Teacher knowledge: A crucial factor in supporting mathematical learning through play

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This paper reports on the mathematical thinking taking place during play in a sessional kindergarten. It identifies ways in which early childhood teachers can broaden their professional development in mathematics education, and indeed why many early childhood teachers might need to do so, in order to enhance the mathematical learning of their children. Narratives in the form of learning stories, and photographs of the children at play, augmented and supported the findings of the investigation.

Introduction

There has always been an assumption that in the early years the initial stages of a child's mathematics learning can be seen through their play. While the child learns by doing, however, the teacher teaches by knowing. Therefore in order to maximise support of this early mathematical learning an early childhood teacher needs a thorough and extensive mathematical knowledge-base, coupled with theory and experience of appropriate professional pedagogy. Too often the teacher is bereft of sufficient mathematical knowledge with which to fully employ appropriate skills and strategies needed to enhance mathematical knowledge for the child.

The significance of play in developing early mathematics understanding

Play creates a natural environment of discovery for children, allowing them to learn about themselves and the world around them. According to Stone (1995) play is defined as an intrinsically motivated, freely chosen, process-oriented over product-oriented, non-literal, and enjoyable activity. Play serves an important function in children’s holistic development, which includes physical, emotional, social and intellectual growth. Through play children learn to think for themselves, to make choices and decisions, to reflect, and to tolerate uncertainty, thus enabling them to become more flexible and confident in themselves. These are important and integral aspects of both the early childhood curriculum, *Te Whaariki* (Ministry of Education,

1996) and the national mathematics curriculum, *Mathematics in the New Zealand curriculum* (Ministry of Education, 1992).

Pound (1999) believes the thinking in action which occurs in play forms a rich foundation for the more subject-specific problem solving, mental imaging and recording, in mathematics education, that can develop from play. Much of what young children learn is incidental, or natural, and happens through their play. They also observe adults using mathematics for meaningful purposes, and begin to use number and other mathematical concepts themselves as part of their everyday lives.

Young children as problem solvers

Mathematical know-how is the ability to solve problems which require some degree of independence, judgement, originality and creativity, as well as the ability to solve routine problems (Polya, 1995 cited in Pound, 1999). Mathematics, like all other human knowledge, is a consequence of social interaction. It is a means, or framework, used to support ongoing enquiry into aspects of the world (Pateman & Johnson, 1990 cited in Steffe & Wood, 1990).

How children go about learning mathematics varies greatly from child to child according to cultural background, family orientation to mathematics, the child's own disposition to learning, and teacher confidence. Carr (1999) writes of children's emerging working theories about what it is to be a learner, and about themselves as learners. She had earlier developed the idea that the working theories were made up of packages of learning dispositions and defined such dispositions as "habits of mind", or "patterns of learning". She further developed a framework of learning dispositions (Carr, 1998), known as learning stories, closely linked to the strands of *Te Whaariki* (Ministry of Education 1996). The framework of dispositions included courage and curiosity, trust, perseverance, confidence to express an idea, and taking responsibility for fairness and justice. In particular, these dispositions support quality mathematics learning through children's engagement in the problem solving nature of the mathematical processes (Ministry of Education, 1992).

Teachers supporting early mathematics learning

Early childhood teachers have a vital role in the total educative process. Alexander (1997, cited in Pound, 1999: 35), believes teachers have a responsibility to make sure that the "imperatives of early childhood" are not lost among the noisy demands for early achievement. Meade (1997) found, when referring to learning related to early literacy, early mathematics and reasoning, that most early childhood teachers opted for children to learn about these through play with little adult intervention. Children, however, do not learn mathematics unless exposed to it, and thus it requires a teacher to have a commitment to both the pedagogical principles of early childhood and personal mathematical knowledge in order to provide mathematically rich environments which do not interfere with the child-centred nature of play. As Haynes (2000: 101) says

> It is personal knowledge and disposition which enables teachers to take a "national curriculum and turn it into a child's curriculum". (citing Malaty, 1996).

The level of mathematical knowledge held by teachers might well vary, but, without the confidence and skill to interpret children's activities in learning situations, the actual teaching will be less effective than it could be. This comes down to how well the teachers themselves have been educated, which in turn depends upon the quality and focus of teacher education to which, as students, they were exposed. Farquhar (1994) believes that improvement in the quality of early childhood education programmes can best come from the improved quality of teachers, a corollary of which is that only the best applicants should be recruited to teach young children. Addressing a Teacher Refresher Course for early childhood teachers, Aitken (2000) pointed out that teachers all need highly developed skills, not just amateur understandings, if they are to analyse and respond effectively to each individual child or student's learning capability and progress. The importance of quality teacher education cannot be overlooked if teachers are to provide quality learning (Snook, 1992, cited in Farquhar, 1994). Further to this, Evans and Robinson (1992, cited in Farquhar, 1994), asserted that early childhood teachers should be versatile, flexible and creative in order to effectively manage the multiplicity of their roles and relationships. This would appear to be no less true in regard to mathematics learning than to other disciplines.

Teachers need to have the subject knowledge and teaching strategies which allow them to extend children's foundational knowledge (Cullen, 1999). Further, says Cullen, it is important for teachers to have confidence in their own knowledge of mathematics and to value the conceptual thinking that emerges through play, to recognise its potential for higher level thinking, and to take action accordingly. Haynes (1999) states that theories about facilitating play are not sufficient: teachers need sound knowledge of mathematical concepts themselves in order to address the 'what' of mathematics teaching. These observations complement the assertions of Farquhar (1994) and Pound (1999) that educating the educators is of paramount importance for optimal teaching outcomes at whatever level. As well as teaching for learning, providers of teacher-education must be able to enthuse their students, to know their subjects, to have a sense of humour, and to have a high sense of self-esteem, according to McInerney & McInerney (1998). Early childhood teachers, themselves, need a positive disposition towards mathematics in order to encourage children to think and reflect. They need to be able to use their own ideas as a basis for getting children to think and reflect, and to create situations in which the children can gain an awareness of specific content. Cullen (1999) believes strongly that young children need teachers who are immersed in subject-knowledge but are also able to impart their knowledge by developing reflective, analytical, creative and practical thinking about that knowledge-base. This validates the appropriateness of *Mathematics in the New Zealand curriculum* (Ministry of Education, 1992), *(MiNZC)*, as a framework for the development of mathematical concepts in early childhood through its emphasis on process as an integral part of mathematical learning.

Gathering the data

The study was conducted in the researcher's own place of practice, a kindergarten, with 44 four-year-old children in morning session as subjects. The kindergarten concerned is located in a middle-class socio-economic area in which all local schools are decile 10. The children came from a variety of cultural backgrounds, although mainly from New Zealand Pakeha and Asian cultures.

The study began with observations, both written and photographs, of children at play in a variety of situations within the kindergarten. The written observations were recorded as narratives in the form of learning stories (Carr, 1998). Initially the aim was to look at five areas of play to see what was happening in each, and later to analyse the learning story to identify any mathematical thinking taking place. This was to be further analysed and categorised according to criteria drawn from *MiNZC* (Ministry of Education 1992). In the event, eighteen learning stories in nine areas of mathematics were completed, and each was then categorised against one of the five content strands of *MiNZC* (number, measurement, geometry, algebra, statistics). In light of this, and the initial focus on a small number of areas of play, the investigation was extended further into most recognised areas of play in a kindergarten. Another thirteen observations were made in these areas and analysed using the same criteria.

The researcher herself had trained as a kindergarten teacher thirty years previously, which was well before the implementation of both the national curriculum for early childhood education and the national mathematics curriculum. While having worked with *Te Whaariki* (Ministry of Education 1996), she was actually unaware of the contents and components of *MiNZC* prior to undertaking the study.

Summary of results

Every learning story identified some mathematical activity, thinking, and/or mathematical language within the play concerned. The seventeen areas of play observed were sand, science, puzzles, games, mat-time, outdoor adventure, see-saw, woodwork, family, dough, cooking, collage, music, water, blocks, pen and paper and hide and seek. Table 1 indicates the instances of mathematical thinking observed across these areas of play grouped according to the content strands of *MiNZC.*

Strand in MiNZC	***Instances of Mathematical Thinking at Level 1 First Strand***	***Instances of Mathematical Thinking at Level 1 Second Strand***
Number	9	4
Measurement	11	8
Geometry	6	11
Algebra	3	1
Statistics	2	1
Total observations	31	25

Table 1. Play observations and strands of *MiNZC*

All thirty one observations related to a specific *MiNZC* strand, and all but six indicated mathematical activity across a second strand as well, evidenced in the same observation. This confirmed that concepts of level one mathematics *are* emerging through play *before* school.

Mathematical thinking associated with the number and measurement strands were predominant and the strands of mathematics do not occur in isolation is illustrated by the number of observations where instances of two strands were demonstrated.
A significant feature of this research was the analysis of the photographic records for mathematical content. The various facial expressions of the children gave some indication of how the experience affected them during play, illustrating a variety of dispositions such as enthusiasm, curiosity and concentration. Together with the written observations, they are indicative of the children's positive attitudes to mathematical exploration. At this age most children are curious and experiment readily, but it has been demonstrated here that the actual breadth of mathematical learning depends upon the levels of enthusiasm and competence practised by the teachers.

Linking *Te Whaariki* and *MiNZC*

The study demonstrated a definite link between *Te Whaariki* (Ministry of Education 1996) and *MiNZC* (Ministry of Education 1992) with every play activity having at least one mathematics strand evidenced. However, as Carr, Peters & Young-Loveridge (1994) point out, mathematics is not an isolated subject: it is but one part of the whole curriculum, and most of the time is not the focus of the play. To illustrate this, one child, who was playing on the see-saw, used this activity in a manner that showed she knew how to experiment with weight in order to make the see-saw work for her. This example also served to illustrate the problem solving underpinnings of both *Te Whaariki* and the mathematical processes of *MiNZC*: the child was constructing her own learning based on prior knowledge, understanding, trial and error, communication and experimentation in relation to context. When she goes to school it is anticipated that this child will use and build upon all these strategies in future mathematics learning. The kindergarten setting and programme based on *Te Whaariki* (Ministry of Education 1996) offers children time to choose, observe, listen, experiment, articulate, reflect, control, interact and work alongside other children and adults in ways that are basic to the play setting within the learning environment.

Teacher disposition to mathematics

From reflection on the 'learning-by-doing' displayed by the children a clearer perception emerged of what was being learned and how it was being learned. Although the children were not taking part in a structured mathematics lesson, what they were in fact engaged in, on each occasion, was a play situation which promoted the basis for more formal learning at a later stage. Learning almost anything is more effective when it is as contextually authentic as possible, but even more effective when the teacher can use the engagement and involvement aspect to help identify teachable moments in which to extend and cement specific learning.

Many adult acquaintances of the researcher, when spoken to about mathematics and the purpose of this research, spontaneously acknowledged that although they 'coped' at school and have since been able to do 'most' of the everyday calculations required for everyday living, their experience of learning mathematics imbued them with a sort of 'bogey' image of mathematics as a subject. It seems that while many of the mathematics teachers were known to be good at their subject they were not always good at imparting knowledge. It is probable that students who thought they were weak in mathematics made little progress because their actual abilities had never been identified and developed. So again, the capacity of the teacher to indicate his or her enthusiasm for the subject, in terms which relate clearly to the level at which the children are at, is a significant factor in any discussion of teaching and learning mathematics.

It seems a logical corollary, then, that the teaching of mathematical concepts be focused on activities that engage and involve, rather than on more structured pedagogical processes, and certainly at kindergarten level.

Teacher education in mathematics

Throughout this study it became apparent that knowledge *is* a pre-requisite for effective teaching of mathematics in early childhood. It is not only student-teachers who need subject education as provided at Auckland College of Education (Haynes, 1999) but also teachers in the field. Coincidentally, during the study, two colleagues in the researcher's teaching team attended a half-day seminar on mathematics in early childhood education, an outcome of which was a new awareness and focus for the team to work at, discuss, and reflect upon. This may have strengthened the focus of the study and therefore also serves to illustrate that with on-going professional development for teachers in the area of mathematics education, it is possible that a more productive emphasis might well be placed upon mathematics as a programme component in early childhood settings.

Socio-cultural issues in mathematics education

Considering the smallness of the sample in the study no statistical significance can be attached to gender ratios, or to cultural differences. However it is worthy of note that on this particular session there appeared to be more girls than boys who enjoyed meeting challenges that were actually mathematical in essence. A third of the sample were of Asian origin, a cultural group believed to be positively oriented towards mathematics. It is assumed that most Asian children are early imbued with a studious work ethic, regardless of actual or assumed ability. Certainly the Asian children, on this session, when playing in the kindergarten environment, are always communicating with each other about their play. Furthermore, observation suggests that it is girls who correct boys when mistakes are made, or who help when guidance is required. It is of interest to note that, of the three teachers at this particular kindergarten, the teacher who is most aware of mathematical potential was educated in Taiwan.

Conclusion

The findings of this study clearly indicate that the incidence of four-year-old children successfully engaging in the concepts of level one (or even level two occasionally) in *MiNZC* (Ministry of Education, 1992) is not merely circumstantial and should not be overlooked. An encompassing question for further investigation, suggested by this research, is whether the mathematical needs of children in the earlier years of their education are being adequately catered for. As a corollary, now that *MiNZC* is ten years old, it seems timely to review the document in the light of its significance for early childhood education. As evidenced in this study, the document does provide an appropriate framework for early childhood mathematics education but it is not often found in kindergartens. Newly graduated teachers have copies whereas other teachers are required to purchase their own copies.

Throughout the relevant literature, and particularly during the course of the study itself, the most potent implication became the necessity for all teachers to have greater in-depth knowledge and understanding of mathematical content and processes, and to be confident in their use of mathematical language. This was demonstrated through the researcher, herself: as her awareness of the mathematical significance of what the children were doing increased, so did the extent of her mathematical interpretation of their activity widen. This led to a growth in enthusiasm and gave a new depth to the researcher’s teaching practice.

Our education system owes it to children to ensure provision of early childhood teachers well educated in mathematics to maximise the children's learning in what must always be an essential learning area. This study into early childhood mathematics education proves the point, and if this means that greater provision of professional development for early childhood teachers must be made, then so be it.

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