Author: E. Harley, B. Perry and S. Dockett
Author Address: bperry@csu.edu.au
sdockett@csu.edu.au
Title: Early childhood educators celebrating and assessing young children's powerful mathematical ideas
Year: 2007
Journal: Journal of Australian Research in Early Childhood Education
Volume: 14
Issue: If applicable
Pages: e.g. pp18-35
ISSN: Enter like xxxx-xxxx
URL: Keywords: Subject/keywords to enhance retrieval

EARLY CHILDHOOD EDUCATORS CELEBRATING AND ASSESSING YOUNG CHILDREN'S POWERFUL MATHEMATICAL IDEAS

Elspeth Harley
South Australian Department of Education and Children's Services
Bob Perry and Sue Dockett
Charles Sturt University

Young children can be powerful mathematical learners (Perry & Dockett, in press; Thomson, Rowe, Underwood, & Peck, 2005). This paper reports work done with preschool educators in South Australia in which powerful ideas in mathematics were identified, linked to the Developmental Learning Outcomes in the mandated South Australian curriculum through a numeracy matrix, and celebrated and extended through narrative assessment (Carr, 2001). It emphasises the processes involved in building the educators' confidence and competence in the observation, development, implementation and assessment of meaningful mathematical learning for young children and suggests ways in which this approach can improve the mathematics education of these children without weakening the strongly held traditional principles of sound early childhood practice.

Keywords: mathematics, learning stories, early childhood educators, assessment

INTRODUCTION

The Southern Numeracy Initiative (SNI) was established in 2004 among five high schools, sixteen primary schools and six preschools in two districts south of Adelaide. The aims of SNI included the following:

- to develop and implement successful teaching and learning practices to improve numeracy; and
- to challenge teachers to explore their beliefs and understandings about how children develop their understanding of mathematics, and how this can be supported through the teaching program.

The preschools in SNI had some concerns about the direction being taken by the schools involved, especially in terms of apparent tension between the formality of instruction and the methods of assessment chosen by the schools and the child-centred, play-based approaches that characterised their early childhood programs. As a consequence, two of the authors of this paper were invited to work with the preschool educators in SNI to develop a program aimed at improving teaching, learning and assessment practices in the numeracy development of young children. The key research question for the overall early childhood project was: *how can the powerful mathematical ideas that are displayed by young children before they start school be recognised and celebrated in a valid manner within the context of a mandated reporting regime and a child-centred, play-based approach to learning?*

In this paper, the results of the project are reported by firstly describing the products of the professional development program and then illustrating these through examples of the mathematical learning of young children and their early childhood educators.

NUMERACY MATRIX – A BRIEF INTRODUCTION

The central product of the SNI preschool project is the *Numeracy Matrix*. This is a large table in which a list of powerful mathematical ideas on one axis and a list of developmental learning outcomes on the other are brought together in a way that has proven to be very helpful for the project participants. In this paper, we consider examples of how participants have used the *Numeracy Matrix* along with the narrative assessment approach known as *Learning Stories* (Carr, 2001) to enhance their approaches to planing, implementing, assessing and celebrating young children's mathematical learning. Consideration is now given to each of the components of the matrix.

DEVELOPMENTAL LEARNING OUTCOMES

Educators in South Australian preschools and schools are accountable to *The South Australian Curriculum, Standards and Accountability (SACSA) Framework* (Department of Education, Training and Employment, 2001). In the preschool year, this accountability for children's learning is reported against eight Developmental Learning Outcomes (DLOs)—broad, observable and assessable consequences of the curriculum that reflect the integration of learning and development and allow for the different developmental pathways of individual children. The Developmental Learning Outcomes are:

- Children develop trust and confidence;
- Children develop a positive sense of self and a confident personal and group identity;
- Children develop a sense of being connected with others and their world;
- Children are intellectually inquisitive;
- Children develop a range of thinking skills;
- Children are effective communicators;
- Children demonstrate a sense of physical wellbeing; and
- Children develop a range of physical competencies.

Further details about these DLOs can be found in the *SACSA Framework* (Department of Education, Training and Employment, 2001).

POWERFUL MATHEMATICAL IDEAS

The notion of school children having access to powerful mathematical ideas is not new (Jones, Langrall, Thornton, & Nisbet, 2002) even though there has not always been agreement on what constitutes these powerful mathematical ideas (Malloy, 2002). It has been less well accepted that children are capable of accessing powerful mathematical ideas that are relevant to their lives before they start school (Kilpatrick, Swafford, & Findell, 2001; Perry & Dockett, 2005a; Thomson et al., 2005). Baroody (2000, p. 66) suggests that "preschoolers are capable of mathematical thinking and knowledge that may be surprising to many adults".

The authors have used the notion of powerful mathematical ideas for some time to plan, observe, facilitate and assess young children's mathematical learning (Perry & Dockett, 2002, 2005b, in press; Perry, Dockett, & Harley, in press). These powerful

mathematical ideas synthesise the minutiae of mathematics learning and teaching into the following areas:

- mathematisation;
- connections;
- argumentation;
- number sense and mental computation;
- algebraic reasoning;
- spatial and geometric reasoning; and
- data and probability sense.

Detailed explanations of each of these areas have been reported elsewhere (Greenes, Ginsburg, & Balfanz, 2004; National Council of Teachers of Mathematics, 2000; Perry & Dockett, 2002, in press; Perry et al., in press).

THE NUMERACY MATRIX

The theoretical basis for the numeracy matrix is that the key determinants of children's successful outcomes are the pedagogical relationships and practices of educators (Laevers & Heylen, 2004). Hence, the elements of the matrix that bring the DLOs and the powerful mathematical ideas together are 'pedagogical inquiry questions'—questions early childhood educators ask about the practices they use to promote children's powerful mathematical ideas and the DLOs.

The numeracy matrix was constructed during four professional development days over 2005-2006. Participants in these days were a small group of early childhood educators from Wallara and Southern Sea and Vines education districts on the southern outskirts of Adelaide and the first two authors of this paper. As well as developing the matrix, these participants also considered ways in which the *Learning Stories* approach to assessment could be used in conjunction with the matrix.

The *Numeracy Matrix* consists of 56 cells (eight DLOs x seven powerful mathematical ideas) in which each cell provides examples of pedagogical inquiry questions early childhood educators can ask themselves as they teach towards, assess or report on the DLOs while simultaneously focussing on the appropriate mathematical development of children. An example of one of the cells of the *Numeracy Matrix* is presented in Table 1. Space precludes the inclusion of the entire matrix in here. It is available in Perry et al. (in press).

TABLE 1

AN EXAMPLE OF A CELL FROM THE NUMERACY MATRIX

	DLO: *Children are effective communicators*
Powerful mathematical idea: *Algebraic reasoning*	How do we encourage children to demonstrate an understanding that symbols are a powerful means of communication? What opportunities do we provide for children to engage in symbolic play?

In this cell are two pedagogical questions which challenge early childhood educators to reflect on what they are doing to help children develop both the mathematical idea and the DLO. The answers to these questions will affirm those educators who are working towards these goals, as well as suggest to them that more activities might be needed to help the children develop further. The questions also stimulate educators who have not considered their practices in these areas to investigate the relevance of current activities and practices or the need for new practices. The *Numeracy Matrix* encourages early childhood educators steeped in play-based, child-centred pedagogies to extend these into the often foreign, scary and neglected area of mathematics. Such an approach fits well with other current statements on mathematical learning for young children (Australian Association of Mathematics Teachers and Early Childhood Australia, 2006; National Association for the Education of Young Children and National Council of Teachers of Mathematics, 2002) and has gone a long way towards providing one answer to the original research question for the SNI preschool project.

The numeracy matrix is, by its very nature, a work in progress. As the early childhood educators using the matrix have become more confident and competent, they have suggested changes. Some mathematics educators who have studied the matrix have suggested possible changes on the basis of recent research in their field – research which is not normally available to practising early childhood educators. The matrix is a dynamic reflection of the knowledge of the educators using it and, as such, should be expected not only to be grounded in the contexts in which these educators work but to change as their knowledge changes.

LEARNING STORIES APPROACH TO ASSESSMENT

Learning Stories are qualitative snapshots, recorded as structured written narratives, often with accompanying photographs that document and communicate the context and complexity of children's learning (Carr, 2001). They include relationships, dispositions and an interpretation by someone who knows the child well. They are "structured observations in everyday or 'authentic' settings, designed to provide a cumulative series of snapshots" (Carr & Claxton, 2002, p. 22). Learning stories acknowledge the multiple intelligences and holistic nature of young children's learning, educators' pedagogy and the context in which the learning takes place.

In South Australia, learning stories have been used by preschool educators for some time, especially in the area of literacy learning. However, they tended not to be used in the area of mathematics, partly because the preschool educators did not have sufficient confidence in their ability to link what they were observing with mathematical learning outcomes. The introduction of the *Numeracy Matrix* has given this confidence to the group of educators working with the authors and has produced some outstanding results.

USING THE *NUMERACY MATRIX* AND *LEARNING STORIES* – SOME EXAMPLES

Three groups of early childhood educators in very different prior-to-school settings in the Wallara and Southern Sea and Vines districts of the South Australian Department

of Education and Children's Services worked within the SNI preschool project to record, assess and celebrate the mathematical activity of their children. In this section of the paper, we celebrate the work of these educators as they strived to answer the research question posed by the project: *how can the powerful mathematical ideas that are displayed by young children before they start school be recognised and celebrated in a valid manner within the context of a mandated reporting regime and a child-centred, play-based approach to learning?*

Setting 1 is a small semi-rural centre in the hills to the south of Adelaide; Setting 2 is a 40-place centre servicing working class families in the southern suburbs of Adelaide and Setting 3 is a large centre servicing a mainly white middle-class suburb approximately 30 km from the centre of Adelaide. In each of these settings, staff have accepted the challenge to prepare learning stories on children's mathematical development and activities and to analyse these against the numeracy matrix so that children's mathematical ideas are recognised, celebrated and used in the further development of the children's mathematical potential.

Setting 1

As part of their work on the development of children's voice in the planning and implementation of learning activities and practices, the staff at this setting determined that they would concentrate on the pedagogical inquiry question: *What (children's voice) opportunities do we provide to enable children to reflect upon and communicate their mathematical thinking?* that appears in the *Mathematisation / Children develop a range of thinking skills* cell of the *Numeracy Matrix*. After analysing the key words in this question, the educators determined that they would make some initial observations of two boys playing with a construction material *Clikko*. One observation was about the different approaches the boys took to the material.

Jack's independent approach:

- Experimental and emergent.
- Creation became an object once it was constructed.
- Demonstrated how his construction worked using moving parts.

Callum's technical approach:

- Eager to work to a plan.
- Initial help was to establish a starting point and then he proceeded with minimal intervention.
- Verbalised knowledge of shapes he needed as he read from the plan eg open or solid shape.
- Help was requested for the final folding.

Figure 1: Observation by educators of different approaches taken to *Clikko*

Jack and another boy, Nathan, also made some interesting discoveries about shapes and materials while playing with a magnet construction toy.

- Nathan and Jack spent considerable time over many sessions exploring the Magnetic construction set.
- Self discovery by the children enabled them to extend beyond the original wooden table to a metal table, a metal vertical surface and metal poles.
- Since their early successful experience with the Magnetic Construction, Jack and Nathan have spent further time exploring possibilities and discovered a new way of building (under the table).

An excerpt from Nathan's learning story "Nathan continues to show curiosity as he explores the area of construction using different medium. He shows strong concentration as he spends time becoming familiar with the properties of the materials and then draws from previous knowledge to make the shapes that he is able to name, describe and teach to others. He is also proud of his efforts and celebrates his achievements with others."

Figure 2: Observation by educators of play with Magnetic Construction

The stimulus provided by the particular pedagogical inquiry question chosen has continued as the educators extended their work to include the families of the children at the centre and their own reflections on the SNI preschool approach. In their own reflections on what has been the key mathematical learning for them as educators, the following comments were made by the educators in Setting 1:

- The learning stories provide rich assessment of the children's learning. They have changed over time becoming more in depth and releasing the numeracy within.
- We have enriched our knowledge of the children with discussions with parents through our Governing Council, celebrations shared of literacy and numeracy as well as individual discussions with parents and networks.
- Our teaching has been enriched by the discussions and sharing of new stories within our learning circles.
- This has encouraged us to question what the children know and what they are capable of working out given time, opportunity and their own expression.

Setting 2

At this preschool, investigation and problem solving were often undertaken but without a lot of planning and little assessment. Hence, it was natural for the educators

in this setting to choose the pedagogical inquiry question: *What opportunities do we provide for children to participate actively in collaborative mathematical problem solving and problem posing?* from the *Mathematisation / Children develop a positive sense of self and a confident personal and group identity* cell for their initial foray into using the *Numeracy Matrix.*

One of the activities chosen for their work was around the strength of air. Figure 3 records the group learning story which arose from this activity. (Note that while the learning story was written by an educator, it reads as if the children have written it.) The gradual implementation of the strategy of 'one more on the table' showed the children's willingness to mathematise the situation by introducing ideas of heaviness and counting to help them solve the physical problem presented.

We have all been learning about air –

Children have observed the weather, and noted how it moves leaves, even though we can't see it.
Children have experimented with air – blowing paint and balls along the carpet through straws, and predicting how far an air filled balloon rocket will fly.

Today Hazel asked us if a balloon would be strong enough to hold up a table.

We said **NO** !

She blew up 1,2,3,4 balloons, and placed them under the corners of the upside down table, and the balloons didn't even pop.

She asked us if the balloons would be strong enough to hold a person on the table.

We said **NO** !

Jeremy volunteered to add some more weight. **The balloons didn't burst.**

Some children were quite scared and apprehensive. Others were excited.

Gradually more and more children volunteered to stand on the table.
Suddenly there was a bang !

Now we were too heavy.

Figure 3: Group learning story on the strength of air

In this setting, there were many other examples of the pursuit of learning through investigation of the pedagogical inquiry question. Activities such as planning, preparing shopping lists, shopping and cooking for a family day; walking in the park

and collecting leaves; and voting for which activities the group might do in the future all involved collaborative mathematical problem solving and problem posing. The impact of the learning stories approach on how the educators communicate with their children and families is clear from the use of a *Learning Story Wall* in the centre.

Figure 4: Learning story wall

The educators from Setting 2 reflected on their involvement in the SNI preschool project in the following ways:

- I think that if we had not chosen an inquiry question, we may not have discovered such powerful learning in preschool children.
- Using the matrix and being able to develop one inquiry question and explore it in depth has illustrated to me how and when to assess children in a variety of ways.
- My ability to focus on mathematical learning and extend individual children's learning as well as assess it positively in learning stories is quite empowering.
- I have been energised, enthused and inspired by being part of the SNI project. I am now eager to incorporate any/all mathematical teaching into everyday practice.

Setting 3

In this setting, the team of three early childhood educators involved in SNI decided that they would work with two related pedagogical inquiry questions: *How do we provide opportunities for children to experiment and think about number in different contexts, including their own family group, traditions and rituals?* from the *Number sense and mental computation / Children develop a positive sense of self and a confident personal and group identity* cell and *What opportunities do we provide for children to explore different mathematical ideas through collaborative group work?* from the *Connections / Children develop a positive sense of self and a confident personal and group identity* cell. Many activities were undertaken. In this paper, we report on just one: *the puppet theatre.*

The puppet theatre project began after a visit to the primary school library when the preschool children saw a puppet theatre and decided that they wanted one for their centre. Over many months, the project developed with the children drawing plans, discussing them with the builder (a father), measuring and ordering materials including curtains, supervising the cutting of the timber, helping to assemble the

theatre and make the curtains, choosing the paint colour, painting, performing and enjoying their work.

As an example of the achievements of the children and their teachers, the following excerpt from the extended learning story shows the care two boys took with the construction of their plans for the theatre.

Jason and Thomas decided to share a large piece of paper to draw their plans. Jason looks at the photo of the Puppet Theatre and begins drawing the sides, shelves, window and top and bottom edges.
"That's it" he says. He finds the ruler and begins making straight lines, bordering his plan. He comments "That's longer", pointing to the bottom line. I ask him what the number is. Jason counts along the ruler markers, stopping at 14. "14 long" he states, carefully copying the numerals. We look at the ruler again and decide the 14 would be centimetres. Jason asks me how to write that. He copies 'cm'. Jason then measures the height of the structure stating "It's 8 tall" as he reads the ruler again. Thomas has been writing numerals along the paper. I ask him what the numerals mean. He says "This says look at the numbers Joe". I ask him why we need the numbers. Thomas replies "So Joe can saw it (wood) right".

Figure 5: Plans for the puppet theatre

Reflections on what the educators at Setting 3 are learning from implementing the SNI preschool project included the following:

- Deepen our own mathematical understandings;
- Recognise the mathematical learnings the children demonstrated in the context of play;
- All areas of mathematics were integrated, not just a focus on number;
- Allow children and educators to take risks;
- Different perspectives on tackling the same 'mathematical' task;
- Knowledge and confidence in numeracy (eg. writing a learning story and pulling out the various numeracy content and process strands – reaffirmed that what we are doing supports numeracy development);
- Partnerships with parents; and
- Mathematics is happening in our current program, we just need to recognise it.

CONCLUSION

The impact of the SNI preschool project is just beginning to be felt by the participants involved and the children in their centres. There is clear evidence in the material presented that the educators are beginning to recognise the power of young children's

mathematics and to realise ways in which they can nurture this power within the mandated reporting mechanisms under which they work. The educators have not 'sold out' on their early childhood principles to achieve this. Rather, they have maintained their child-centred, play-based approach to learning while achieving spectacular outcomes for their children. This has been achieved through the increases in confidence about mathematics and mathematics learning that have been displayed, recognised and celebrated by each of the early childhood professionals involved. Both the *Numeracy Matrix* and *Learning Stories* have played a part in this success. In the words of one of the educators involved:

> The numeracy matrix has been an extremely useful tool for helping us to maintain a focus on holistic learning while exploring mathematical concepts and processes in the context of our mandated curriculum framework. The development and use of a narrative form of assessment has been one of THE most useful tools in helping us to remain true to our underlying early childhood philosophy of learning and to assess children's learning without formal testing.

REFERENCES

Australian Association of Mathematics Teachers and Early Childhood Australia (2006). *Position paper on early childhood mathematics*. Available on-line from: http://www.aamt.edu.au/about/policy/earlymaths_a3.pdf

Baroody, A. J. (2000). Does mathematics instruction for three- to five-year-olds really make sense? *Young Children, 55*(4), 61-67.

Carr, M. (2001). *Assessment in early childhood settings: Learning stories*. London: Paul Chapman.

Carr, M., & Claxton, G. (2002). Tracking the development of learning dispositions. *Assessment in Education, 9*(1), 9-37.

Department of Education, Training and Employment. (2001). *South Australian curriculum, standards and accountability framework*. Adelaide: Author. Available online from: http://www.sacsa.sa.edu.au

Greenes, C., Ginsburg, H. P., & Balfanz, R. (2004). Big math for little kids. *Early Childhood Research Quarterly,* 19(1), 159-166.

Jones, G. A., Langrall, C, W,, Thornton, C. A., & Nisbet, S. (2002). Elementary students' access to powerful mathematical ideas. In L. D. English (Ed.). *Handbook of international research in mathematics education: Directions for the 21st century* (pp. 113-141). Mahwah, NJ: Lawrence Erlbaum.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.) (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Laevers, F., & Heylen, L. (Eds.). (2004). *Involvement of children and teacher style: Insights from an international study on experiential education.* Leuven, Belgium: Leuven University Press.

Malloy, C. E. (2002). Democratic access to mathematics through democratic education: An introduction. In L. D. English (Ed.). *Handbook of international research in mathematics education: Directions for the 21st century* (pp. 17-25). Mahwah, NJ: Lawrence Erlbaum.

National Association for the Education of Young Children and National Council of Teachers of Mathematics (2002). *Early childhood mathematics: Promoting*

good beginnings. Washington, DC: Author. Available online from: http://www.naeyc.org/about/positions/pdf/psmath.pdf

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Perry, B., & Dockett, S. (2002). Young children's access to powerful mathematical ideas. In L. D. English (Ed.). *Handbook of international research in mathematics education: Directions for the 21st century* (pp. 81-111). Mahwah, NJ: Lawrence Erlbaum.

Perry, B., & Dockett, S. (2005a). "I know that you don't have to work hard": Mathematics learning in the first year of primary school. In H. L. Chick & J. L. Vincent (Eds.), *Proceedings of the 29th conference of the International Group for the Psychology of Mathematics Education,* (Vol. 4, pp. 65-72). Melbourne: University of Melbourne.

Perry, B., & Dockett, S. (2005b). What did you do in maths today? *Australian Journal of Early Childhood. 30*(3), 32-36.

Perry, B., & Dockett, S. (in press). Young children's access to powerful mathematical ideas. In L. D. English (Ed.). *Handbook of international research in mathematics education: Directions for the 21st century* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.

Perry, B., Dockett, S., & Harley, E. (in press). Learning stories and children's powerful mathematics. *Early Childhood Research and Practice.*

Thomson, S., Rowe, K., Underwood, C., & Peck, R. (2005). *Numeracy in the early years: Project Good Start.* Melbourne: Australian Council for Educational Research.

AUTHORS

Elspeth Harley, Policy and Program Officer (Early Years) Office of Early Childhood Services, DECS South Australia, Education Centre, Level 4, 31 Flinders Street, Adelaide 5000. Specialisations: Early childhood curriculum, play in the early years, assessment for learning in the early years.
Email: harley.elspeth@saugov.sa.gov.au

Bob Perry, Associate Professor of Education, Murray School of Education, Charles Sturt University, PO Box 789, ALBURY NSW 2640. Specialisations: Early childhood mathematics education, educational transitions, early childhood and primary teacher education.
Email: bperry@csu.edu.au

Sue Dockett, Professor of Early Childhood Education, Murray School of Education, Charles Sturt University, PO Box 789, ALBURY NSW 2640. Specialisations: Early childhood education, educational transitions, children's play, children's thinking, early childhood teacher education.
Email: sdockett@csu.edu.au

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of the following early childhood professionals in the SNI preschool project and the development of this paper: Melissa Anderson; Glenda Fletcher; Shelley Mair; Marian Nayda; Meredith Retallack; Julianne Roy; Wendy Stevens.