the researchers noticed some 5-year-olds struggling with writing numerals on mini-whiteboards. One child was observed making a tracing motion over a numeral on a wall chart then attempting to write the numeral himself. This observation was mentioned at the first professional learning session with the teachers, in relation to the key idea: *Using the index finger to ‘touch-point’ or trace graphics can enhance learning.*

b) The teachers were encouraged to post photos and brief reports of what they had been trying in their classrooms using the online platform *Seesaw* to which researchers responded in various ways. One teacher posted an item (Figure 1), connecting finger-tracing with the development of fine-motor skills and the promotion of drawing development – thereby connecting another key idea: *Other modes of embodied learning are inter-connected with drawing.*

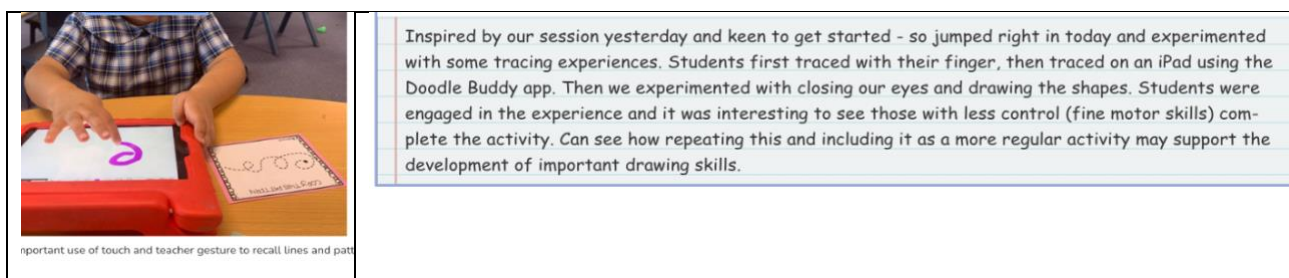


Figure 1: Student tracing work sample and teacher reflective journal entry in Seesaw

c) The researchers further explored the connections between finger-tracing and drawing through individual task-based interviews with 54 children from 4 to 8 years.

The task was: a) Show a figure, hide it, and ask the child to ‘draw what you saw’. b) Show figure again and ask the child to trace over it as if they were drawing it. c) Hide and ask the child to draw it again. (See Figure 2)

Our initial analysis revealed 65% of the children (Preschool to Year 2) improved their second drawing by apparently noticing additional structures and spatial relationships in the figure. Figure 2 shows the example of a preschool child (age 4) who changed from drawing separate shapes to drawing one shape enclosing the other – a significant shift in representation of the topological ideas of separation and enclosure.

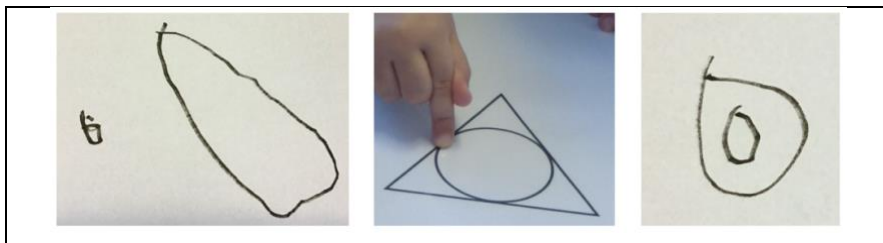


Figure 2: Improving figure drawing through finger-tracing

During the individual interviews, the researchers discovered the puzzling phenomenon of two children who could only trace using a thumb, even when specifically encouraged to use their ‘pointing’ finger – raising questions for future studies.

d) The potential applications and benefits of finger-tracing were discussed with the teachers at the next professional learning session, and most of them worked on integrating tracing, including eyes-closed tracing, in a variety of mathematics topics. In relation to students’ learning of spatial concepts Year 1 teacher Belinda reflected that, “once they trace ... it made them really understand what the object was, they weren’t just looking at it, they were involved, they were touching it ... I think it really helped” [T1_02].

Scenario 2: Egocentric body movement and the number line

a) In the first round of ‘baseline’ classroom observations the researchers noticed a teacher using hand gestures to her left and to her right when talking to her class about counting forwards and backwards, and ‘number before’ and ‘number after’. The gestures were presumably in relation to her imagined number line, but this image was not shared with the children, and would probably have been reversed relative to the gestures if they did happen to picture a number line themselves.

b) At the first professional learning session the teachers were introduced to the key idea: *Body-movement experiences that facilitate egocentric spatial frames of reference are beneficial for young learners*. As an example, we experienced how stepping forward and backwards along a floor number-track can help establish a sense of number sequencing and magnitude in relation to our own body’s directionality and positioning. The teachers realised that if the children had these experiences regularly, gestures in relation to moving forward and backwards would make more sense to them – connecting to the key idea: *Deliberate use of gesture by the teacher can enhance learning and support vocabulary development*.

c) One of the Year 1 teachers, decided to explore the use of body movement to help her students understand the structure of the number line. She asked her students to each take a large numeral card then arrange themselves in order along a line. Despite most children knowing the numeral sequence, many of them were not able to physically position themselves in relation to other children and the numerals they held. Tina explained to the researchers that after two years of interrupted schooling due to the pandemic, they lacked experiences in ‘lining up’, so repeated the activity. Tina noted a shift in students’ conceptual understanding over time through using body movement with number sequencing: “... getting them to stand there and move using their body ... it was confusing for them ... they could tell me verbally but to do it physically was very different ... after practising it a few times you could see the ones working it out, ‘no you’re in the wrong spot’” [T1_01].

d) The experience was shared at the second professional learning session, and the implications discussed. We realised that such physical/social/spatial experiences could not occur in the online learning environment and appear to contribute something worthwhile to children’s number sense.

Scenario 3: Conceptual gesture and communication

a) Two of the key ideas introduced to the teachers at the first professional learning session were: *Co-speech gestures (non-representational and representational) can enhance learning, communication, and vocabulary development* and, *Deliberate use of gesture by the teacher can enhance learning and support vocabulary development*.

b) Early in the year the researchers noted that a substantial number of children were reluctant speakers, including a few elective-mutes, and many other children who were learning English as their second language, or had limited vocabulary development. As the teachers began to increase their use of purposeful, conceptual gesture, the question of whether an increased use of conceptual and mime-type gesture and body movement would help or hinder the language and communication development of these children became an on-going point of interest.

c) The teachers began noticing the children’s increased use of conceptual gestures as a communication tool (both teacher-mirrored and self-initiated) and the increased engagement of children, and realised the value of purposefully connecting gestures with key vocabulary. Some teachers reported that they were now often saying ‘use your hands’ instead of ‘use your words’, and ‘show me’ more often than ‘tell me’ – and had noticed increased participation by the students and the use of gesture as an alternate form of communicating ideas and understanding. A Year 1 teacher said, “it gives them that opportunity, if they can’t articulate what they are trying to get out, it gives them that chance to show you in another way” [T1_02]. The other Year 1 teacher saw gesture as useful for second language learners: “We have a lot of EAL/D students ... their vocab, their oral language ... they find it more difficult ... so using gesture, they can actually show their understanding in a different way rather than having to verbally say an answer. I think it made it more accessible for them” [T1_01].

Discussion

The aim of this paper is to illustrate how collaboration between researchers and teachers in naturalistic classroom settings can translate previous research findings on embodied learning into mathematics

curriculum-connected pedagogy to enhance children's learning and cater for diversity in learning needs. The three scenarios demonstrate how the genuine exchange of ideas between teachers and researchers simultaneously met the immediate learning needs of the children, facilitated the development of teaching advice for other teachers and allowed new research outcomes to emerge.

A recurring finding was the way in which teachers naturally combined *key ideas* that had originated from diverse research studies to address selected mathematics curriculum content and the learning needs of their classes. We suggest that the combination and conceptual co-ordination of embodied modes, such as body movement and gesture, to achieve learning goals would not have occurred without the collective/collaborative approach to translating research findings into classroom practice. Deeper analysis of the data collected on the combination of embodied representations in these classroom experiences will potentially add new findings to research on embodied learning that typically addressed embodied modes in isolation from each other. Another emerging finding from Phase 1 is the importance of both the teacher and the students' involvement with the embodied practices and actions as a means to communicate learning and understanding in two ways – teacher to student, and student to teacher.

Acknowledgments

The ELEMS project is funded by the NSW Department of Education, Strategic Research Fund (2021-2024). The other members of the University of Sydney research team: Dr Christine Preston (Science), Dr Amanda Niland (Early Childhood), Dr Jonnell Uptin (TESOL).

References

- Alibali, M., & Nathan, M. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of Learning Sciences*, 21(2), 24786. <https://doi.org/10.1080/10508406.2011.611446>
- Clarke, D. J. (2001). Complementary accounts methodology. In D. J. Clarke (Ed.), *Perspective on practice and meaning in mathematics and science classrooms* (pp. 13–32). Kluwer. https://doi.org/10.1007/0-306-47228-7_2
- Dackermann, T., Fischer, U., Nuerk, H.C., & Cress, U. (2017). Applying embodied cognition: From useful interventions and their theoretical underpinnings to practical applications. *ZDM – Mathematics Education*, 49(4), 545–557. <https://doi.org/10.1007/s11858-017-0850-z>
- de Freitas, E., & Sinclair, N. (2012). Diagram, gesture, agency: theorizing embodiment in the mathematics classroom. *Educational Studies in Mathematics*, 80(1–2), 133–152. <https://doi.org/10.1007/s10649-011-9364-8>
- Fleet, A., De Gioia, K. & Patterson, C. (2016). *Engaging with Educational Change: Voices of Practitioner Inquiry*. Bloomsbury Academic.
- Ginns, P., Hu, F. T., Byrne, E., & Bobis, J. (2016). Learning by tracing worked examples. *Applied Cognitive Psychology*, 30, 160–169. <https://doi.org/10.1002/acp.3171>
- Goldin, G. (1998). Representational systems, learning and problem solving in mathematics. *Journal of Mathematical Behavior*, 17(2), 137–165. [https://doi.org/10.1016/S0364-0213\(99\)80056-1](https://doi.org/10.1016/S0364-0213(99)80056-1)

- Goldin-Meadow, S. G. (2015). From action to abstraction: Gesture as a mechanism of change. *Developmental Review*, 38, 167–184. <https://doi.org/10.1016/j.dr.2015.07.007>
- Hutto, D. D., Kirchoff, M. D., & Abrahamson, D. (2015). The enactive roots of STEM: Rethinking educational design in mathematics. *Educational Psychology Review*, 27, 371–389. <https://doi.org/10.1007/s10648-015-9326-2>
- Kersting, M., Haglund, J., & Steier, R. (2021). A growing body of knowledge: On four different senses of embodiment in science education. *Science & Education*, 30, 1183–1210. <https://doi.org/10.1007/s11191-021-00232-z>
- Martinez-Lincoln, A., Tran, L.E., & Powell, S. (2019). What the hands tell us about mathematics learning: A synthesis of gesture use in mathematics instruction. *Gesture*, 17(3), 375–416. <https://doi.org/10.1075/gest.17014.mar>
- Olin, A., Almqvist, J., & Hamza, K. (2021). To recognize oneself and others in teacher-research collaboration. *Educational Action Researcher*, 31(2), 247–264. <https://doi.org/10.1080/09650792.2021.1897949>
- Poland, M. M., & van Oers, B. (2007). Effects of schematizing on mathematical development. *European Early Childhood Education Research Journal*, 15(2), 269–293. <https://doi.org/10.1080/13502930701321600>
- Reimann, P. (2010). Design-based research. In L. Markauskaite, P. Freebody & J. Irwin (Eds.), *Methodological Choices and Research Designs for Educational and Social Change: Linking Scholarship, Policy and Practice* (pp. 37–50). Springer.
- Thom, J., & McGarvey, L. (2015). The act of drawing(s): Observing geometric thinking with, in, and through children's drawings. (2015). *ZDM – Mathematics Education*, 47, 464–481. <https://doi.org/10.1007/s11858-015-0697-0>
- 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 (Proceedings of the 44th Annual Conference of the Mathematics Education Research Group of Australasia, July 3–7)* pp. 538–545. Launceston: MERGA