Count one count all: Numeracy in the foundation phase

*Paula Ensor, Ursula Hoadley, Heather Jacklin, Cally Kühne and Esme Schmitt
(School of Education, University of Cape Town) and Ana Paula Lombard (Cape Peninsula University of Technology)

The development of numeracy is crucial for children's meaningful access to basic education, and beyond. By the time they leave primary school, children should have a confident grasp of counting, number and arithmetic which will provide a solid platform for engagement with mathematics at secondary school.

Evidence from international, national and local assessments suggests that the majority of children in South Africa are not competent in numeracy at the end of primary school. Recognising this crisis in mathematics education, and a similar crisis in literacy, former Education Minister Naledi Pandor launched the Foundations for Learning Campaign (FFLC) in March 2008. The campaign has been hailed as a substantial step forward in addressing the need for strong foundations in mathematics and language education in South Africa.

This essay focuses on the teaching and learning of numeracy in the foundation phase, and critically reflects on the prospects of the FFLC for tackling persistent problems in mathematics education:

- What is the nature and scope of the problem in basic mathematics education?
- How does the FFLC aim to support the development of numeracy in the early grades?
- How do children learn to work with number?
- What do findings from the Count One Count All research project suggest about the potential limitations of the FFLC?
- What are the implications for teaching and learning number in the foundation phase?

What is the problem in basic mathematics education?

Documentation produced by the Western Cape Education Department at the launch of the FFLC indicates that grade 3 mathematics results saw a decline in average scores from 37.3% in 2004 to 31% in 2006. Grade 6 results saw an increase from 15.6% in 2003 to 17.2% in 2005, and then a decline to 14% in 2007. This problem was underscored by Schollar in 2008, pointing to the fact that only 1.5% of the 1995 grade 1 cohort achieved higher grade passes in mathematics in the 2006 matric exams.

These figures speak to a severe crisis in education in South Africa. It begins in the early years of schooling and is compounded in later years to produce a widening gulf between students from middle-class backgrounds who attend well-resourced schools, and those who come from poor families and attend poorly-resourced schools in townships and rural areas. It is sobering to note that even in the Western Cape — a well-resourced province that had the highest pass rate in the 2008 matric exams — the number of schools with a pass rate lower than 60% increased dramatically from 57 schools in 2007 to 75 schools in 2008.

How does the Foundations for Learning Campaign address the problem?

The FFLC addresses the numeracy problem by specifying the content, pace, instructional methods and equipment to be used for teaching mathematics in the foundation and intermediate phases. It entails:

- a curriculum that stipulates milestones to guide teachers in pacing curriculum content over a school year;
- a template for managing instruction in a typical lesson;
- a list of appropriate apparatus and resources to be placed in all classrooms;
- standardised assessment programmes; and
- teacher support, and in the near future, materials and resources for use in classrooms.

All of this is admirable. However, the lesson templates and content milestones in the FFLC are very difficult to translate into a clear picture of what a well-taught classroom looks like in the foundation phase. If teachers follow the prescriptions of the FFLC, but don't have a proper understanding of how children learn to work with numbers, then the campaign may not succeed in improving children's access to mathematics.

* Professor Marja van den Heuvel-Panhuizen of the Freudenthal Institute, University of Utrecht, is co-principal investigator of the SANPAD-funded Count One Count All Project, which informs sections of this essay. She has led the development of a Learning Pathway for Number, which was an outcome of the professional development aspect of this project.


© Jean Place

How do children learn to work with numbers?

Becoming numerate is a complex cognitive process. Children will not be able to work with numbers and calculate successfully unless they can count. But counting alone is not enough to be able to calculate successfully. At the same time, children must grasp a profound shift in understanding and recognise that a number such as 5 can be produced as the result of counting five objects, but that it is also an object that can be manipulated according to the laws of arithmetic. Children need to recognise, for example, that 5+4=9 without having to count out four objects, then five objects, and then count them all together.

Gelman and Gallistel, in their book *The child's understanding of number,* suggest that children have mastered counting when they:

- can mark off items in a collection with distinct markers or tags so that one and only one marker is used for each item;
- recognise that the tags themselves are organised in a repeatable, stable order;
- understand that a number, such as 5, represents the total number of items;
- understand that a number can become an object which can be manipulated; and
- understand that counting procedures can be applied to any collection of items.

In becoming numerate, children have to learn to manage different kinds of countable items. Steffe, Von Glasersfeld, Richards and Cobb suggest that there are five different types of things that are progressively difficult for a child to count: *perceptual units* (things which can be seen), *figural items* (things not present, but recallable, such as the number of people at home); *motor units* (movements like steps or handclaps); *verbal units* (number words) and *abstract units*. Finally, children need to understand that the order in which items in a collection are counted does not affect the numerosity (or size) of the collection.

Children begin the process of learning to count in their preschool years, but it is not until well into the foundation phase that counting can become the springboard for learning arithmetic. Children start with the counting of physical objects (including their fingers) and as they become more adept, their attention shifts, as Gray notes, "from the objects of the real world to objects of the arithmetical world — numbers and their symbols". For example: for children to comprehend two-digit numbers (or place value) they have to understand that 10 is a concept and not a real world object.

In order to accomplish this developmental sequence, teachers and children need to do a lot of work to deepen notions of counting and develop flexible and powerful means of representing number (using apparatus such as fingers, counters, beads, number lines, and numerical symbols). For example, learning the generative rules for counting beyond 10 is not trivial — children need to be able to know how to count in 10s, and then generate units appropriately as they count to 100 and beyond. Learning number bonds to 10, and learning to appropriately partition numbers*, assist in developing this expertise.

Anghileri and others argue that oral work is crucial in the early years, as it encourages students to work with numbers mentally. In the process they develop rich connections and strategies, which can serve as a basis for solving more difficult procedures. Karpov argues that children also need opportunities to solve problems, develop a range of strategies which they make visible for discussion, and try out different representations of a problem and its solution. They need problems and activities that allow them to make their own connections, find new facts and commit facts to memory. They also need to be taught a range of possible strategies for adding, subtracting, multiplying and dividing numbers.

What are the findings of the Count One Count All (COCA) research project?

It is often argued that South Africa's teachers lack an adequate conceptual knowledge of mathematics and that this accounts for children's poor performance. However, the COCA research suggests that what teachers lack is an understanding of how children learn number and that this has a significant impact on the teaching and learning of number in the foundation phase.

The COCA project is based on observing 18 foundation phase numeracy lessons, six per grade, in three schools in a poor, semi-urban area of the Western Cape province. All teachers and most learners in these schools speak isiXhosa as their first language, and isiXhosa is the medium of instruction except for the use of number names, which are learned in English. All teachers are qualified to teach at the foundation phase level and range in teaching experience from five to 25 years. Classes are on average large, with as many as 57 learners in one grade 2 class. Only two of the classes fall within the national teacher-to-learner ratio norm of 1:40.

An analysis of classroom data from the COCA research shows that teachers' lack of understanding of how children learn number is evident in teachers' approaches to whole class teaching and group work; in diagnosing difficulties and taking remedial action; and in using apparatus, textbooks and written work.

Understanding how number knowledge develops

The following interchange is taken from a grade 1 class. The children were asked to estimate the number of counters in the teacher's hand, which were then counted out, and the class was asked to work out how their estimates differed from the actual number.

T: *Right, let us count from 9 to 13.*
The learners began to count from 1, in 1s (a 'count all' strategy).
T: *No, I told you to start from 9.*
Learners then proceed to counting *"9,10,11,12,13"* (a 'count on' strategy)
T: *What are we supposed to add to 9 to get 13?*
L: *14*
T: *Ha-a, what do we have to add?*
L: *15*
T: *No, count, what must you add to 9 to get 14?*
L: *17*
T: *Count from 13 and go backwards. How many?*
L: *18*
T: *No, we are confused now.*
L: *3*
T: *What number will you add to 9 and you get 13 as an answer?*
L: *4*
T: *Who just said 4? Very good.*

A number of issues emerge from this interchange. Children do not appear to have strategies other than 'counting all' to solve the problem put to them. The teacher insists that they "count on" from 9 to 13, and when this fails, she urges them to "count backwards". Both processes involve double counting, which is a complex and difficult strategy to master. The teacher assumes the children have mastered it, which they clearly have not.

Learning early number is an immensely difficult and challenging task. Teachers need to be conversant with current thinking and research in this area. The milestones outlined in the FFLC document can, in our view, only come to life when located within a learning trajectory for number which spans the foundation phase. This trajectory maps out how number sense develops over the first few years of schooling and the strategies learners successively use to count, to calculate using counting, and then to calculate without reliance on counting. It can assist teachers to understand the successive challenges children face in gaining mastery of number, and how learners can be helped to achieve this.

Whole-class teaching, group and independent work

Every classroom observed was dominated by teacher talk in the context of whole-class teaching. Teachers determined the

* Number bonds are pairs which make up each number. For example: the number bonds for 5 are 2+3, 1+4 and 0+5. Partitioning a number shows the sum of its distinct parts. For example, the particians of 4 are: 4; 3+1; 2+2; 2+1+1 and 1+1+1+1.

pace of the lessons, rarely re-orienting a lesson to any significant extent to take account of learners' difficulties. In the observed lessons, on average 66% of all lesson time was spent by the teacher talking to the class from the front of the classroom and eliciting collective verbal responses from learners.

There was no evidence of 'group work' in the sense this is commonly understood, namely the engagement by a group of learners with a significantly challenging task which necessarily entails their joint involvement in solving it. Classes were commonly organised into groups, in that children sat around a table, or group of tables. 'Group work' most often entailed providing a task which one child undertook and the others observed. It was not uncommon to find 4 – 10 learners in a group, with one pencil and one piece of paper which one child used while the others watched.

In those infrequent cases where all children were expected to work on a task, they worked alone, even though physically sitting in a group. These tasks usually involved practicing a small number of calculations rather than solving problems. There were no sustained opportunities for individual, independent work by learners. Verbal, collective responses overwhelmingly dominated lessons.

The FFLC emphasis on group work may be potentially counter-productive. All too often in the COCA research this device was seen by teachers as an end in itself, not as a means for achieving a desired objective. Researchers saw no evidence of group work being used to engage children in serious mathematical activities.

Diagnostic assessment and remedial action

Group work and collective responses to whole-class teaching can inhibit the evaluation of individual student learning. COCA researchers saw very little evidence of teachers' diagnostic assessment of learners or of remedial action. Children's responses to questions in grade 1 and 2 classrooms indicated that they had not grasped the principles of counting set out by Gelman and Gallistel. The following typical extract is taken from a grade 1 class. This interchange followed an estimation problem similar to that described in the first extract.

T: *Now listen. Listen, is 8 smaller or bigger than 10. Which is bigger, 8 or 10?*

L: *It's 10.*

T: *By how many is 10 more than 8, use your mind. If you have 8 things and another has 10, how many more are yours less than his? For you to have 10 things, how many must you add to your 8 to make 10? How many things must you add? You have 8 things and you want them to be 10, how many must you add?*

L: *I must add 5, miss.*

T: *No, those of you saying 5 keep quiet that is not the correct answer.*

L: *With 2.* (Showing two fingers)

T: *Yes, 2.*

In this lesson there were five other occasions where children called out incorrect answers, and they were ignored. Dealing with incorrect answers by ignoring them or simply repeating the question was common across the grades. Identifying problems and using these in teaching to overcome conceptual difficulties was not in evidence in any of the lessons observed. The proposal of the FFLC to implement standardised assessments will assist in establishing milestones and levels of competence, but cannot replace diagnostic teaching in the classroom. Without the latter, all that standardised assessment will do is indicate how poorly students are doing.

Teachers utilised a very limited range of strategies for guiding learners' engagement with concepts and problems, and for dealing with errors. The observed teachers regularly used only instructing, modelling and closed questions, but seldom used the practices of justifying, noticing, focusing, probing, extending, explicating and so forth.

The use of apparatus

All the classrooms observed had some apparatus (such as counters and beads). However, in the vast majority of cases, the apparatus was used by teachers to demonstrate to the class, rather than used by the learners themselves. Apparatus was mainly used as an end in itself and not as a means to build learners' understanding and confidence. Activities involving apparatus often took a whole lesson with no identifiable learning outcomes. Rarely did children use apparatus individually to solve problems. As with group work, insisting on the use of apparatus without a clear understanding of its pedagogic purpose can undermine rather than promote the teaching of number, taking up valuable teaching time without students learning anything of value.

The use of textbooks, workbooks and written work

Very little writing took place in any of the grades observed. This is linked to the lack of independent work by students, which is in turn linked to the lack of diagnostic assessment. The only way learners could make visible their lack of understanding in a whole-class teaching format is if they failed to give a correct response to a question posed by the teacher. Children's questions were not generally entertained by the teachers, who usually ignored or rebuffed hands put up.

Children require resources (textbooks, worksheets and jotters) for what Thompson refers to as meaningful mathematical "mark making". This provides opportunities for independent work and gives learners access to a structured curriculum, allowing them to work at their own pace, and providing teachers with a mechanism for evaluating performance. The proposal of the FFLC that each child should be involved in 20 minutes of written work each day is important, but this can only translate into improved performance if the set tasks are mathematically worthwhile, structured in such a way that all learners engage with them, and accompanied with appropriate feedback.

What are the implications for teaching and learning number in the foundation phase?

The COCA research described here highlights a number of pedagogic practices prevalent in the foundation phase numeracy classrooms that were observed: the predominance of whole-class teaching in which few opportunities were provided for learners to make visible their understanding and have misconceptions corrected; the low level of mathematical tasks set; the widespread use of apparatus and group work which consumed significant amounts of time at the expense of mathematically demanding activities; and relatively little reliance on independent written work.

The FFLC, by suggesting lesson templates which apportion time to whole-class teaching, group work and individual work will go some way in addressing the problems faced in the foundation phase. However these changes will only have meaningful impact if combined with appropriate resources and support for teachers, especially guidance in relation to how children learn number. For teachers to become effective teachers of number they need to master the processes by which children learn number, develop mechanisms to diagnose problems and help students along, and find ways of providing learners with opportunities to engage with and internalise concepts through well-structured purposeful individual or group activities.

What are the conclusions?

Addressing these concerns appropriately and speedily is a challenge facing all teacher educators currently working in pre- and in-service teacher education at the foundation level. Teacher education policy and practice need to be informed by well-funded, large-scale research projects on teachers and teaching. In South Africa, considerable resources have been spent on testing learners, and this is useful for showing what children do not know. However, large-scale testing says nothing about why children do not succeed, or what teachers think about how children learn number, and why they fail to do so. The work of the COCA project is a modest contribution to research on what is going on, and going wrong, in numeracy learning in the early years of education.

Sources

Anghileri J (2006) *Teaching number sense*. London: Continuum.

Department of Education (2008) *Foundations for Learning Assessment Framework: Foundation Phase.* Pretoria: DOE.

Department of Education (2008) Foundations for Learning Campaign 2008 – *2011. Government Gazette* No. 30880, 14 March 2008. Pretoria: DoE.

Gelman R & Gallistel CR (1986) *The child's understanding of number*. Cambridge, Massachusetts: Harvard University Press.

Gray EM (2008) Compressing the counting process: strength from the flexible interpretation of symbols. In: Thompson I (ed) (2008) *Teaching and learning early number*. Second edition. Maidenhead: Open University Press.

Karpov YV (2003) Internalization of children's problem solving and individual differences in learning. *Cognitive Development*, 18: 377-398.

Schollar E (2008) *Final report: The primary mathematics research project 2004 – 2007. Towards evidence-based educational development in South Africa*. Johannesburg: Eric Schollar and Associates c.c.

Steffe LP, von Glasersfeld E, Richards J & Cobb P (1983) *Children's counting types: philosophy, theory and application.* New York: Praeger.

Thompson I (ed) (2008) *Teaching and learning early number*. Second edition. Maidenhead: Open University Press.

Western Cape Education Department (2008) *WCED launches Foundations for Learning Campaign*. Media Release, 21 January 2009.