Reflecting on Young Children's Mathematics Learning

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Over the last 6 years, South Australian preschool and first years of school educators[1] have come together to consider how they can facilitate young children's[2] learning of powerful mathematical ideas without jeopardizing the well-established benefits of young children learning through play. The chapter begins with a brief discussion around the recognition of young children as powerful mathematicians and how this recognition is facilitated through the documentation of children's mathematical learning using learning stories. It then introduces the *Early Years Numeracy Project* in South Australia and reviews the development of a major artifact from the project—the *Reflective Continua*. Ways in which educators have used the *Reflective Continua* to stimulate the powerful mathematics learning of young children complete the chapter.

Young Children as Powerful Mathematicians

It is well known that young children can be powerful mathematicians and that they are able to demonstrate this power through their actions in both play and structured learning (Hunting et al. 2012; Kilpatrick et al. 2001; Lee and Ginsburg 2007; Perry and Dockett 2008; Sarama and Clements 2009; Thomson et al. 2005). The Australian Association of Mathematics Teachers (AAMT) and Early Childhood Australia (ECA) (2006, p. 1) state that

[1]The term 'educators' is used throughout this chapter to designate anyone working with children in prior-to-school or school settings who may impact on the children's learning. For example, 'educators' may be teachers, assistants, preschool directors, and school principals.

[2]The term 'children' is used throughout this chapter rather than 'students'. This allows the one word to be used for young people in preschool and school settings.

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> all children in their early childhood years are capable of accessing powerful mathematical ideas that are both relevant to their current lives and form a critical foundation to their future mathematical and other learning. Children should be given the opportunity to access these ideas through high quality child-centred activities in their homes, communities, prior-to-school settings and schools.

The first curriculum framework for Australian early childhood education—*Early Years Learning Framework for Australia* (Department of Education, Employment and Workplace Relations (DEEWR), 2009, p. 38) provides a list of these powerful mathematical ideas:

> Spatial sense, structure and pattern, number, measurement, data, argumentation, connections and exploring the world mathematically are the powerful mathematical ideas children need to become numerate.

Australia has also recently introduced its first national curriculum in mathematics (Australian Curriculum, Assessment and Reporting Authority (ACARA) 2011) which contains a similar list of powerful mathematical ideas: number and algebra; measurement and geometry; statistics and probability; understanding; fluency; problem solving; and reasoning. These powerful mathematical ideas form an important foundation for the *Reflective Continua* to be investigated in this chapter. Another foundation is the notion of *learning stories.*

Learning stories (Carr 2001; Carr and Lee 2012)

> 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 and 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. Educators use their evaluation of the learning story to plan for future, ongoing learning (Perry et al. 2007a).

Such learning stories have allowed the components of the *Reflective Continua* to be demonstrated through the use of 'work samples' created by children and educators in authentic contexts. Links between a young child's observed and documented activity, and powerful mathematical ideas are illustrated through the following example of a learning story, written by a preschool educator, which considers 4-year-old Rachel's interest in shapes (Fig. 1).

> Rachel likes to play with shapes and was laying out the shapes on the table and putting them together so there were no gaps. She used the colours and the shapes to create a pattern. She stood some of the blocks upright to make a border around her pattern. Rachel could tell me [the educator] what colours she had used and how she had made her pattern. When I asked her why she thought it was a pattern she said "It goes green triangle, then red square, then red square and back to green triangle". I asked her why she had put the shapes standing up. She replied "This is the border and they are all the same shape".

Rachel has a clear view of what a pattern is and how patterns can be used in her play and learning. She is able to explain and justify her decisions and to use the results of her investigations to extend her thinking. Powerful ideas in mathematics

Fig. 1 Rachel—powerful mathematician

and Rachel's play have coalesced to provide an opportunity for learning in a relevant and meaningful context. How educators recognise these powerful mathematical ideas and undertake their own pedagogical inquiry about planning future mathematical learning experiences for their children provide the focus of this chapter.

The Early Years Numeracy Project

The *Early Years Numeracy Project* (EYNP) ran in various guises from 2004 to 2011 in the state of South Australia using a collaborative approach to professional development for both preschool and first years of school educators (Perry 2011; Perry et al. 2007b). While there have been many positive outcomes from this project, the two most tangible artefacts have been the *Numeracy Matrix* and the *Reflective Continua*. The development and use of the *Numeracy Matrix* have been reported elsewhere (Harley et al. 2007; Perry et al. 2012). In this chapter, we consider the development and use of the *Reflective Continua*.

The Reflective Continua

The final phase of EYNP, from 2009 to 2011, had the following aims:

- to develop the mathematics content knowledge and pedagogical content knowledge of the site-based early childhood educators;
- to build on previous work that had led to the development of the numeracy matrix linking powerful mathematical ideas to developmental learning outcomes; and
- to develop and trial reflective continua based on the numeracy matrix and the use of learning stories (Carr 2001) to guide mathematics teaching and learning for children aged 3–8 years in preschools and the first years of school.

This chapter reports on the fulfilment of the third of these aims.

For the development of the *Reflective Continua*, the researchers worked with four Numeracy Leaders—three from the first years of school, and one from preschool.

The Numeracy Leaders' role was to work with a total of 45 site-based early childhood educators in preschools and schools to introduce and implement the *Reflective Continua*.

From July, 2009 until December, 2010, regular professional learning meetings were held for the four Numeracy Leaders. These meetings were led by the researchers and centred on powerful mathematical ideas and links to both school and preschool curricula. The professional learning meetings also focused on the role of Numeracy Leaders in the development of collaborative partnerships with colleagues. The role of the Numeracy Leaders was challenging, as each was responsible for engaging and guiding both preschool and school educators in their clusters. Ongoing support from each other and the project leaders was a critical element of the Numeracy Leaders' programs.

Educator reflection on their own pedagogical practice had been a key component of the EYNP from its inception (Perry et al. 2007a, 2006). Hence, the development of a *Reflective Continuum* for each of the powerful mathematical ideas that encapsulated the pedagogies of their settings was a natural consequence of the earlier work.

Through an iterative approach involving the Numeracy Leaders and the educators in the clusters, the *Reflective Continua* were created.

What Are the Reflective Continua?

In their final form, the *Reflective Continua* consist of a set of seven tables—one for each of the strands and competencies (powerful mathematical ideas) in the *Australian Curriculum—Mathematics* (ACARA 2011): number and algebra; measurement and geometry; statistics and probability; understanding; fluency; problem solving; and reasoning—which provide frameworks to guide educator reflections on children's mathematical work. Such reflective practice is designed to assist educators plan future learning experiences for their children. Each *Reflective Continuum* highlights a progression of development and engagement with the relevant powerful mathematical idea. These progressions have been developed by the site educators under the tutelage of the Numeracy Leaders and the researchers, using the current curriculum documents for guidance.

Four levels of development and engagement are used to demonstrate children's progression—*Emerging, Investigation, Application and Generalisation*. The meanings given to each of these levels are:

- *Emerging*: the learner is beginning to understand the basic concepts involved in the powerful mathematical idea but is not yet able to use this early understanding;
- *Investigation*: the learner is confident enough in her/his understanding of the powerful mathematical idea to explore problems and real-life situations;
- *Application*: the learner's knowledge and understanding of the powerful mathematical idea can be applied to find solutions to problems;

- *Generalisation*: the learner is able to transfer her/his knowledge and understandings between powerful mathematical ideas and/or powerful ideas from other key learning areas.

An example of one Reflective Continuum is given in Fig. 2.

For each level in each *Reflective Continuum*, a number of 'indicators' are provided as guidance to educators about what might be expected to be observed from children working at the level. As well, there are children's names in each column which are hyperlinked to work samples and/or learning stories. For example, clicking on Example 2: Sol in the 'Emerging' column leads to the following learning story:

> Sol went over to the toy tray and pulled out the stacking cups. Very carefully, with lots of balance, she began to stack the cups in sizes. She tried different sizes at first realising a smaller cup would disappear inside a larger one. With trial and error she built a big tower. Sol is showing reflective thinking and problem solving skills which are basic numeracy skills. We could extend her numeracy skills by introducing basic shapes.

This story provides one example of what the Emerging level could look like in Measurement and Geometry. For every level in every continuum, there is at least one example from preschool and one from the first years of school, thus illustrating that all levels are possible in both settings.

The *Reflective Continua* are designed to allow educators to ascertain quickly at which level each of their children is demonstrating her/his knowledge of the powerful mathematical ideas. Children's work samples are provided to illustrate how each level might present in preschools or the first years of school. For example, a preschool child at the Application level of the powerful idea Measurement and Geometry might 'describe position in relation to surroundings' by applying proximity terminology such as 'next to' or 'close'. On the other hand a child in the first years of school might use units of measure or directions to describe her/his position.

The *Reflective Continua* help educators make sense—in terms of powerful mathematical ideas—of their observations of learners that they make as part of the normal routine of each day. By reflecting on observations of learner actions and coupling these to the educators' own understandings of hypothetical learning trajectories (Sarama and Clements 2009), progress towards developing and understanding the seven powerful mathematical ideas can be observed.

There is no suggestion that any child would perform at the same level for each of the powerful mathematical ideas and, therefore, be labelled with one of these level names. As well, there was no attempt to link the *Reflective Continua* levels with either curriculum or Year/age stages. Instead the levels provide a hypothetical learning trajectory (Sarama and Clements 2009) for each of the powerful mathematical ideas. It would be eminently possible for a child in preschool to be demonstrating behaviours that would suggest positioning her/him at, say, the Application level for one of the powerful mathematical ideas while, by contrast, a child in Year 2 might be engaging with this idea at the Emerging level.

There were a number of other issues raised by the Numeracy Leaders and their cluster colleagues during the development of the *Reflective Continua.* Four are of interest here.

Measurement and geometry

Emerging	Investigation	Application	Generalisation
Uses mathematical language without making comparisons of measurable attributes Incidentally compares measurement attributes Shows awareness of space as it relates to one's movement Describes their own position in their environment using words such as 'over', 'under', 'beside', etc.	Investigates the use of units in the measurement process Uses relevant non-standard units to measure through comparing, counting and describing the results in appropriate language Sorts objects according to shape Investigates properties of shapes and the ways they can be manipulated Explores understandings of directional language and mapping	Applies knowledge of the measurement processes to estimate and measure using standard units Applies knowledge of shape and space to help them communicate aspects of their own lives and environment Describes position in relation to surroundings Creates and uses visual representations of various environments	Transfers the understanding of measurement processes using standard units to measure various attributes of an object Uses directions and/or landmarks to plan and describe a journey Employs (mental) visualisation of shapes to solve problems
Example 1: Leon Example 2: Sol Example 3: Kamal	Example 1: Eliza Example 2: Bolek Example 3: Dani	Example 1: Fatima Example 2: Elke Example 3: Katrina	Example 1: Corbie Example 2: Lexie Example 3: Thein

Fig. 2 Reflective continuum for measurement and geometry

Profiling of Children

The possibility of using the *Reflective Continua* to produce individual profiles of children across the seven powerful mathematical ideas was considered but was determined not to be of sufficient value to the educators and children to justify the time that would be necessary to develop profiles.

Local Development of Indicators of Development and Engagement

The possibility that levels of development and engagement with each of the powerful mathematical ideas could be rewritten or substituted by individual educators in order to reflect the particular contexts of the learners was considered. This consideration was seen by the Numeracy Leaders as a positive engagement by the cluster educators with the *Reflective Continua*. However, it was felt that educators needed to become familiar with the continua and use them in their own contexts before they would be able to change the indicators with reliability. Hence, it was communicated to educators in the clusters that they should remain with the published indicators initially, with the aim of changing them to suit only after more extensive use.

Consistency of Judgement

Consistency of educator judgement has been a critical issue in classroom assessment for many years in Australia. It is well known that "a variety of influences and knowledges impact on teacher judgement" (Connolly et al. 2011). The importance of moderation through consultation, negotiation and use of standards in achieving consistency of judgement has also been established (Klenowski and Adie 2009; Wyatt-Smith et al. 2010). Such consistency was an issue for some of the Numeracy Leaders and many of the educators in the clusters. Many of the cluster educators were concerned that they might make different judgements from other educators and that they 'would not get it right'. However, it was determined that, given the primary purpose of the continua was to encourage and facilitate reflection on the part of educators, rather than assessment of the children's mathematics, it did not matter whether one educator made precisely the same judgement based on a particular work sample as others. In the documentation introducing the *Reflective Continua*, it is stated explicitly that the decision about placement of a child on a continuum should be made by an educator who knows the child and has observed the learning experience being judged. As the purpose of the decision is to reflect on the child's work within the learning experience and to answer the question 'Where to next?', there is no need for consistency of judgement. What is important is that the educator making the judgement is able to use that judgement to facilitate further learning by the child.

Expectations of Levels of Development and Engagement for Preschool and First Years of School Children

Not surprisingly, many educators assume that younger children will not be able to develop and engage with powerful mathematical ideas to the same levels as older children (Hunting et al. 2012). This was the case for many of the cluster educators. These educators had not taken into consideration that children's development and engagement with powerful mathematical ideas is determined not only by what the children could do but also by what the educators did. Children are unlikely to demonstrate their full potential unless they are provided with the challenging and supportive contexts that allow them to do so (Bobis et al. 2012; Hunting et al. 2012). The Numeracy Leaders were adamant that the final version of the reflective continua had to demonstrate that children in preschool and the first years of school could perform at all four of the levels. The way of demonstrating this was through the provision of work samples and learning stories from children and educators in both sectors.

Learning Stories

Learning stories and other work samples have been used in the *Reflective Continua* to provide guidance for educators about how children might indicate the level of their development and engagement with each of the powerful mathematical ideas; and, then, what both the educators and the children might do next. At each level of each *Reflective Continuum*, work samples and learning stories are provided from both preschool and school children, illustrating what performance at this level might look like in these settings. We conclude this chapter with several examples of the links between work samples/learning stories and levels in the *Reflective Continua*, using the measurement continuum introduced earlier as an exemplar. All of the judgements concerning the levels illustrated by the samples have been made by cluster preschool and school educators under the guidance of the Numeracy Leaders.

Emerging An example from this level (Sol and the stacking cups) has already been provided earlier in the chapter. However, another is added here for completion.

This learning story reports on a group activity in a first year of school class when the children had been set the task of making gnocchi.

> Leon and some other children were making gnocchi using a recipe that had to be read before cooking the potatoes and mixing them with the flour. While rolling the dough, the children compared size and shape to see if they were on the right track. Leon was particularly keen to make the gnocchi into uniform shapes (same shape and size). We can look for other opportunities to make uniform shapes.

Investigation The following learning story (Fig. 3) developed by a preschool teacher provides evidence of the indicator, 'Uses relevant non-standard units to

Fig. 3 Using non-standard units of measurement—investigation

measure through comparing, counting and describing the results in appropriate language'. The educator also notes in the learning story that the children have demonstrated their learning with other powerful mathematics ideas such as Number and Algebra.

> Today we gave the children the opportunity to measure shapes with some non-standard units of measurement—pebbles, seed pods, shells and dried beans. The children enjoyed chatting to each other about how many of the resources were needed to go around the perimeter of each shape. Once they had measured with one of the resources they would choose another and compare their results. The children were encouraged to record their findings and they did this by writing down the number of shells, pebbles etc they had used and then they drew the shape they had measured. It was interesting to note that they then started to form patterns around the perimeters of the shapes using the pebbles, pods, shells and beans. Bolek went out into the garden and found sticks and rosemary twigs and used these to measure around the shapes, showing that he had an understanding of the fact that many things can be used to measure. The children also noticed that more small objects and less large objects were required to measure the perimeter of a given shape. I need to provide more opportunities for them to explore this further.

Application The use of standard units—represented here by the materials available to the child—and the applications required to undertake estimation in measurement are illustrated by Katrina's understanding of the measurement of area in this learning story (Fig. 4).

> Today the children were given the opportunity to measure the area of different sized leaves using Unifix blocks. Katrina set to work and covered a leaf with blocks and discovered that she had used 18 blocks to cover the area of the leaf. She then chose a smaller leaf and I asked her how many blocks she thought she would need to cover this leaf. I explained to

Fig. 4 Learning about area—application

her that this was called estimating and she predicted that the leaf would be covered with 8 blocks. Katrina's estimation was very good as the area of the leaf was in fact 7 blocks. She continued to choose leaves and cover them with blocks, estimating each time the number of blocks she thought she would need. For a middle sized leaf she estimated 9 and the area was in fact 10, for a bigger leaf she estimated 28 and the area was in fact 25.
Through this activity Katrina demonstrated that she can use relevant units to measure attributes of objects, through comparison and counting and describe the results in appropriate language. She is also aware that number has meaning in everyday worlds, can count in rote and she also recognises patterns of numbers to quantify small collections without counting.

Generalisation This example from a Year 4 class provides an insight into how school educators might utilise learning stories and the power it can give the educator to reflect on children's learning. Even though the *Reflective Continua* were developed for use in early childhood settings, it would seem that they might have application with older children.

Corbie was working in a group of five children and their task was to measure and give directions from the classroom to the flying fox, but they had to travel around the hitting wall. They were asked to choose appropriate measuring tools and estimate as they went. The group decided to bring a trundle wheel and a measuring tape.
The first suggestion for the first step was, "Go out the door and walk down the ramp."
Corbie didn't think this should be the first step as there was no measurement involved.
Corbie: We could say go through the door and turn to the left and then we could measure all the way to the end of the art room because we don't have to change direction until then.
Educator: How far to the left would you need to turn?
Another group member: A quarter turn?
C: Can I write 90° instead?
E: Is it the same as a quarter of a turn?
C: Yeah.
E: Then of course you can use it in your recording.
The group then estimated how far they thought it was to the end of the art room and measured it with the trundle wheel. Corbie took great care to ensure that the trundle wheel was stopped precisely on the measurement he recorded and started from that exact same spot.
As they worked their way towards the hitting wall, there were a couple of measurements that were much shorter. Corbie suggested we use the tape measure for these measurements as it was far more accurate as it had mm on it. They then reached a point that they would have to make continual quarter turns and walk short distances in between each turn.
E: Is there a simpler way to get there rather than making all these quarter turns?
C: Yeah, we could make half a quarter turn and that would take us straight to the flying fox.
E: What would half a quarter turn be?
C: An eighth of a turn.
E: How do you know that half of a quarter is an eighth?
C: I learnt ages ago that if you halve a fraction, you double the denominator.
When looking back at Corbie's work, I noticed that instead of recording this as an eighth of a turn, he had changed it to a 45° turn to fit in with the way he had recorded his other turns.
I think Corbie is working at Generalisation level because he makes strong links between Spatial Sense and Geometric Reasoning and Measurement. He uses the generalisation about fractions that he has picked up from previous learning and applies it to help solve the problem.

The examples illustrate the potential of the *Reflective Continua* to support educators in the interpretation of their observations and reflections. While not all observations need to be transformed into learning stories, this format does provide a rich perspective from which educators can develop future plans for children's mathematics learning. By providing a stimulus and structure for reflection, the *Reflective Continua* provide a tool for educators to use in their quest for excellence in the development of young children's powerful mathematical ideas.

Conclusion

During the Early Years Numeracy Project and afterwards, both the *Numeracy Matrix* and the *Reflective Continua* have been utilised by educators in South Australia to assist them in facilitating the learning of mathematics in both preschools and the first years of school. At the conclusion of the Early Years Numeracy Project, one of the Numeracy Leaders reported that she was using the *Reflective Continua* to assist her identify different levels of mathematical thinking and that "this tool has really motivated me to explore how children think and ways of extending their thinking" (personal communication). Another cluster educator working in the first years of school wrote:

> I know that my time with the numeracy project supported me to develop a wider view of the learner, to learn more about the child's context, needs and abilities. It is a model that I can use in my current site with my own class, of inquiring into what I am doing to make a difference for children learning mathematics.

Another of the cluster educators summed up her experiences with the Early Years Numeracy Project in the following words.

> For many years I have craved the opportunity to be challenged in my thinking and professional practice. I have been constantly trying to do this myself but it is difficult without a structure and time for reflection and professional dialogue. This project, and in particular the reflective continua have provided the most wonderful opportunity for me to receive this challenge to my professional practice. ... It has been an awesome scaffold for that professional dialogue and also that self/professional reflection. I believe that I am a better practitioner as a result and will continue to strive to better myself.

The need for educators to reflect on their own pedagogy is well recognised (Grossman and McDonald 2008; Moyles et al. 2006) but many early childhood educators find this difficult to achieve in mathematics because they lack sufficient knowledge of, and confidence in, their own mathematics (Anthony and Walshaw 2007; Perry and Dockett 2008). While they might be able to see their children as powerful mathematicians, they do not necessarily see themselves in this way. The *Reflective Continua* have provided participants in the Early Years Numeracy Project with a scaffold through which to structure their reflections and their pedagogical actions. The impact within the project and beyond suggests that such an approach to pedagogical inquiry can be very beneficial to educators, and children.

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