Calculators as an Agent for Change:

Teachers' Perceptions and Practice *

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As part of the Calculators in Primary Mathematics project, seven infant teachers taking part in a long-term investigation into the effects of the introduction of calculators on the learning and teaching of primary mathematics, were observed in their classrooms and interviewed over a period of three years. One of the original hypotheses of the project was that teachers would adopt a more open-ended teaching style as a result of the increased opportunities for exploration of number presented by the calculator. It was also hypothesised that the presence of the calculator would extend the range of problem solving activities in the classroom. All seven teachers, at some stage of their involvement in the project, claimed to have become more open-ended in their teaching, with the majority stating that their mathematics teaching had become more like their language teaching. Two teachers reported a less open-ended approach in their second year of involvement compared to their first year – mainly due to a perceived need to instruct children on calculator use. A majority of teachers also claimed there was more sharing and discussion in their classrooms, which some identified as providing opportunities for observations of children, leading to catering better for the full ability range. An increase in problem solving activity, often related to the real world, was identified as a change by four teachers. None of these claims were contradicted by the classroom observations.

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Introduction

For well over a decade, calculators have been recognised as having the potential to profoundly change the curriculum and the nature of mathematics teaching, with widespread agreement amongst mathematics educators that calculators should be integrated into the core mathematics curriculum (National Council of Teachers of Mathematics, 1980, p.9; Cockcroft, 1982, p.109; Curriculum Development Centre and The Australian Association of Mathematics Teachers, 1987; Australian Education Council, 1990).

In everyday life, of the three available methods of computation, mental and calculator computations are the ones typically used. However, paper-and-pencil methods still receive the most emphasis in schools. The emergence of calculators and computers serves to highlight the lack of congruence between school mathematics and real mathematics (Willis & Kissane, 1989, p.58).

The Calculator-Aware Number project (CAN), which commenced in the UK in 1986 under the direction of the late Hilary Shuard, was entered into as a curriculum development project. The CAN project, however, found that the calculator's full potential could not be realised without a change in teaching style, which, in turn, required substantial work on the part of teachers and constant support (Duffin, 1989, p.15).

Widespread change in mathematics learning and teaching has not come about with the advent of calculators because it is no trivial matter to change these. Teachers need to rethink the nature and content of mathematics, the mathematics curriculum, mathematics teaching and mathematics learning, as well as develop new and substantially different skills for teaching and assessment (Willis & Kissane, 1989, p.74; Shuard, 1986, p. 51).

The Calculators in Primary Mathematics project is a long-term investigation into the effects of the introduction of calculators on the learning and teaching of primary mathematics. The project, which has been funded by the Australian Research Council, Deakin University and the University of Melbourne, commenced at prep and grade 1 levels in six schools in 1990. Over 60 prep to grade 4 teachers and approximately 1000 children have participated in the project during the period 1990 to 1993. All children were given their own calculator to use whenever they wished, while teachers were provided with systematic professional support to assist them in using calculators to create a rich mathematical environment for children to explore.

The investigation focused on the extent and purpose of calculator use; changes in teachers' expectations of children's mathematical performance and consequent changes in the curriculum; and long-term implications for numeracy. In two of the project schools, the investigation also focused on changes in teachers' beliefs and teaching practice.

Previous conference papers (Groves, Ferres, Bergfeld & Salter, 1990; Groves, 1991; Groves, Cheeseman, Clarke & Hawkes, 1991) have referred to the variety of uses found for the calculator in the lower primary school; the effects on teachers' expectations (Groves & Cheeseman, 1992; 1993); and some results comparing project and non-project children on multiplication and division problems set in "real world" contexts (Groves, 1993).

This paper refers to teacher change in the two project schools where this was a particular focus Of the original nine teachers who commenced in the project in 1990 at these two schools, the seven teachers who remained in the project for two and a half years or more form the sample for this study.

Two of the original hypotheses of the project were that teachers would adopt a more open-ended teaching style as a result of the increased opportunities for exploration of number presented by the calculator, and that the presence of the calculator would extend the range of problem solving activities in the classroom.

This paper reports on these seven teachers' perceptions of changes in their approach to mathematics teaching and briefly compares these perceptions with their observed classroom practice.

The Calculators in Primary Mathematics project and models for change

The Calculators in Primary Mathematics project was based on a model of teacher change which assumes that the major motivation for teachers to change is the desire for improvement in student learning outcomes and that changes in teachers' classroom practice need to precede changes in their beliefs and attitudes (Guskey, 1986, pp. 7-10).

Clarke and Peter (1993) present a dynamic model of teacher professional growth, which traces its origins to Guskey's model. This new model identifies four domains: the personal domain (teacher knowledge and beliefs); the domain of practice (classroom experimentation); the domain of inference (valued outcomes); and the external domain (sources of information, stimulus or support). It further identifies reflection and enaction as two mediating processes which are used to explain how growth in one domain is translated to another.

As stated earlier, all project children were given their own calculators to use whenever they wished. Systematic professional support was provided throughout the project by means of regular classroom visits, regular half-day network meetings, a newsletter which has appeared once a term, opportunities for classroom visits in other project schools, as well as formal and informal meetings of staff within their own schools. However, the project did not provide teachers with a program of calculator activities, or in any way prescribe how the calculators should be used – it was left to individual teachers to devise their own ways of incorporating the calculator into their normal mathematics programs.

A detailed description of the types of support given and teachers' perceptions of their effects will be given in Powell, Cheeseman and Groves (in preparation). Some of the findings of that paper will be foreshadowed here in order to briefly indicate the connections between the project and the Clarke-Peter model for change.

In terms of the Clarke-Peter model, the stimulus of the presence of the calculator, together with the support provided, were changes in the external domain. This could then be translated into action in the domain of practice by means of classroom experimentation. In this case, the classroom experimentation took the form of using calculators on a regular basis.

The regular classroom visits had the sometimes conflicting aims of supporting teachers and collecting data. The project team attempted to provide feedback to teachers by reporting their observations of individual children. So these visits acted as a further stimulus by giving teachers access to a much wider range of observations of children than would otherwise have been

possible. This in turn provided teachers with enhanced opportunities to engage in the reflective process in order to

bring about change in the domain of inference or valued outcomes.

The reflective process was also supported by the network and school meetings, as well as by some of the other forms of data collection, such as the regular written teacher reports and the interviews with teachers. This reflection on changes in both the external domain and the valued outcomes mediated change in the personal domain.

The Clarke-Peter model, which has by no means been completely explained or applied here, allows for entry at any point, in recognition of its dynamic nature. For the purpose of this report, it is change in the personal domain of teachers' knowledge and beliefs which forms the focus of the investigation. However, these changes are frequently expressed in terms of teachers' descriptions of changes in their practice and valued outcomes.

The teacher interviews

The data on teachers' perception of change was collected by means of a series of semi-structured interviews with each teacher. All teachers taking part in the Calculators in Primary Mathematics project have been interviewed at the beginning of their involvement in the project and at the end of each year of their involvement.

Each interview included questions related to a range of issues such as: background information; initial reactions to the project; teachers' expectations of the project; effects of calculators on the children; effects of calculators on mathematics teaching; the support program; and effects of the project on the school.

In order to attempt to establish benchmarks against which to gauge changes in teachers' beliefs, the following questions were asked at the first interview:

What do you see as the major features of your maths teaching?
Could you elaborate on that?
Any other features?
What changes (if any) would you like to see in your maths teaching?
What changes (if any) do you believe there will be in the way you teach maths?

In each succeeding interview, teachers were asked the following

set of questions under the heading Effects of calculators on mathematics teaching:
Have you found you are changing the way you teach maths?
(If yes) how?
Ask for specific examples.
Are you happy with these changes?

In 1990, due to the lateness of approval of funding, the project only commenced at the end of first term and it was impossible to conduct the initial interview until almost a term later. Because of this, teachers were asked to reflect on their experiences to date. This included asking the following question at the initial interview with the seven teachers:
Have you found you are changing the way you teach maths?
(If yes) how?

Interviews were tape-recorded and transcribed. For the purpose of data analysis, a set of categories, under headings indicated by the original research questions, were developed using an iterative process Responses were analysed in terms of these

categories. All responses which related to a particular category were recorded, whether or not they were given in response to the question designed to address that issue.

All of the questions related to changes in mathematics teaching were phrased in such a way as to avoid prompting respondents. As the interviews were semi-structured, the text was not always followed. For the purpose of this analysis, on the rare occasions when responses were prompted by the interviewer, the resulting data has been ignored.

Teachers' perceptions of change

Table 1 provides a summary of teachers' responses to the interview questions related to their perceptions of changes in their mathematics teaching over the period of their involvement in the project.

Major features at commencement of project

Most responses to the question of what teachers saw as the major features of their mathematics teaching at the time of the first interview werebrief. For example:

Well I try to make it practical and related to them, related to their everyday lives. And I relate it around themes. Does that answer the question?
Heather, After one term

Four teachers identified the use of materials or an active, "hands on" approach as a major feature of their mathematics teaching, while three mentioned a discovery approach and three referred to situations related to everyday life or a thematic approach. Problem solving and an understanding of basic concepts were each mentioned by two teachers.

Five teachers responded to the question on what changes they would like to see in their mathematics teaching. One teacher had no specific desire for change, while the others listed better observation of children, catering better for the full ability range, better use of real life problems, and a more discovery learning / open-ended approach.

Two teachers anticipated that the project would result in changes in the way they taught mathematics – one anticipated unspecified change, while the other expected more exploration to occur.

Moving towards a more open-ended approach

The original research question relating to teacher change was phrased as follows:

Do teachers change their beliefs about the nature of children's learning of mathematics? Are there any corresponding changes in teaching style? Is there a change in the amount of child initiated, open-ended, exploration of number?

Table 1 Teachers' perceptions of their mathematics teaching

Name/grade Current features After one term End of year 1 End of year 2 End of year 3
Anita

1990: P
1991: @
1992: 3

1993: 3 Small groups.
Problem solving.
Discovery, open-ended approach desired. No change at present.
Future change anticipated. More like language, more open-ended desired.
Much more open-ended.
Much more sharing & discussion. Tool to observe & understand children.
More open-ended.
Calculator not sole cause of change. @

Barbara

1990: P/1
1991: P
1992: P Use of materials.
Discovery learning.
Sharing & discussion.
Thematic.
EMIC influenced. More sharing & discussion.
More open-ended.
More like language. Much more problem solving.
More integrated. Less open-ended than year before.
More like language.
More sharing & discussion.
More open-ended desired.
More thematic desired. Much more problem solving.
More open-ended.
More like language.
More sharing & discussion.
More knowledge of children through observation.
Cathy

1990: 1
1991: 1/2
1992: 2* Children "doing".
Discovery learning.
No specific change desired. No change, except for using calculators. More open-ended.
More like language. Much more open-ended.
More problem solving. *Much more open-ended.
More problem solving.
More thematic.
Catering better for full ability range.
Heather

1990: P
1991: P#
1992: 2 Related to everyday life.
Better observation of children desired. More exploration expected.
More like language.
More integrated.
Perhaps caused by EMIC. Less problem solving.
More sharing & discussion.
Better observation of children desired.
More integrated.
Influence of EMIC also. # Influence of EMIC also.
More open-ended.
More problem solving.
More integrated.

Meryl

1990: P
1991: P
1992: P Basic concepts.
Hands on. More open-ended.

More sharing & discussion.
More activity. More open-ended. No change.
Less open-ended (more direction on how to use calculator). No change.
Sharon

1990: P
1991: 1
1992: 1/2 Use of materials.
Problem solving.
Catering better for full ability range desired. Change ongoing.
Less teacher directed. Less teacher directed. No real change.
No real change.
Much less calculator use than previous year.
Wendy

1990: 1
1991: 1/2
1992: 1/2 Basic concepts.
Related to everyday life.
Better use of real life problems desired. Much more open-ended.
More sharing & discussion.
More real problem solving.
More open-ended.
More sharing & discussion. More open-ended.
More open-ended desired.
Calculator not sole cause of change. More open-ended.
More sharing & discussion.
Calculator not sole cause of change.
@ Anita was in grade 3 in 1991 and hence not part of the project.
At the time of writing, she has not yet had her end of year interview for 1993.
* Cathy was not part of the project during the second half of 1992 due to family leave.
The last interview was conducted in February 1993.
Heather was on long-service leave for a term in 1991 and was not interviewed that year.

Underlying this question is the belief that teachers would

observe children using their calculators – presumably in ways which will challenge their existing beliefs about the nature of young children's learning of mathematics – and that reflection on the "classroom experiment" of calculator use and the consequent observations of children would lead to a change in their teaching. By implication, it was assumed that such a change would be in the direction of a more open-ended, exploratory approach.

Although teachers were given no hint of this, either in the interviews or at other times, all seven teachers commented at least once that their mathematics teaching had become more open-ended. Moreover, six of the seven teachers made such comments in at least two interviews. For example:

Yes, it has changed a bit. As I say, it's much more unstructured and we tend to carry on like if something gets started and I just let it go as long as they want to pursue it.

Meryl, End of year 1

I'm a lot happier to go where the children want … it's a lot less teacher directed… The calculators have enabled us to do that … You don't have to structure things so that you know the answer will be within their reach… If the children want to find out

stuff, I say "go for it"… because I'm not so worried about them finding out things they won't understand anymore… I think I'm being a lot more open-ended with their activities… I'm putting more on them to do more finding out. I'm just sort of starting them off. In some ways we are still structure driven when we play games … but the activities I try and do with them are the ones they can take themselves where they want to go … You never know what's going to happen.
Cathy, End of year 2

Two teachers specifically mentioned their increased knowledge of children's conceptual development, with one specifically linking this knowledge to their more open-ended style.

It's provided a tool for me to understand a lot better the way they are thinking and processing than I have been able to do before.
Anita, End of year 2

I don't think I've ever been as concerned as to what the children know … before. I think it has opened things up a little bit more and I'm more interested in them telling me what they know. I guess that's a general change in my teaching overall anyway. It was a bit slow coming to maths. I think the maths aspect has

lagged behind language, but having the calculator in the classroom has helped that – just finding out from the children what they know rather than me teaching.
Barbara, End of year 3

In all, four teachers describe their mathematics teaching as having become "more like language".

Yes, I think it's less structured. I think I'm a bit more relaxed there and let the children discover things. It's becoming a bit more like language where you let children explore their own limits and everything is acceptable. All the approximations and the answer doesn't have to be correct, as long as the procedure is getting there, and I think it's making the way I look at it a lot more flexible and open ended.
Cathy, End of year 1

This is my third year of teaching since I came back (from family leave) and I've been building on what I did. Having been out of it for a while you come back with different ideas. I got the language going and I felt happy with what was happening there and got to maths and it was not going the way I wanted to do it. So I was wanting to look for change as to how I would organise the classroom and wanted to make everything more open-ended. I felt it was too directed…. I felt open-ended tasks were the way to go rather than more directed group work which I was comfortable with and was what we were doing… . One of the things that the calculators did, they enhanced that idea. So this year it is just a year of on-going process and change all the time. I think I was changing all last year to try and make it more open-ended and let the children make more decisions themselves about what they were doing and how they did it. The calculator this year has enabled us to go that much further.
Anita, End of year 1

Teachers see calculators as encouraging them to talk more with the children, as well as providing opportunities for children to share and discuss what they have done. Five teachers specifically mention more sharing and discussion as a change in the mathematics teaching. For example:

I think it's getting up the free exploration and discovery time,

and it just seems to be a good tool to do that with. How else would I have had a whole hour a week where you play with them? What other material could I have used to get the same result? There probably would be something, but I haven't thought of doing it. I haven't really done it.
Anita, End of year 1

I've had to really encourage them to share what they've done. I think I've always done that in language. I haven't really done that very much at all in maths before. What I see in the use of calculators and how it's changed my maths teaching is that I think I'm teaching maths now more in a way that I've been teaching language for a while, and I've always taught maths much more formally … . It certainly encouraged me to talk to the children much more in maths, and discuss how did they do this, why did they do that, and getting them to justify what they're doing, which I guess previously I haven't done in maths. Much more discussion and sharing.
Barbara, After one term

Not all change has been in the direction of becoming more open-ended. Two teachers at the end of their second year of involvement described their teaching as less open-ended than in the previous year. Part of this was due to a concern that, by allowing free exploration, teachers were not catering for the weaker children.

I haven't seen as much creativity this year with the calculator as I did last year … maybe it's the way I'm doing it this year. I think last year, probably, I allowed the children more free time and experimentation, but I haven't done as much this year …. I found some of the weaker children last year were very nervous about the calculator. They couldn't work out how on earth the other children were doing this. Last year I didn't want to step in and say "this is what you do". … I think looking back on some of those children, I think I did them a bit of a disservice.
Barbara, End of year 2

Barbara, however, reverts to a more open-ended style in her third year of the project, as can be seen from Table 1.

Sharon, on the other hand, began by describing her teaching as becoming less teacher directed. By the end of the third year, she was claiming no real change in her teaching and less use of the calculator. Although it is not evident from the interview data, an impromptu and unrecorded interview with Sharon at the commencement of the third year of the project revealed that she was very concerned about the weaker children in the class were being "left behind" while all the sharing and discussion took place. As a result, she decided to move back to a more teacher directed style and in fact only use calculators for checking answers and similar relatively "closed" activities.

This year there has been less (use of calculators) than in the last two years. At the most once a week. (Their main uses have been) checking answers … counting, games related to money,

calculating totals of money …. It's just another tool. … I came to the conclusion that it wasn't having a positive effect on the children's total maths concepts as I originally felt. I spent a lot more time doing other things this year and a lot less time on calculator work.
Sharon, End of year 2

Extending problem solving

The original research question relating to teacher change was

phrased as follows:

Does the presence of the calculator facilitate problem solving? Are calculators used to provide data for investigations into pure number? Are calculators used to facilitate real problem solving - i.e. using real data? How often do teachers give children problems which require calculations beyond their mental and pencil-and-paper skills?

This question deals with issues relating to both content and teaching style. When asked about the ways in which their mathematics teaching had changed, four of the seven teachers indicated more problem solving as one change. Some teachers saw problem solving activities as a vehicle for relating their mathematics teaching to children's everyday lives, with the calculator clearly playing a part in facilitating the use of such activities.

Well, probably yes. They've been doing things like, how can I put it, everyday maths that occurs in the classroom in the school, which you try to utilise. They're more able to use those experiences like doing a survey on the school, and totalling the number of children in each grade and the number of boys and the number of girls. Doing the money trail and totalling up the amount of money. Doing the Friday treat and totalling the amount of money. So they provide an opportunity to make use of the real math,s that involves large figures, that you would talk about but they wouldn't actually be able to do the calculations without a calculator.
Wendy, End of year 1

Teachers' practice

Classroom observations were carried out about 10 times per year for each of the seven teachers.

In the first two years of the project, the observations were

originally recorded in a free format. This mostly took the form of a description of the activity being carried out and examples of children's work. This data was then transcribed into a grid format, with data categorised according to two different dimensions: the role of the calculator in the activity (e.g. recording device, counting device) and a crude measure of the open-endedness of the task (e.g. free exploration, exploration within a directed activity). Other dimensions, such as who initiated the use of the calculator (e.g. child, teacher); and the purpose of the task (e.g. problem solving, teaching or re-inforcing a concept) were used to annotate the entries.

During the last two years, a formal observation schedule was used. This schedule was based on the categories developed in the first two years.

Space does not permit a detailed analysis of the classroom observation data to be given here. However, an initial analysis of the data reveals no trends which might indicate a contradiction between teachers' perceptions of changes in their teaching and their observed practice.

The data reveals interesting differences in patterns of calculator use between different teachers. These will be reported elsewhere.

Conclusion

By the end of the third year of their involvement in the Calculators in Primary Mathematics project, most of the seven teachers in this study claimed to have made substantial changes to their teaching of mathematics. Teachers claimed to have adopted a more open-ended approach to their mathematics teaching, thus making it more like their language teaching. The use of calculators was seen as facilitating problem solving, often set in a "real world" context. These changes support the underlying hypothese of the project and were in line with trends obtained from an initial analysis of the classroom observation data.

In terms of the Clarke-Peter model for teacher change, the introduction of calculators resulted in a change to teachers' external domains, which resulted in teachers engaging in classroom experimentation. Teachers identified the calculator as providing a tool to observe children's knowledge and use of mathematics. These observations, together with those arising from the increased class sharing and discussion, provided the means by which teachers could reflect on their classroom experimentation with calculators, thus leading to change in their valued

outcomes. Changes in the external domain (e.g. various aspects of the support program, such as network meetings) and the changes in teachers' valued outcomes could then be viewed as forming the basis for further reflection, resulting in changes teachers' personal domain of knowledge and beliefs.

It would, however, be a mistake to attribute all of the change to the introduction of the calculator. There are always other sources of stimulation and support to alter the external domain. In this case, two of the teachers specifically identified the teacher development program EMIC as having had a significant influence on their teaching, while two others acknowledged that the calculator was not the sole cause for change.

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