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Early Childhood Numeracy in a Multiage Setting

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This research is a case study examining numeracy teaching and learning practices in an early childhood multiage setting with Pre-Primary to Year 2 children. Data were collected via running records, researcher reflection notes, and video and audio recordings. Video and audio transcripts were analysed using a mathematical discourse and social interactions coding system designed by MacMillan (1998), while the running records and reflection notes contributed to descriptions of the children's interactions with each other and with the teachers. Teachers used an 'assisted performance' approach to instruction that supported problem solving and inquiry processes in mathematics activities, and this, combined with a child-centred pedagogy and specific values about community learning, created a learning environment designed to stimulate and foster learning. The mathematics discourse analysis showed a use of explanatory language in mathematics discourse, and this language supported scaffolding among children for new mathematics concepts. These and other interactions related to peer sharing, tutoring and regulation also emerged as key aspects of students' learning practices. However, the findings indicated that multiage grouping alone did not support learning. Rather, effective learning was dependent upon the teacher's capacities to develop productive discussion among children, as well as implement developmentally appropriate curricula that addressed the needs of the different children.

Background

The importance of supporting children to become numerate citizens is acknowledged worldwide. The National Council of Teachers of Mathematics' (2000) *Principles and Standards for School Mathematics* states "In this changing world, those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures" (p. 5). In Australia, the definition and understanding of what numeracy is has stemmed from the Commonwealth funded Numeracy Education Strategy Development Conference, under the joint auspices of the Education Department of Western Australia and the Australian Association of Mathematics Teachers. The outcomes from this conference were published in the paper *Numeracy = Everyone's Business* which stated that "numeracy involves using … some mathematics … to achieve some purpose in a particular context" (cited in Doig, 2001, p. 3).

More articulated definitions of 'numeracy' have been suggested that focus on the use of mathematics in real contexts where the purpose of the activity is not a school mathematics curriculum endeavour (Hogan, 2000; Scott, 1999). For example, Hogan (2000) suggested the following framework:

- *Mathematical knowledge:* understanding and using the mathematical ideas and techniques in Number, Space, Chance and Data, Algebra and Measurement;
- *Contextual knowledge:* the capacity to link mathematics to life experiences; and
- *Strategic knowledge:* being able to identify the key features in a problem. (p. 19)

Since 1997, many endeavours to increase student numeracy achievements have been completed in Australia, including *Count Me In Too!* in New South Wales (NSW Department of Education and Training, 2002), the *Early Numeracy Research Project* in Victoria (Clarke, 2001; Clarke, Sullivan, Cheeseman, & Clarke, 2000), and *First Steps in Mathematics* in Western Australia (Willis, Devlin, Jacob, Treacy, Tomazos, & Powell, 2004). A common feature of these programs has been development of growth points in numeracy learning that teachers can use to profile student knowledge in various mathematical domains. All these programs focus on supporting children's learning from the beginning of formal schooling, or earlier. Growth points have been developed through research with children and teachers in early childhood and primary educational contexts, but have not often focused specifically on multiage educational settings. Hence, the research reported here provides additional insight into early numeracy learning.

Multiage education has attracted a revival of interest both internationally and within Australia as researchers and practitioners strive to meet new standards of best practice in education. There has also been a growing worldwide concern within the education community that students have not been provided with the mathematics learning that would enable them to successfully cope with life in an ever-changing, technological world. These two educational concerns framed the conceptualisation of this research study that aimed to investigate early numeracy learning within multiage pedagogic practices. Specifically, the study addressed the following research question:

> What is the nature of numeracy teaching and learning practices in a multiage classroom?

The significance of addressing this research question is three-fold. First, the study provides important information regarding teaching practices and learning environments to support young children's numeracy learning. Second, the findings have direct applications to curriculum practices nationally and internationally because they provide information relevant to implementation of outcomes-based education. More specifically, they provide insight into the ways in which teaching practices can be enacted to cater for diverse levels of achievement within one classroom; that is, without identifying children and their achievement according to their school grade or year. Third, the findings have both practical and theoretical implications for the professional development of teachers, since the full potential of the findings rely upon effective implementation of multiage educational philosophy and practices.

Theoretical Framework

Multiage Education – A Definition

The definition of multiage education used in this study is that of Rathbone (1993): "classrooms where children of different ages and grades are intentionally placed together, where graded distinctions are minimalised and where teaching and learning make use of the range of knowledge inherent in the group" (p. iv). Other definitions within the literature are similar in that they focus on an intentional grouping of children of at least two age groups for the purpose of enhanced education through a child-centred approach and the employment of specific teaching strategies (Miller, 1994; Politano & Davies, 1994; Rice & Shortland-Jones, 1999). The child-centred approach is based on fostering a classroom environment that values and attends to the diversity of learners with regard to achievement levels and learning styles. Further, children are not compared one to another on their achievements, as in single age groupings, but instead there is a focus on their progress overall. A multiage approach is also child-centred in that children work with peers, sharing learning experiences to construct personally meaningful knowledge. This discussion-oriented approach to teaching explicitly recognises that "language and talk become the connector between teacher, student, object and thought" (Rathbone, 1993, p. 64).

Learning Theory in a Multiage Setting

Pratt (1983), considering social learning theory, suggested there is a strong theoretical case for multiage grouping, particularly concerning the potential for cross-age tutoring as a vehicle to support cognitive achievement and positive attitudes in learning. Harmon (2001), in referring to the work of Piaget, noted that a crucial part of a child's development is through peer interactions that result in "cognitive conflict" so that children are prompted to consider alternative points of view. Interactions with other children at various developmental levels, as in multiage groupings, can create cognitive conflicts. Simultaneously, these groupings can support the notion of scaffolding as described by Vygotsky (1978) in outlining his ideas related to the 'Zone of Proximal Development' (ZPD).

Kinsey (2001) added to this theoretical perspective when discussing the 'support systems' that exist in multiage education. Kinsey suggested that it is not just the peer interactions that support enhanced learning but the specific ways teachers in multiage classrooms guide these interactions. Similarly, Katz, Evangalou, and Hartman (1990) found that multiage groupings were not in themselves a catalyst for higher social and academic success. Rather, it was the implementation of specific teaching strategies as a result of the grouping, and the resulting community or family-like setting that fostered learning experiences. More specifically, they suggested that taking on the 'expert' role by the older students was beneficial to both the older students and the younger students. The older students gained through peer tutoring and consolidation of conceptual knowledge that results from breaking the information down to teach it, while the younger students gained through knowledge building in conjunction with 'expert others', who have an understanding of the learning. Harmon (2001) also found that older children benefited from taking on the 'expert' or 'advisor' role, by gaining self-confidence and self-esteem and through maintaining proficiency with skills by constantly reviewing them when 'advising' younger students.

Further, with regard to examining the potential of multiage education, Hunt (1999, pp. 2–3) cited three Australian projects that indicated:

- Multiage grouping supports teachers in providing quality education (Education Department of South Australia);
- The benefits were such that "The First Three Years" pilot program was established in Victoria; and
- The 'Scott Report' in Western Australia (Scott, 1999) found that multiage grouping supports developmentally appropriate practice by providing for flexibility to foster successful experiences for all children.

In summary, major ideas outlined by Harmon (2001) that link to educational learning theory in the context of multiage education are:

- Multiage education provides abundant opportunities to participate in in-depth discussion, fosters engagement in learning and acts as a mediator of information (constructivist theory);
- The opportunities to scaffold new learning are promoted through interacting with people in the child's surroundings and in collaboration with other children (Vygotsky's ZPD);
- Peer learning gives children access to social learning through vast opportunities to emulate students of different developmental levels (social cognitive theory); and
- Multiage education enables students to take responsibility for their learning (attribution theory).

Method

This research study was designed to investigate teaching and learning practices demonstrated in a multiage classroom. Therefore, in order that a rich and descriptive reporting of the data could occur, a qualitative research paradigm was seen as most appropriate (Merriam, 1988). More specifically, the research was designed as a case study in line with Fraenkel and Wallen's (2002) description of a case study as "a form of qualitative research in which a single individual or example is studied through extensive data collection" (p. 683), and the requirement that it aims to explain "the unique features and circumstances surrounding a case" (Teppo, 1999, p. 34).

Research Setting

The research took place in Terms 1 and 2 (January to July), 2003, in a Pre-Primary (PP)-Year 1-Year 2 classroom in a metropolitan primary school in Western Australia. For these year groups in Western Australia in 2003, the children were turning ages 5, 6, and 7 within the first half of the year. The school, established in the late 1950s, was situated in a middle-class suburb. At the time of the study, there were 22 full-time teaching staff and the student population consisted of 283 full-time students in PP to Year 7, with an additional 40 Kindergarten students (the year prior to Pre-Primary), who attended school part-time. This school was chosen because it had a multiage program; it was accessible for the researcher (KW); and the classroom teachers were supportive of the research project.

The group of students who are the focus of this study consisted of a total of 44 children: 13 students of chronological age for PP (8 boys and 5 girls); 16 of Year 1 age (9 boys and 7 girls); and 15 of Year 2 age (8 boys and 7 girls). There was also a boy of Year 3 age in this group because he was developmentally delayed as a result of a severe illness. He was assigned a full-time teaching assistant to support his learning. In addition, there were three full-time teachers and one additional teaching assistant. The 'classroom space' was two classrooms separated by a concertina door that was usually left open. The three teachers jointly programmed the overall curriculum with their planning focused upon viewing students as within: a PP/Year 1/Year 2 cohort; and a PP/Year 1 or Year 1/Year 2 cohort. The PP/Year 1/Year 2 grouping operated for learning centre activities each morning, with all three teachers taking on supervision roles. Learning activities for the other two groupings were planned for jointly, with two of the three teachers working predominantly with one group or the other and the third teacher assisting where needed. The assignment of children to the two smaller groups within the full cohort for some of their learning experiences was for organisational reasons, to facilitate management of resources and space, and to allow the teachers to plan within an outcomes-focused curriculum. That is, the teachers planned learning activities by considering the current achievement levels of the students, rather than their ages. In this regard, although the two groups were partially distinguished by increasing age, children were moved from one group to another if it was considered to be more appropriate for their level of achievement.

Data Collection

The research period commenced with the researcher, as a "participant-as-observer" (Gold, 1969), spending time to become familiar with the children, the staff, and the classroom routines, while also allowing the children to become familiar with her. This preliminary component of the 20-week research schedule lasted 2 weeks with the researcher visiting the classroom for 2 mornings in each of these weeks. The researcher and the teachers then planned the research schedule so that the researcher could spend time in the classroom at least once a week over the next 18 weeks of the two school terms at times when learning activities with a specific numeracy focus were planned. Not all planned visits were completed because sometimes the classroom timetable was changed and the researcher was not available at alternate times. In total, 12 classroom observations during the 18 weeks were completed with observation periods lasting 40 to 60 minutes. The researcher's observation notes along with classroom video and audio recordings were used to collect data to answer the research question. The data collection methods, and related data analysis and interpretation methods are outlined below.

Classroom observations. Throughout the research period observations were documented by the researcher using running records and reflection notes. These were a primary data source for all visits, and also served as a form of triangulation of data from video and audio recordings. Overall, the observations were used to gather data about peer and student-teacher interactions during learning, including what children said and did individually as well as in discussion with others. The running records were made by noting the time and as much as possible of what the teaching staff and children were saying or doing. After an observation session the researcher made short reflection notes about what had been observed, and when possible she shared her thoughts with the teaching staff to obtain alternative perspectives on the related classroom happenings. In these notes, preliminary 'hypotheses' were made about the children's interactions, possible learning, and related links to the research literature. For example, notes made after the observation period on May 21, 2003, included:

> I noted that the two boys helped each other … but that the two girls worked separately on smaller projects and were less engrossed with the activity. The classroom teacher commented that you can't assume cooperation and group work will take place. "You need to work on it", she said. "You need to model and support the learning to work in that way." The comment is directly linked to the theory and particularly Tudge and Rogoff who state that opportunities are there in social interactions, but they contend that there are not blanket benefits.

Classroom video and audio recordings. Practice sessions with the video camera and audio recording system were conducted during the preliminary 2-week period of the research to identify the most appropriate positioning of the equipment and to provide opportunity for the children to see the equipment as a normal part of learning activities. It became evident at this time that it would be difficult to obtain recordings, even for small groups of children, that captured adequately what all the children said. Many of the children spoke quietly, and the small group nature of many of the classroom learning activities meant there was always much background noise. The researcher then sought access to higher quality recording equipment; in particular, a more sensitive, multidirectional microphone. This equipment was available for audio recordings only, but was not available regularly or for extended loan periods. Hence, it was used when available for three audio recordings, while video recordings were conducted on four occasions. The recordings were made of small group activities during classroom learning activities that had a numeracy focus. Hence, for each recording session, small groups were recorded, with the researcher focusing her observation notes for that session upon these groups.

Data Analysis

The recordings were transcribed to analyse the discourse according to the coding categories for discourse interactions developed by MacMillan (1998) (see Table 1). This model was chosen for its focus on the mathematical as well as social uses of language and because a “purpose of classifying elements of linguistic interaction in such a way is to provide insights into the learning environment and the learning process” (MacMillan, 1998, p. 111). That is, this analysis gave insights into the teaching and learning processes operating in the multiage setting.

Table 1
Coding Categories for Children’s Interactions (MacMillan, 1998)

Main Category Mathematical Discourse	**Sub-Category**
	Counting
	Measuring
	Locating
	Designing
	Explaining
	Playing
Socio-Regulative Interactions	**Sub-Category**
A. Interpersonal motivations	Recognition
	Respect
	Co-operation
B. Individual motivation	Choice
	Imagination
	Competition
	Curiosity
	Non-engagement

C.	Interpersonal responsive control	Modelling
		Assisting
		Observing
		Improvising
		Positioning
		Direct instruction
D.	Interpersonal restrictive control	Exclude
		Resist
		Classify
		Rules
		Threat
E.	Identity formation	Co-participation
		Responsible self-regulation
		Clear access
		Non responsive regulation

Data analysis proceeded inductively through a grounded approach (Powney & Watts, 1987), with initial emergence of key themes from the classroom observations considered further within examination of further observations and data from the recordings.

Findings

Key practices to support numeracy learning that emerged from examination of the teaching and learning in this multiage classroom related to four main themes: teacher planning, teacher "assisted performance", peer sharing and tutoring, and peer regulation.

Teacher Planning

In accordance with Hogan's (2000) definition of "numeracy", there was evidence to suggest that the specific curriculum as planned by the teachers within this case study was conducive to the students becoming numerate. More specifically, the data indicated that the nature and variety of mathematics tasks the teachers incorporated into their programs in contextual, integrated ways could be categorised within Hogan's numeracy framework. First, children were given opportunities to experience mathematics concepts across a variety of mathematics domains, including Number, Measurement, Space, and Chance and Data. This is an important element of becoming numerate, as outlined in the mathematical knowledge component of Hogan's (2000) numeracy framework.

Second, the teachers designed numeracy related activities to integrate with other aspects of the children's experiences, in other parts of the classroom curriculum or outside of school experiences. One teacher commented on the mathematics program by saying: "So they can bring into school something that's happening at home. We try to link it with what's happening at home." This deliberate linking of the activities with other aspects of children's experiences fits within Hogan's (2000) contextual knowledge component of numeracy. The teachers were explicit in their attempts to apply mathematics learning to everyday situations or other components of the curriculum. One example was the clay castle building activity (Space strand) that is outlined in an upcoming section of this paper. This activity was designed to link to a curriculum theme about medieval life. Another activity involved recording and reporting on eye colours within the classroom cohort (Chance and Data strand). In yet another activity, the children were involved in finding a way to measure the height of the goal posts on the school oval (Measurement strand).

The final part of the numeracy framework proposed by Hogan (2000), *strategic knowledge*, was also evident in the design of learning activities in that there was a deliberate focus on problem solving. The problem solving nature of many of the observed activities is examined in later sections of this paper alongside an analysis of what the children said and did in completing the activities. As well as utilising a problem solving approach, the observed activities were open-ended in nature, allowing for diverse ways of entering into and completing the task. Often, this was from a 'play' or exploration orientation, as in the clay castle building activity. This sort of flexibility within activities is encouraged within early childhood pedagogical practices (MacMillan, 2001). It also fits with Doig's (2001) list of recommendations to support numeracy learning, which include: having a well-structured program with achievable goals; making greater use of open-ended questions; giving students more time to explore concepts; and giving students more opportunity to share their strategies.

Teacher 'Assisted Performance'

Observations showed that teachers used direct instruction when they needed to explain activities and set parameters for completion of these activities. However, when monitoring students' progress in activities, or when students sought assistance with their learning, the teachers used questioning, paraphrasing, and suggestions as alternative strategies to guide the children to solve the problems by themselves. The approach has been called "assisted performance" (Aschermann, 2001). Its key feature is that teachers support children by "providing structure and assistance in their work" (p. 15). As a teaching strategy, assisted performance utilises problem solving as the process for a learning activity, and the teacher, through careful observation and timing, supports students in building new understandings. Teachers were observed on many occasions stepping in at appropriate times and asking specific 'leading' questions that assisted children to draw appropriate conclusions or take appropriate actions. For example, they asked questions such as: "Is that the best way to go?" and "But how do you know?" (audio recording, June 3, 2003).

This fostering of problem solving capacities supported the children in their numeracy learning experiences with regard to both the mathematical and strategic knowledge components of numeracy learning as outlined by Hogan (2000). Children were supported in clarifying their ideas and coming to understand their own thinking processes. As noted by Woolfolk (1998), "the culture of a classroom can teach lessons about thinking by giving us models of good thinking, providing direct instruction in thinking processes, and encouraging practice in those thinking processes through interactions with others" (p. 315). Peer interactions that occurred in this multiage classroom also fostered the sharing of language and related ideas and thinking process (discussed in upcoming sections), but what must be noted here is that teachers played a role in this overall process, modelling the process to students to encourage effective peer interactions. The observations also indicated that the staff used choice as a vehicle for guiding children in their problem solving efforts so that, rather than telling students what materials or procedures they should use to complete an activity, they gave them a selection of possibilities. For example, during a whole class measurement activity children were asked to select from blocks, pop-sticks, match sticks, teddy bears or a ruler to complete the task.

However, it was also the case that the teachers and teacher assistants used direct instruction to support learning, for example: "You've got to use your fingers like this" (during the castle building); "So now you have to estimate" (during a learning centre measurement activity, video recording, 12/06/03); and "That adds up to seven, you need to …[full instruction inaudible]" (during a number based worksheet activity, video recording, 28/05/03). Learning was also reinforced in a direct way through re-stating what a child had said or done, for example: "So you guessed how many sprinkles were there." In these examples the students were more passive in their role as a learner, however they were still encouraged to actively participate during other parts of the same activities.

An illustration of teacher assisted performance and direct guidance is shown in the transcript in Table 2 of a measurement activity during learning centre activities. The children were asked to measure how many smaller containers of wheat it would take to fill a larger container — this was repeated for different sizes of containers.

This example shows the teacher supporting the students' learning through direct guidance and questioning. The question "How many cupfuls do you think will go in there?" invites the child to experiment to solve the problem. Whilst the teacher guides procedural completion of the task, she encourages the child to think about what is happening, by estimating. These sorts of assisted performance strategies were observed during all forms of mathematics activities during the research period, indicating that they were key elements in the children's mathematics learning experiences.

Table 2
Wheat Volume Measuring Activity

Action	Language
	Teacher (T)* – "Right you're doing a really good job."
T gives directions for what to do next.	T – "So now you need to estimate." T – "Not measuring yet you're just guessing."
T assists by questioning.	T – "How many cupfuls do you think will go in there." Child (C1) – "One"
T gives directions to the child for completing the task.	T – "Do all your containers and have a guess at them."
C2 watches C1 and then copies the procedure/task.	
C3 looks at a container (a box) carefully and then writes on his answer sheet. T asks about progress. * T refers to the same teacher throughout this video segment.	T – "How are we going with our estimates?"

(Source: video recording, 18/6/03)

Peer Sharing and Tutoring

Two mathematics activities for which video recordings were of sufficient quality to yield comprehensive data regarding what children said and did are used in this section to examine the children's mathematical discourse according to MacMillan's (1998) model. The two activities were also chosen because they are different in mathematical content and different in teaching and learning format. The first activity, *Building a clay castle*, relates to shapes and position, and was completed by the children as a learning centre activity. The other activity, *How many 100s and 1000s on a slice of bread?*, involves estimation and counting, and it was completed as a 'buddy' activity with Year 5/6 students.

Building a clay castle: As part of a curriculum theme about medieval life, students completed a learning centre task focused on making a small clay castle. They worked in small groups on this task, which had numeracy learning objectives related to spatial concepts (shapes in the overall form of a castle and relative positioning of components of the castle). As a learning centre task, students did not all complete the activity at the same time. One group of four children with the researcher present was video recorded building a clay castle. While this small group was completing the task, four additional students came to the clay table. Thus, analysis of the children's mathematical discourse for this activity was based on eight children's participation.

How many 100s and 1000s on a slice of bread?: This measurement-based activity was a 'buddy' class task in which students were paired with a Year 5/6 student to work on the problem: "How can you measure the number of 100s and 1000s on a slice of bread? Record your thinking." The recording of the buddy activity was made during a free discussion time while the children worked with their buddies. The children were involved in talking about how to solve the problem, and the recording involved input from three pairs of students working near one another. Thus, although students were completing the task as a 'pair', their ideas were influenced by those of the larger group.

MacMillan's (1998) model was used for analysis of these activities because it can be used for "classifying elements of linguistic interaction in such a way as to provide insights into the learning environment and learning process" (p. 111). More specifically, analysis of the children's linguistic interactions in this study identified specific learning patterns used by the children. The results of applying MacMillan's model to the data are shown in Table 3.

Table 3
Mathematical Discourse in the Clay Castle and 100s and 1000s Activities

Mathematical Discourse Sub-Category	Frequency (Castle)	Frequency (100s & 1000s)
Counting	0	37
Measuring	0	1
Locating	1	0
Designing	4	1
Explaining	7	27
Playing	0	2

The results in Table 3 show that the children primarily used *counting* and *explaining* mathematical discourses during these activities. An example of the use of counting discourse was: "There's a thousand there!" An example of explaining discourse was: "We don't really know how many times. I shaked [sic] it so we couldn't count it." The language use varied between the two activities, with 37 counting interactions and 27 explaining utterances occurring during the 100s and 1000s activity. In comparison, during the learning centre clay castle activity, seven of the interactions were *explaining*, with the most frequent other language interaction being *designing*, which had four occurrences for the small group recorded. The clay castle learning centre activity results indicate less talk and discussion overall, however, the children were immersed in the physical construction of a clay castle. That is, much of their focus and time was on physical manipulation of the clay. Hence, the activity did not lend itself to as much discussion as did the 100s and 1000s task. Despite this, the results indicate that explanatory interactions played a role in both activities.

The presence of explanatory language supports the idea that the children were scaffolding each other's learning, through three forms of explanatory language as proposed by MacMillan (1998): requesting explanations; providing reports; and giving reasons for actions. Examples of each of these are, respectively: "What colours do we have?" (100s and 1000s activity); "It looks like a triangle" (clay castle activity); and "You've got to press it to stretch it" (clay castle activity). Although the data samples are not extensive enough to support a claim that these three language forms were a pervasive component of the children's language use, the fact that they were present in these learning interactions indicates they can arise within learning activities.

The presence of counting language shows the children used specific mathematical terminology in their interactions. In the 100s and 1000s activity the mathematics language used by the older children such as, "So we did five shakes each, each third", "One hundred, no that would be too many" or "We got a half measure to the middle then added that together" (running record, buddy activity, 17/06/03), encouraged the younger children to consider numbers or concepts with which they might not have been familiar. For example, there were references to fractions and large numbers. However, since the older students' comments were in a context that could be seen, the children were given a concrete representation by which they might be able to construct mathematical meanings for unfamiliar concepts.

These language interactions show the Year 5/6 students doing more than sharing ideas. They took a leadership role, as teachers or peer tutors, to provide information or guide procedures to support the numeracy learning of their less knowledgeable buddies. A detailed example of this is outlined in Table 4. In this case the older student steps in near the end of the passage of talk to reinforce procedure and keep the group on task. Throughout the talk, large numbers are used, exposing the younger children to these concepts. The older student also reinforced the concept of estimation.

In the clay castle and 100s and 1000s activities students exchanged ideas with one another. In fact, the children were encouraged, as part of normal classroom routines, to share ideas, to examine how another child solved a problem, and to make use of these other ideas for their own learning. Interactions that could more appropriately be labelled 'leadership' or 'tutoring' occurred frequently when more capable students were intentionally grouped with less capable students. This was always the case for the buddy activities with the Year 5/6 students, which occurred once a week for an hour with a focus on the Measurement strand in mathematics. In general, the data showed that leadership or tutoring roles taken on by the older Year 5/6 students stimulated mathematical discussions. For example, the problem given to the buddy pairs on 17/06/03 was: *How can you measure the height of the goal posts on the oval?* The buddy pairs discussed how they thought they could solve the problem; they then proceeded to the oval to complete the task. The whole group discussion after this activity showed the Year 5/6 students led the younger students in some thorough explorations of the mathematics. One buddy pair was observed to use perspective and other pairs used the shadows of the poles and calculated the difference in height

Table 4
A Segment of Discourse in the 100s and 1000s Activity

Discourse/activity	**Sub-Category** (McMillan, 1998)
laughter	
"No, you're supposed to…[inaudible]"	Rules
"That bit's my bit."	Resist
"How many shakes does a (inaudible) make?" (Yr 5/6 student)	Counting
"We did heaps."	Counting
"We did about a hundred."	Counting
"The one with the hole in is mine."	Exclude
"And…[inaudible] we tipped it all over it."	Measuring
"No, no, no not yet. When we've finished" [laughter and talking together]	Co-operation
"OK start counting every sprinkle." [laughter]	Counting
"All the reds are …[inaudible]… get a pencil." (Year5/6 student)	Explaining
"1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12"	Counting
"Its too hard, they're all clogged up." [laughter]	Explaining
"There's a thousand there." (Year 5/6 student)	Counting
"There's a thousand on there."	Counting
"Estimate." (Year 5/6 student) "You guys do an estimate first." (Year 5/6 student)	Designing
[Teacher comes to desk]	

(Source: buddy activity transcript, measurement activity, 3/6/03) of the shadows before completing their calculation. Discussion, talk and interaction occurred prior to completion of the task, during exploration of the task on the oval, and after solving the problem. It showed how integral peer interaction and collaboration were in relation to students' numeracy learning experiences in this multiage context.

Peer Regulation

Table 5 shows the results of applying the Socio-Regulative Interactions component of McMillan's (1998) discourse analysis framework to the clay castle and 100s and 1000s activities.

Table 5
Socio-Regulative Interactions in the Clay Castle and 100s and 1000s Activities

Socio-Regulative Interactions **Main Category**	**Sub-Category**	**Frequency** (Castle)	**Frequency** (100s & 1000s)
A. Interpersonal motivations	Recognition	1	0
	Respect	0	0
	Co-operation	0	7
B. Individual motivation	Choice	0	0
	Imagination	2	0
	Competition	0	2
	Curiosity	1	1
	Non-engagement	0	5
C. Interpersonal responsive control	Modelling	0	0
	Assisting	0	0
	Observing	0	0
	Improvising	0	0
	Positioning	0	0
	Direct instruction	2	3
D. Interpersonal restrictive control	Exclude	2	0
	Resist	2	1
	Classify	1	0
	Rules	0	9
	Threat	1	0
E. Identity formation	Co-participation	0	1
	Responsible self-regulation	0	0
	Clear access	0	0
	Non responsive regulation	0	1

Noteworthy results for the 100s and 1000s activity were for the *co-operation* (Category A), *non-engagement* (Category B), and *rules* (Category D) interactions. The high number of interactions classified as *non-engagement* arose from a need to classify social talk that was unrelated to the activity, such as comments about a television program, sporting event, or school happening. This "talk" did not necessarily reflect non-engagement in the activity, but rather, it appeared to occur as a natural part of having students work together who do not see each other every day in class. Interactions that were classified within the rules sub-category reflect when students reinforced classroom norms or rules of their own accord, indicating a degree of self-regulatory awareness and action. For example, in reiterating to another child the classroom norm of keeping track of one's work, one child said: "You've got to calculate it first and write it down." The *co-operation* sub-category relates to interpersonal co-operation. An example was, "You cut one and I'll cut another." In this example, one child shared the task components and elicited co-operation from a peer in order to complete the task. The presence of *co-operation* indicated that classroom values to work with one another productively were reinforced by the children themselves. This self-regulation served to support learning in that children kept track of one another while working towards completion of an activity, for example, by offering suggestions for what might be done: "Do you want to estimate how many sprinkles on …[the piece of bread]." Thus, language-based social interactions that supported the values of community learning were an integral part of children's numeracy learning within this multiage environment.

In comparison, the information in Table 5 for the clay castle activity provides scant insight into the possible learning value of language-based social interactions. The activity, as already indicated, involved students in physical activity in the presence of a small group of children, but it did not require the children to work cooperatively. That is, unlike the 100s and 1000s activity, the clay castle activity was not structured to necessitate a sharing of ideas amongst peers, and as noted previously by one of the teachers, "you need to model and support the learning to work in that way". This is not in fact a new finding, as it has previously been noted in the research literature that group work, multiage or otherwise, does not necessarily lead to interactions in which students share and discuss ideas or work collaboratively to solve a problem (e.g., Tudge & Rogoff, 1989).

Overall, data from the classroom observations indicated that teachers explicitly fostered a family or community atmosphere in which teachers and students work together. Respect for peers, tolerance, and non-competitiveness were valued, and were included in the class virtues program. As part of class meetings, social issues were resolved, and according to one of the teachers, there was much self-regulation of behaviours, with "very rarely a cross word." The degree to which children saw themselves as responsible for assisting and supporting others was further reflected in a question asked by a student upon completion of a task:

"Can I help someone?" This child was later observed to voluntarily support peers in a "students at educational risk" grouping.

Conclusions and Implications

In summary, the key numeracy teaching and learning practices that emerged as themes in this case study of a multiage early childhood classroom were: teacher planning, teacher "assisted performance", peer sharing and tutoring, and peer regulation. A further examination of the nature of each of these four facets of the teaching and learning context reveals that they differ with regard to the degree to which they have a "structure" orientation versus a "learning interaction" orientation. For example, planning by the teacher for developmentally and contextually appropriate learning activities to foster numeracy learning was a component of the structure of the learning environment. Planning emerged as an important component of the learning experience in that it was directly related to the ways in which children could engage in learning activities. Similarly, the social environment of the classroom was built within a multiage educational philosophy that values and explicitly aims to build individual and group self-responsibility and self-regulation in learning. As structural components of the learning environment, planning, and self-responsibility and self-regulation were potentially valuable because through the associated social interactions of teacher-assisted performance, and peer sharing and tutoring, there was support and encouragement for children to further develop their mathematics concepts and processes. Thus, at a more global level, the children's numeracy learning experiences were integrally embedded in the social and language interactions in which they engaged.

The success of the social interactions; that is, whether or not new learning could occur, appeared to be dependent on intersubjectivity. "Intersubjectivity is created between children when they are able to come to a shared understanding of the process and goals of the activity" (Aschermann, 2001, p. 13). This notion was relevant for this case study as it appeared as integral for more knowledgeable peers to scaffold the learning of less knowledgeable peers. Often, when a more knowledgeable student discusses a concept with a less knowledgeable peer, a condition of different perspectives or 'cognitive conflict' is induced (Tudge & Rogoff, 1989). The intersubjectivity through the interaction allows the less knowing student to be supported (scaffolded) through the learning process until a joint new understanding is acquired. Thus, peer sharing and tutoring emerge as key components of teaching and learning practices that can support children's numeracy learning.

Peer sharing and tutoring are not unique to multiage settings, and, in fact, research has shown that students cannot learn thoroughly without interaction with more knowledgeable peers. Thus, peer tutoring has been a major focus for researchers in multiage education. Interaction with peers has been found to be particularly important in 4- and 5-year-olds' education because these children are more likely to advance cognitively when working with a partner (Tudge & Rogoff, 1989). The importance of peer tutoring that emerged in this study was also recognised by one of the teachers in the classroom:

> I have to sit back and think why are we [teachers] interfering? Why don't you allow them to do it more than they do? Because they [the students] can answer each other's questions really easily. They can show each other how to do the problem.

Students were observed giving direct support to peers. Teachers felt that peer tutoring was very important and one of the major advantages of multiage grouping. Peer tutoring was seen as a natural, highly effective way to support students' learning of new concepts. The children appeared to construct knowledge through sharing, talk and problem solving with their peers in a variety of ways. Whilst peer tutoring can be implemented in any classroom, an advantage of multiage groupings is the relatively easy pairing of more knowledgeable peers with less knowledgeable peers because the wider diversity of ages leads naturally to a diversity of levels of achievement. The importance of this for other teachers is that peer tutoring is an effective, important teaching strategy that is more easily utilised in a classroom structured as the one observed in this study — a classroom with an appropriate community culture (e.g., peer regulation), and appropriate teacher planning.

A further component of the social and language facets of the learning experiences was the explanatory language that was used in peer discussion. Language viewed as symbols forms a part of mathematical representations, other representations being enactive (concrete or hands-on) and iconic (pictorial or diagrammatic) (Frid, 2001). In the castle building activity the mathematical concept of shape was investigated by manipulating the clay to make the triangular turrets and other shapes in the buildings (enactive). There were pictures of castles pinned to the nearby board to stimulate and give a pictorial reference to the shapes in castles (iconic), and talk and discussion during the activity. Although not extensive, the pictures and talk contained references to the names (symbols) of shapes, what they looked like, and how to create them.

Qualitative studies such as this one provide insights into actual processes in a classroom. Teachers can apply the findings of this study directly to a classroom situation. In particular, the teachers in this study fostered a problem solving approach to support numeracy learning, and within this approach they used flexibility. Teacher assisted performance was used when it was deemed appropriate, but at other times students were left to work through an activity entirely on their own.

A community of learners was observed in this case study. The children were self-regulating and enacted community values of sharing and helping. As a result, classroom management was based on trust, understanding and common goals, and not an enforced unrelated set of rules. Again, although these are not aspects of a classroom culture that can only be enacted in a multiage setting, this environment provides a natural context in which a diversity of learning needs and achievement levels must be recognised and accommodated. In single-age classrooms, there are other avenues by which the benefits of peer interactions between children of different ages can be obtained, for example, as with the buddy pairs' activities in this study.

The findings of this study raise a number of issues in need of further research. Specifically:

- Studies investigating the types of mathematical discourse used in differing numeracy related activities are needed and could inform future curriculum planning at early childhood as well as other levels of education;
- More research is needed into prominent features of classroom pedagogic environments designed to support early childhood numeracy learning including multiage and single-age class groupings; and
- The learning outcomes achieved by students in multiage settings over extended periods of time need to be examined using formal or standardised assessment tools.

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