

Developing Mathematical Concepts in Australian Pre-school Settings: Children's Mathematical Thinking

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This paper describes some key findings from the analysis of video data comprising part of the SIMERR project "Mathematical thinking of pre-school children in rural and regional Australia: Research and practice". This analysis focused on the identification of young children's mathematical thinking as it occurred naturalistically in two different pre-school environments. The broad categories of children's mathematical thinking drawn from the video data were consistent with those identified by early childhood professionals when they were interviewed as part of the larger study.

Background to the Study

The aim of this component of the larger project was to identify, describe and illustrate young children's mathematical thinking in two rural and regional preschools. Our approach was to capture naturalistic observation data of preschool learning environments; these were considered typical examples of those preschools described by early childhood professionals at interview. Another purpose was to identify how professionals fostered children's mathematical thinking, and to highlight examples of this practice.

A review of current research on early childhood mathematics learning was compiled as the first phase of the larger study providing an annotated bibliography to support the investigation (Mousley & Perry, this volume). The focus on young children's mathematical thinking was considered one aspect shaping early childcare professionals' beliefs and practices. There is a growing body of new research in early mathematics education based on the evidence that young children are more capable of developing mathematical concepts and processes than previously thought (Clements & Sarama, 2007; Mulligan & Vergnaud, 2006). This has been encouraged by research that focuses on general mathematical processes such as problem solving, argumentation and justification (Perry & Dockett, 2008), analogical reasoning (English, 2004), and early algebraic reasoning (Papic & Mulligan, 2007).

Method

Setting and Participants

Two large NSW long-day care centres (one rural and one regional) were selected as case studies for the collection of video data. Both centres were similar in size and had comparable enrolments (76 in the rural and 88 in the regional). While the rural centre is government funded and caters for children birth to 6 years of age, the regional centre is privately owned and caters for children from 2-6 years of age. Both centres employed one university qualified, and two diploma-trained teachers. The regional centre drew children from mid-socioeconomic background with a high percentage from non-English speaking backgrounds. Eighty-three percent of staff and 70% of children at the rural centre were of Aboriginal or Torres Strait Islander background. In comparison, there were no Aboriginal or Torres Strait Islander staff or children attending the regional centre.

Data Collection

Data collection included digitally recorded interviews with staff using the same interview process employed in the larger study. Photographs, video recordings and observations were taken of most children engaged in their regular preschool activities. These included planned experiences within an emergent early childhood curriculum, structured mathematics learning experiences, and spontaneous play situations. The centres' planning and assessment documentation were accessed and some samples of these were digitally recorded. Data collection occurred over a five-day period with researchers spending a total of 14 hours at each centre.

Analysis

Analysis of photographs and video data occurred in several phases and broadly followed the process suggested by Denzin (2002) for analysing film data. Initially, the three researchers independently viewed the photographs and entire video footage as a whole. Each researcher coded key photographs and scenes exemplifying important aspects of children's mathematical thinking and developing knowledge, thus identifying emergent themes or categories in the data. The three researchers then met to discuss the proposed categories and agreed on an initial set to be used in the coding of all visual data. Each researcher independently applied the coding to individual photographs and micro-analysed individual segments of the video recordings. Inter-rater reliability of the coding was checked at a subsequent meeting and adjustments to coding were made so that three researchers were consistent with their analysis of data. Where there were inconsistencies in coding, discussion took place to achieve compliance. If agreement could not be reached, an aspect or category was discarded, thus reducing the overall number of major categories emerging from the data. Further to our own cross-checking of the data, an advisory steering committee validated the categorisation of themes for the video analysis to ensure that there was consensus and consistency between the two data sets—visual and interview data.

Results and Discussion

This section describes four main categories of mathematical thinking that emerged from the visual data; photographs and video transcripts are used to exemplify each category.

1. Number (e.g., oral counting and numeral recognition);
2. Algebraic thinking (e.g., classifying, ordering, grouping and patterning);
3. Spatial thinking (e.g., block building, 2D shape and puzzles); and,
4. Measurement (e.g., mass and capacity).

These categories were consistent with mathematical content areas highlighted in the interview data where early childcare professionals were questioned about the type of mathematics learning that occurred for the pre-school children in their centre.

Number

Aspects of children's number knowledge and developing strategies were most prevalent throughout the video data from both centres. In particular, oral counting was incorporated into nearly every experience of the day as part of structured activities such as when they were required to roll a die and count the dots. It was also evident in planned

experiences such as story reading and cake making, and during play or incidental activities such as when the children counted blocks as they were packed away. Figure 1 shows a child counting the dots on a die as part of a structured activity. The adjacent transcript, illustrates how the educator promoted number learning by modelling oral counting to six.



Figure 1. Counting the dots on a die during a structured activity.

Teacher 1: This up here is number six, oh excellent.
 Teacher 2: Well done Riley. Now I think that you get six red stickers, just hold out your hand so that you remember that you got number six. Can you get them off, one, two, count with him, three, four, five, six.

Algebraic Thinking

Algebraic thinking was particular evident in the many patterning activities the children were engaged in. It was observed that children initiated patterning in their free play such as when they threaded coloured pasta on ‘necklaces’ or when they made border patterns with coloured pegs. Educators were seen to capitalise on the occurrences of unplanned learning experiences by questioning children about the patterns in their activities. The importance of asking questions was identified by many interviewees as a strategy to foster children’s mathematical thinking.

Teacher: You have got two colours in your pattern, what colors are they? Can you tell me the colours in your pattern? Why is it a pattern?
 Boy: Red, green... .

Spatial Thinking

Spatial thinking was evident in a wide range of learning experiences—from free play with building blocks (see Figure 2) and outdoor climbing equipment, to planned activities involving puzzles and modelling with play doh. Educators purposefully selected materials that would encourage deep thinking, prediction, and problem solving. This was supported by their descriptions of the activities and interactions with the children.



Figure 2. Free play experiences with building blocks required children to use spatial thinking.

Measurement

Young children were engaged in the development of measurement concepts and skills such as length, mass and capacity, particularly through play situations where they would model and compare parts of quantities. This would generally involve regular activities with sand and water play or using play doh. Figure 3 illustrates how sand play immersed the children into a situation requiring them to apply their knowledge and skills of measurement concepts. Figure 4 provides an example of a structured water play activity with the children challenged to measure ‘equal’ quantities.



Figure 3. Sand play provided opportunities for children to explore capacity.



Figure 4. Structured measurement activity.

Conclusions and Implications

Key aspects of mathematical thinking were identified in both pre-school settings across planned experiences, structured experiences and play situations. The analysis of video data for four categories of mathematical content reflected the early childcare educators' perceptions and beliefs about young children's mathematical thinking. In particular the emphasis on developing early counting and number skills through structured and unstructured experiences was prominent in their descriptions of their practice and emergent curriculum. These concept-driven descriptions of mathematical thinking were reflected in our analysis of the video data. However, evidence of deep mathematical thinking such as children's explanations and justification of problem-solving strategies, emerged from the analysis of child/carer interactions embedded in the video data. The quality of the professionals' interactions with children and their questioning techniques was critical to children's mathematical thinking.

A secondary analysis focussing on discourse (child/ child and child/ carer) would provide a more coherent picture of the general features of mathematical thinking that were salient across learning experiences. It seems that some professionals' descriptions of mathematical thinking were limited to four mathematical 'topics' even though they indicated an awareness that the children were engaged in deep mathematical processes such as reasoning and problem solving. There were many instances evident in the video data that indicated the potential development of rich mathematical learning experiences that were not realised. One of the aims of the larger project is to determine those processes and enabling strategies to support professionals in this endeavour.

References

- Clements, D. H., & Sarama, J. (2007). Effects of a preschool mathematics curriculum: Summative research on the *Building Blocks* project. *Journal for Research in Mathematics Education*, 38, 136-163.
- Denzin, N. K. (2002). Reading film. In U. Flick, E.v. Kardorff & Steinke (Eds.), *Qualitative Research: A Handbook*. London: Sage.
- English, L. D. (2004). Promoting the development of young children's mathematical and analogical reasoning. In L. English (Ed.), *Mathematical and analogical reasoning of young learners*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Mulligan, J. T. & Vergnaud, G. (2006). Research on children's early mathematical development: Towards integrated perspectives. In A. Gutiérrez & P. Boero (Eds.), *Handbook of research on the psychology of mathematics education: Past, present and future* (pp. 261 - 276). London: Sense Publishers.
- Papic, M., & Mulligan, J. T. (2007). The growth of early mathematical patterning: An intervention study. In J. Watson, & K. Beswick (Eds.), *Mathematics: Essential research, essential practice*. (Proceedings of the 30th annual conference of the Mathematics Education Research Group of Australasia, Hobart, Vol. 2, pp. 591-600). Adelaide: MERGA.
- Perry, B., & Dockett, S. (2008). Young children's access to powerful mathematical ideas. In L. D. English (Ed.), *Handbook of international research in mathematics education* (2nd ed) (pp. 75-108). New York: Routledge.