Teachers building number sense amid the challenges of change: Some case studies

Len Sparrow & Alistair McIntosh
Edith Cowan University
Western Australia

The paper describes some preliminary findings from a project in which teachers from two primary schools were observed over one school term as they implemented their own plans for encouraging number sense in their classrooms. Ownership of the entire project was invested in the teachers involved. Comment is made on some of the impediments to change and on one teacher as she implements mental computation activities.

This paper will describe a project undertaken in two schools in Perth during the time period July to December 1997. Analysis of data is still at a preliminary level and only some of the initial, tentative findings are described here. The paper will comprise three parts, namely an overview of the project, issues of professional development and finally outcomes of number sense development with teachers in the project schools.

The Project — Developing Number Sense in Education (DENSE)

The aims of the project were to:

- provide data from an in depth study of classrooms in which teachers have consciously introduced number sense approaches;
- evaluate a professional development model which empowered teachers to design and implement classroom change related to number sense.

Two Perth metropolitan primary schools were invited to join the project, one staff member of each school had had contact with the researchers on a previous project. Interested teachers within the schools attended the initial meetings. From these meetings three teachers and one coordinating teacher from School A and four teachers and one coordinating teacher from School B became involved in the project. The classes were almost parallel in age grouping from each school — two grade 3, one grade 4/5, one grade 5, a grade 7 and a grade 5/6/7 combined. The Developing Number Sense in Education (DENSE) project commenced with a meeting at the end of Term Two (June) and took place during Terms Three and Four (July to December 1997).

Data Gathering Methods

As the project was descriptive in nature qualitative data gathering techniques were employed, namely teacher journal writing, audio taping of group meetings, field notes and lesson observation notes by the researchers. In particular each teacher had a small audio-cassette in which she was encouraged to record her thoughts at any time. These tapes were quickly transcribed and sent to all teachers. Initial analysis is being undertaken by means of the NUD*IST computer program to identify emerging themes and issues.

Professional Development Model

From the literature on professional development one can loosely categorise models as, first, approaches which transmit new information to teachers via conferences, workshops and inservice work. Gordon and Tyson (1995) commented that this style of working has received much criticism in recent years because of its failure to foster long term change and to use teacher expertise. Secondly, there are approaches which involve the teacher and researcher in

various forms of collaboration, usually a partnership and usually through an Action Research model. Reports of these projects suggest considerable learning by both partners and some more lengthy change taking place (Cobb, Wood & Yackel, 1990; Ellerton, Clements & Skehan, 1989).

Gordon and Tyson (1995) commented that the important thing which was missing from both of these models was an emphasis on the role of teachers as the decision makers in setting the agenda. In fact professional development often holds an assumption that the developing, reforming or empowering is done by someone else—not the teachers themselves.

Some initial research by Herrington, Sparrow and Swan (1995) attempted to use a model of professional development which considered an emphasis of teachers setting their own agenda. The mathematics case methods model (Barnett, 1992; Barnett & Tyson, 1993(a); Barnett & Friedman, 1995(a); Gordon & Tyson, 1995) has an expectation of teachers recognizing themselves as their own change agents. These projects provide evidence of a third category of professional development model. Essentially, in this model, the program originates in, and is driven by teachers' concerns, interests and the realities of their classroom. In that sense it is a model of teacher empowerment in which teachers identify and meet their own needs for professional development. Robinson (1989) discussed the empowerment paradigm and noted the shift from teachers being manipulated by others into changing to one of personal control of professional development. This represents a move from an instrumental view of teachers to one of teachers as responsible professionals.

The Process of Change

Clarke and Peter (1993) have noted the processes of change in teachers' practice, knowledge and beliefs are intertwined and form part of a learning process. They suggested two central components of professional growth:

- teacher experimentation, and
- teacher reflection.

Bearing this in mind and the earlier comments on the inadequacy of the transmission models of professional development in establishing long term change, it would seem more appropriate to consider models that involved the teacher directly and overtly in the process. One will need to create situations where beliefs are faced and considered. This demands powerful interventions which challenge, and yet are safe situations in which teachers can take mathematical, emotional and intellectual risks (Wilcox, Schram, Lappan & Lanier, 1991). The empowerment paradigm sees the change process as situation specific and cannot be seen as an attempt to implement a specific reform or apply a specific change model to a school generally. Change and professional development, Robinson argued, should be seen as an educative process with no universally correct and acceptable end point to be achieved. Teachers are given information about the range of choices available so that they can make meaningful choices for their classroom.

Work by Ellerton, Clements and Skehan (1989) and Herrington, Sparrow and Swan (1995) used the Action Research Cycle with an emphasis on the *insider* (teacher) rather than the *outsider* (researcher, curriculum leader) setting the agenda for discussion and development. The Action Research Spiral of plan, act, observe and reflect was central to the work and was designed to establish the need for reflection and experimentation by the teacher and to set the problem in the specific and real classroom.

From the models of working with teachers in professional development the Action Research Cycle embodies the reflection and experimentation aspects necessary for change (Clarke & Peter,1993) and where this can be coupled with more natural teacher methods of narrative (Johnston, 1994) it should support the reflection-on-action aspects of teaching. Schon (1983) has used the term *reflection-in-action* to describe this continual process in

which teachers are engaged. He also noted the idea of *reflection-on-action* which is carried out after the event and is more able to be assisted by a collaborative process. The DENSE project used both models of reflection with teachers so that they could broaden their own content and pedagogical knowledge base related to number sense and its development in the classroom.

Emerging Issues from Professional Development

Impediments to Change

The major issue emerging is concerned with change and the impediments and challenges felt by the teachers trying to implement change in their classrooms. The impediments impacting on the teacher paint quite a complex picture. Even where there is a willing teacher, the effort to change and develop classroom practice beyond a traditional form is countered at almost every stage.

Expectations

In itself, this is quite a complex constraint being constructed of a range of sub issues. One might argue that some of these are 'felt issues' rather than 'actual issues'. The 'felt issues' being derived possibly from the social heritage of the staffroom (Mousley & Clements, 1990). Generally they are not tested in reality i.e. actually asking the parent body if this is their expectation of the teacher and the school. Expectations emerging were attributed to parents, other teachers in the school and teachers from the high school which the children would attend. The expectations issue was especially strong in the comments of the Year 7 teacher.

> *I'm in a difficult position really, having Year Sevens, it's the year before they go to High School, and unfortunately there is an expectation of what a Year 7 student should know.*
> *I'm also very aware of the expectations of parents, other Year Seven teachers and the High School next year,... but I have to tread very carefully, or a lot of parents will chop my head off.*

Concerns were evident related to the expectations of other teachers in the school and to comparisons which might be made between classes.

> *... but I'm doing this bit of maths this way, but the other Year Fives are not doing it this way, and if you compared all the Year Fives, how are you going to compare them, are you going to compare them by saying, here's a sheet of algorithms go for it, and the other lot of Year Fives will get them all right and mine will get them all wrong, but they'll know why they got them wrong.*
> *I think where P. feels a little bit threatened is that she's come in new to the school, and these teachers have been teaching here for a long, long time, and they feel that they know how to do it.*

The expectation of a traditional way of doing mathematics is strong and exerts a pressure on teachers to conform. One needs to be quite confident in oneself and in mathematics to be able to move away from the normal because as soon as one does change one is open to criticism from a number of sources.

Time Factors and the Syllabus

A feeling emerging from the data was one of the teacher being presented with yet another thing to fit into the finite school day. There did not seem to be an alternative argument, for example, that if something was good and had to be put into the day then something judged less important would have to go out of the day to make room. An image of

the teacher trying to do all things but not giving any sufficient coverage to be effective began to emerge.

> *Yes it's true, you've got to get these kids through the syllabus.*
> *I think at my last school, it was very much sort of, this is what's in the syllabus, this is what the Headmaster comes in and wants to talk to them, they need to know the things they are supposed to know according to the syllabus.*
> *You know it's really good doing all this number sense but I still have to do long multiplication*

It appears for many teachers that syllabus coverage is paramount. The quality of the outcomes, in terms of the children's learning, was only a minor concern. It is interesting to note that number sense was seen as extra to the syllabus, the latter emphasis being, one might surmise, in the eyes of many teachers, to be concerned with mastery of the standard methods of computation.

The Children in the Classrooms

Comments from the teachers related to the children often seemed to have a negative spin to them. Typical would be a comment that pointed out what the children could not do and this was offered as a constraint to doing whatever was intended.

> *Especially when it's Year Seven when you want them to give you how they've come to their answer, if they've had that conditioning [years of formal algorithms], and one of the things I found teaching our Year Sevens was like, there's your answer, why do you want me to give you any more information?*
> *... and because they have not had all this background in Year One and Two, what we've done in Year Three has virtually been back down in Year One and Two.*

For many teachers the combination of low self confidence, unresponsive children and loneliness, if they are undertaking a new way of working without the support of the project, makes for a non-starter and the ideas are not even tried. One part of Clarke and Peter's (1993) model for change does not take place.

Available Resources

Discussion often noted the constraining effect of resources that were available, notably the set textbook for the class.

> *... and the books that they've got are Boomerang Maths books, which seem quite OK. But I mean, it's not what I would have chosen necessarily, but what I've got to try and do is to sort of justify the people buying this book, and try to fit it in with the way I'm doing maths and the content that we, that we're covering.*

The text book, like the earlier factor of expectations, can impede change. Most textbooks promote a model of computation which emphasises the standard methods of computation and instant recall of basic facts. In many schools there is also an expectation that teachers will teach to the book and that each year will complete their designated book. Again this does not give much time to do the extras such as number sense.

The Teachers' Background Knowledge and Beliefs

Throughout the data there is comment related to a new awareness in mathematics teaching and in particular to the idea of number sense. There is, however, still a recurring tension between this and the almost ingrained beliefs and ways of doing things. Tradition and

the fact that "everyone knows how a teacher operates" from their apprenticeship of observation as a child seem to be major factors in this dilemma.

> *And it's confidence, you know, we are such a structured profession,... and it's very hard to break away from that, and even though I've been teaching, you know, for less than ten years, I came into it knowing that I had to do it [teach in a structured way]*
> *I have to staple my tongue to the roof of my mouth sometimes to stop myself from telling the kids...*

For some of the teachers there is a reluctance to embrace the new idea of number sense due to their own felt inadequacy with mathematics content and understanding.

> *I think I get muddled up because I sort of anticipate, I sort of have in my head what the kids are going to say and how they are going to respond, but if they come up with something different, it sort of throws me a bit, and I'm not clever enough sometimes to sort of use what they say effectively.*

Without the support of the project this would be the main challenge to any adoption or even experimentation with number sense. Everything about mathematics before had been clear-cut and predictable. It is a major shift in teaching style for many teachers to leave a question open and invite a range of often unpredictable responses with the distinct possibility that at least one will be different from the predicted route.

Emerging Issues Related to Mental Computation

Description of a Mental Computation Lesson, Kaye, Year 5 Class

During the project one of the investigators sat in on a number of number sense lessons at his request. His intentions were twofold: first, this would provide the only direct evidence of what was actually happening in the project classrooms; second, it was hoped that presenting teachers with a detailed account of what the investigator saw and heard, together with some comments, might form a useful form of professional development. Here is a description of one lesson, in the form it was later given to the teacher.

11.15am. Class on mat at front. Explanation of strategies for 89+ 26: Kaye describes pictures of three children [shown calculating 89 + 26] on the overhead. 'Imagine you are the girl, think about the answer to 89 + 26 and how you could describe what you did to somebody else.' Kaye has a large sheet of brown paper attached to the blackboard by the OHP picture. It is marked 'How can we work it out?'

After a pause, Kaye asks children to explain what they did. She writes each explanation in words and symbols on the brown paper.

- 8 + 2 = 100, 9 + 6 = 15. 115. (When asked why 8 + 2 = 100 the girl retreated into silence.)
- With fingers. Did 89 add two tens and 6.
- Did it by fives. Added 8 + 2 = 100, then 9 + 6 = 15, added 100 + 15 by 5, 10, 15. 80 + 20, 9 + 6.
- Imagined the numbers written down vertically, did as a written sum.
- Added 8 + 2 then added a zero, then 9 + 6. 'How did you know to add a zero?' Silence from boy.
- Changed it to 86 + 92 and got 115. [Did he mean 86 + 29? This was not resolved]

11.35am. Discussion of Strategies: 'Let's have a look at some of these strategies.'

- Discussed why 8 + 2 = 100, in terms of 8 tens and 2 tens. The child's method was validated.

- Discussed a quicker way of adding 20 to 89 than counting in ones using fingers. 'Count in tens.' 10, 20, 30...' 'Count in tens from 3.' '3, 13, 23...' Count in tens from 9.' 9, 19, 29...59.' Count in 9s from 89.' [More hesitantly] '89, 99, 109...' This felt like a breakthrough for some children.

11.43am. Extension of Activity: 'Before we do some more, would you rather do that calculation [89 + 26] with a calculator, in your head, or on paper?' All three methods were advocated by different children. 'Can someone give me a calculation they would need a calculator for?' '4 billion + 561', 5230 x 1000' were suggested and queried.

11.48am. Activity 2: Ten calculations were revealed on the OHP. 'Which of these could you do in your head?' Each was considered with children being asked to justify their choices.

11.55: Activity 3: 'This example 88 + 88 + 88. Work it out mentally and then write down the answer and explain how you did it.'

12.06 - 12.15pm. Discussion of Activity 3: Several children were asked to share what they had written.

Issues Arising from the Lessons

A mental computation 'lesson' has traditionally been envisaged as lasting about 10 to 15 minutes. In contrast Kaye's mental computation session lasted the entire 60 minutes of the mathematics lesson, although Kaye admitted she had some reservations about this.

> *I would never do this for so long usually and I would prefer to do it with a small group while others were working*

Again, a traditional mental computation lesson would consist of a series of short computations to which children write answers in silence, emphasis being placed on speed and accuracy. In contrast, Kaye's lesson involved a great deal of class discussion with an emphasis on encouraging children to explain their strategies and justify their answers orally.

> *I emphasise children's explanations, children listening to the explanations of others, the fact that there are different ways of mentally doing the same calculation, the value of giving your own idea 'even if you think someone else might think it silly', giving children time to think when I ask them a question.*

The purpose of a traditional mental computation lesson, if a purpose was considered by the teacher, might be to increase knowledge of basic facts or to sharpen up the children before the 'main' part of the lesson. Kaye's reason for emphasising mental computation is clearly different.

> *The area of number sense that I'm dealing with, with my Year 5 class is Developing Mental Strategies. And the reason I've chosen this is that it seems that children generally have a poor understanding of basic facts and place value. And when they're confronted with a problem they're easily stumped. They don't appear to have a variety of strategies in place to work it through, and even those who appear to be fairly well skilled at pencil and paper computations have trouble when they're confronted with a problem that's posed in different ways.*

When reflecting on the value of her mental computation lessons later, Kaye felt that these aims had been realised:

> *Having a concentration on that and just forgetting about the other parts of number maths for the time being, I'm really amazed how very quickly those children who just had absolutely no idea, I think the first session that we had Alistair was here and there were kids who were just gazing into space, absolutely no idea about how to go about doing that, and other kids who were more able were able to*

share their strategies, and those children who had no idea have now got strategies to begin to use, and they are choosing other people's strategies, and with some success, which is really terrific.

However Kaye also saw them as having much broader benefits still.

... but the really terrific spin off is that [their communication skills] have just improved out of sight, as they've realised how precise they have to be in their oral sharing for someone else to understand, because I actually get the person who's listened to someone sharing, they then have to tell that strategy to somebody else and they have to listen very carefully to someone else's strategy and then explain that to another person, so their listening skills have improved, their oral sharing skills and their written skills because they know how precise that has to be for someone else to read it.

Finally the written record of the lesson, while being very informative for the investigators, proved also both valuable and reassuring for the teachers.

I guess copies of the lesson observations are the most useful in terms of perhaps learning teaching strategies used by others. I'm particularly interested in the other Year 5 class at Ashburton, especially as we have a common area of focus.

Interim Conclusions

Implementing a research and curriculum development project in this way has a number of difficulties. From the curriculum development point of view, one has sometimes to follow the teacher's advice and 'staple one's tongue to the roof of one's mouth'. Things can appear to move slowly, erratically, and in unexpected directions. If teachers follow their own intentions, they will not accord in every detail with that of the project leader and director. On the other hand the process generates a much greater head of steam because the teachers, having chosen to take part, stop looking for directions and use their own judgment. And the exciting thing is that they constantly reveal what a wealth of common sense, sound judgment, and educational creativity they possess.

From the research point of view, the reliance on audio-cassettes for most of the data collection proved to have advantages and disadvantages. The main disadvantage is that teachers are, on the whole, much better doers than talkers. They will spend hours planning and preparing lessons, but proved somewhat loathe to spend five minutes on reflections and afterthoughts (though almost all said that they spoke into the cassettes much more than they would have communicated on paper). The great advantage was that in several cases teachers spoke into the cassettes (often late at night) with immense candour with a flavour and intimacy which would not have come through on paper. We conclude with one such glimpse.

I think this whole project has led me to rethink a whole pile of things to do with my own teaching and I think that's a good thing. I don't think I was doing a bad job before, but I think it's made me [give] children back the ownership for their learning, instead of worrying all the time that I haven't taught this and I haven't taught that, now I can give them the opportunities to learn things that they need to learn, and that seems to be spreading right across the things that I do. You know, I've been teaching for 23 years, you get a bit stale, so sort of a new approach is very elevating, stimulating for the children. ... I'm sort of almost sad that our part in this has come to an end, but I won't end what I'm doing, I shall keep on going and I shall make sure that I continue to find new things to do, maybe I'll move on to something other than mental computation, I'd like to develop

[fractions] a bit more, I don't feel so worried about that now, I used to think God, fractions, what am I going to do with this! But the kids are sort of feeling quite chirpy about what we've done, so I think maybe over the holidays I'll think about where I can go with that.

References

Barnett, C. (1992). Building a case based curriculum to enhance the pedagogical content knowledge of mathematics teachers. *Journal of teacher education, 42* (4), 1 - 9.

Barnett, C., & Tyson, P. (1993). Case methods and teacher change: Shifting authority to build autonomy. In B. Atweh, C. Kanes, M. Carss & G. Booker (Eds.), *Contexts in mathematics education.* Brisbane: Mathematics Education Research Group of Australasia.

Clarke, D. J., & Peter, A. (1993). Modelling Teacher change. In B. Atweh, C. Kanes, M. Carss, & G. Booker (Eds.), *Contexts in mathematics education—16th Annual Conference of the Mathematics Education Research Group of Australasia* (Vol 1 pp. 167-175). Brisbane: MERGA.

Clarke, D. M. (1994). Ten key principles from research for the professional development of mathematics teachers. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics—1994 Yearbook* (pp. 37-48). Reston, Virginia: National Council of Teachers of Mathematics.

Cobb, P., Wood, T., & Yackel, E. (1990). Classrooms as learning environments for teachers and researchers. In R. Davis, C. Maher, & N. Noddings (Eds.), *Constructivist views on teaching and learning mathematics.* Reston, VA: NCTM.

Ellerton, N. F., Clements, M. A., & Skehan, S. (1989). Action research and the ownership of change: A case study. In N. F. Ellerton & M. A. Clements (Eds.), *School mathematics: The challenge to change* (pp. 284-302). Geelong, Victoria: Deakin University.

Gordon, A., & Tyson, P. (1995). Assessing the impact of mathematics case methods on teacher practices. *Paper presented at the Annual conference if the American Educational Research Association*, San Francisco: AERA.

Herrington, T., Sparrow, L., & Swan, P. (1995). Professional development: Whose problem is it anyway? In B. Atweh & S. Flavel (Eds.), *GALTHA—18th Annual Conference of the Mathematics Education Research Group of Australasia*, (Vol 1 pp. 338-345). Darwin: MERGA.

Johnson, S. (1994). Is action research a natural process for teachers? *Educational Action Research, 2* (1), 39-47.

Mousley, J., & Clements, M. A. (1990). The culture of mathematics classrooms. In K Clements (Ed.), *Whither Mathematics* (pp. 397-407). Melbourne: Mathematics Association of Victoria.

Richardson, V. (1990). Significant and worthwhile change in teaching practice. *Educational Researcher, 19* (7), 10-18.

Robinson, I. (1989). The empowerment paradigm for the professional development of teachers of mathematics. In N.F. Ellerton & M. A. Clements (Eds.), *School mathematics: the challenge of change* (pp. 269-283). Geelong, Victoria: Deakin University.

Schon, D. A. (1983). *The reflective practitioner.* New York: Basic Books.

Wilcox, S., Schram, P., Lappan, G., & Lanier, P. (1991). The role of a learning community in changing preservice teachers' knowledge and beliefs about mathematics education. *For the Learning of Mathematics, 11*(3), 31-39.