YOUNG CHILDREN'S NUMBER CONCEPTS - The effect of calculator use on teacher expectations

SUSIE GROVES & JILL CHEESEMAN
Deakin University - Burwood Campus

This paper examines the extent to which seven teachers changed their expectations of children's mathematical performance during their first two years of teaching at the preparatory level in the Calculators in Primary Mathematics project – a long-term investigation into the effects of calculator use on the learning and teaching of primary mathematics. Questionnaire results show a slight increase in expectations for most of the 21 items dealing with counting and "large numbers", with a greater increase for the 5 items dealing with negative numbers. In general, teachers' increased expectations reflected their observations of children's performance during the previous year. Nevertheless, teachers' predictions remained conservative compared to actual levels of performance. However, data obtained from interviews and teachers' comments suggest that teachers are adopting a more open-ended approach to their mathematics teaching in order to cater for the increased level of understanding revealed by the presence of the calculator.

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. It is based on the premise that calculators have the potential to significantly change mathematics curriculum and teaching (Corbitt, 1985, p.14; Cockcroft, 1982, p.109). Apart from the *Calculator-Aware Number* (CAN) project (Shuard, Walsh, Goodwin & Worcester, 1991), there is little evidence that such changes are commonly occurring (Curriculum Development Centre, 1986, p.18; Hembree & Dessart, 1986, p.83; Reys, 1989, p.173).

The project commenced at prep and grade 1 level in six schools in 1990, with 45 prep to grade 3 classes participating in 1992. After three years of involvement, prep and grade 1 are no longer part of the project in 1993, leaving 33 grades 2 to 4 classes participating. All children are given their own calculator to use whenever they wish, while teachers are provided with systematic professional support to assist them in using calculators to create a rich mathematical environment for children to explore.

Changes in teachers' expectations of children's mathematical performance and consequent changes in the mathematics curriculum provide one of the major foci for the project.

Previous studies have found that young children's mathematical skills are consistently underestimated by teachers, with the consequence that a high percentage of tasks set by teachers fail to challenge many children (Young-Loveridge, 1989, p.60; Desforges & Cockburn, 1987, pp.90-94; Wright, 1991, p.13).

Young children in the CAN project used their calculators to explore numbers and developed mathematical concepts which were unexpected for their age (Shuard, Walsh, Goodwin, & Worcester, 1991, p.6). Furthermore, teachers began to listen more to children and encourage children to talk more about mathematics (p.45).

Yackel, Cobb and Wood (to appear) regard the classroom as the primary site for teacher learning as teachers interact with their students, with class discussions providing the opportunity for teachers to develop expectations and anticipate children's solutions.

The *Calculators in Primary Mathematics* project is based on a model of teacher change which assumes that the major motivation for teachers to change is the desire for improvement in student

* This research has been funded by the Australian Research Council, Deakin University and the University of Melbourne. The *Calculators in Primary Mathematics* project team consists of Susie Groves, Jill Cheeseman, Terry Beeby, Graham Ferres (Deakin University); Ron Welsh, Kaye Stacey (Melbourne University); and Paul Carlin (Catholic Education Office).

learning outcomes and that changes in teachers' classroom practice need to precede changes in teachers' beliefs and attitudes (Guskey, 1986, pp.7-10).

Considerable anecdotal evidence exists to suggest that young children in the project are dealing with much larger numbers than would normally be expected, as well as negative numbers, and, to a lesser extent, decimals (see, for example, Groves, Cheeseman, Clarke & Hawkes, 1991; Groves & Cheeseman, 1992, pp.3-4). If children exceed teachers' expectations in certain areas, then it might be anticipated that teachers will change their expectations, which will then lead to curriculum change. In order to investigate changes in teachers' expectations, data is being collected each year by means of an extensive written questionnaire and teacher interviews.

This paper examines the extent to which the seven teachers, who participated in the project at preparatory level for two or more years, changed their expectations of children's mathematical performance during their first two years. It focusses on three areas where we hypothesised that children in the calculator project would exceed teachers' previous expectations: counting, "large numbers" and negative numbers. Decimals are not dealt with here, as evidence suggests that gains in this area are not evident at the preparatory level.

QUESTIONNAIRE RESULTS

The written questionnaire contains 121 specific attainment targets, relating to number, at levels of difficulty ranging from what would be usually accepted as relevant to prep children (e.g. *count aloud to 10*) to ones which would normally not be seen as part of the primary mathematics curriculum (e.g. *correctly approximate to 3 significant figures a number on a calculator display*). The choice of items was based on a selection of attainment targets from the *Number* strand of the UK National Curriculum (National Curriculum Council, 1988). The items have been arranged at random, to avoid preconceptions about levels of difficulty. A total of 26 items deal with counting, "large numbers" and negative numbers.

At the beginning of each year of their involvement in the project, teachers are asked to indicate, for each of the items, their expectations of children at the beginning and end of that year. They do this by indicating whether they expect all, most, some or none of the children to be successful on the item. Their own completed questionnaires are then returned to the teachers at the end of the year for them to indicate, in the same manner, children's actual performance by the end of the year, and to make free comments on how they think their expectations of children's mathematical performance have changed over the period of their involvement in the project.

For the purpose of reporting the data here, the responses relating to the number of children expected or actually able to perform a task was mapped onto a linear numerical scale as follows:
None = 0 Some = 1 Most = 2 All = 3 .

Table 1 **Teachers' expectations of children at beginning and end of prep year and children's actual performance for items related to counting**

Item number	Description of task	Response*				
		Yr 1 Beg	Yr 2 Beg	Yr 1 End	Yr 2 End	Yr 1 Act
7	Count aloud to 120 .	3	5	8	10	11
22	Know the number 1 greater than 17 .	5	7	14	13	16
23	Count backwards from 10 to 1 .	7	10	18	20	20

40	Count by 2's from 1 to 17.	1	3	7	9	7
42	Count by 10's from 7 to 77.	1	1	6	5	9
47	Count by 10's from 10 to 100.	4	4	14	12	15
88	Count by 2's from 2 to 28.	1	3	7	8	10
92	Continue 5, 10, 15, 20, ...	2	5	11	11	17
100	Count backwards in 10's from 100 to 0.	1	2	5	8	8
107	Count by 5's from 5 to 50.	0	2	11	10	16
111	Know that 10 more than 42 is 52.	0	1	4	6	7

* sum of responses of seven prep teachers in their first and second years for expectations of children at beginning and end of year and children's actual performance, using the scale of None = 0 ; Some = 1 ; Most = 2 ; All = 3 .

Tables 1 to 3 display, in summary form, the data obtained for the 26 items dealing with counting, "large numbers" and negative numbers. For each item, the numerical scale referred to above was used to sum the responses of the seven teachers for their expectations at the beginning and end of the two years and children's actual performance in the first year. So, for example, for Items 7 and 107 in Table 1, the entries of 10 for expectations at the end of year 2 were obtained since three teachers expected most children to be able to do the task and four teachers expected only some children to do so (10 = 3 x 2 + 4 x 1).

Table 2 **Teachers' expectations of children at beginning and end of prep year and children's actual performance for items related to large numbers**

Item number	Description of task	Response*				
		Yr 1 Beg	Yr 2 Beg	Yr 1 End	Yr 2 End	Yr 1 Act
13	Know that "four hundred and two" is written as 402 and know why neither 42 nor 4002 is correct.	1	0	1	5	5
16	Count from 389 to 407.	0	1	3	5	6
19	Correctly read 14 560.	0	0	1	1	3
20	Know the value of the 2 in 521 400.	0	0	0	0	2

32	Know that 78 is 7 tens and 8 ones.	0	1	4	6	9
36	Write in figures four thousand and seventy three.	0	0	0	1	2
44	Correctly read 1810 .	0	1	1	4	3
55	Correctly read numerals to 1000 .	1	2	4	5	4
83	Count in 10's from 960 to 1050 .	0	0	1	3	5
98	Know the next number to appear on the trip meter of a car after 06399.	0	0	0	0	1

* sum of responses of seven prep teachers in their first and second years for expectations of children at beginning and end of year and children's actual performance, using the scale of None = 0 ; Some = 1 ; Most = 2 ; All = 3 .

Tables 1 and 2 show that for most of the 21 items related to counting and large numbers there was a slight increase or no change in teachers' expectations for children at the beginning and end of the year.

Four items (Items 22, 42 , 47 and 107) showed a slight decrease in expectations at the end of the year, mostly corresponding to just one teacher lowering expectations by one category. All of these items related to counting, with three of the four items relating to counting by 5's or 10's. It is difficult to explain these decreases in expectations as, for each of the four items, teachers had rated children's actual performance at the end of the first year not only higher than their predictions for the second year, but also higher than their expectations for the first year. This tendency to make conservative predictions in comparison with perceived actual performance from the previous year was consistent with data for all 21 items, with only three items (Items 40, 44 and 55) showing teachers predicting a higher end of year performance than actually observed in the previous year, while 15 items produced lower predictions.

Only one item (Item 13) showed a decrease in expectations for the beginning of the year. This item required considerable knowledge of place value, as did five of the six items which showed no change in expectations at the beginning of the year. This result is not surprising as these place value tasks would normally be expected to be much too difficult for children just beginning school. However, Item 13 resulted in the greatest positive change in teachers' expectations for the end of the year, with 5 teachers expecting some children to know how to write 402 in their second year, compared to only one teacher in the first year.

The other items to show significant positive changes in teachers' expectations were Item 23 (beginning of year) and Items 100 and 44 (end of year). Two of these items relate to counting backwards – a popular calculator activity which leads many children to "discover" negative numbers.

Table 3 **Teachers' expectations of children at beginning and end of prep year and children's actual performance for items related to negative numbers**

Item number	Description of task	Response*				
		Yr 1 Beg	Yr 2 Beg	Yr 1 End	Yr 2 End	Yr 1 Act

9	Know the answer for $2 - 6$.	0	0	0	3	3
59	Know that -3 is the number immediately to the left of -2 on a number line marked off in 1's.	0	1	0	3	2
60	Understand what is meant by -7 on a calculator display.	0	0	1	7	6
94	Count backwards from 9 to -9.	0	1	1	3	5
118	Count backwards in 10's from 50 to -70.	0	0	0	0	2

* sum of responses of seven prep teachers in their first and second years for expectations of children at beginning and end of year and children's actual performance, using the scale of None = 0 ; Some = 1 ; Most = 2 ; All = 3 .

Table 3 shows that, for four of the five items related to negative numbers, there was a considerable shift in teachers' expectations of children's performance at the end of the year, with approximately half to all of the teachers moving to expecting some children to be able to perform the task. The biggest change occurred for Item 60, understanding what is meant by -7 on a calculator display, where all teachers in their second year of involvement expected some children to understand this, compared to no teachers in their first year. Teachers' expectations for the end of their second year were closer to their perceptions of actual performance than for the earlier items. The only exception to this was Item 118, counting backwards in 10's from 50 to -70, for which no teacher expected any children to be successful either at the beginning or end of year, despite two teachers reporting that some children could do this in the first year.

TEACHERS' COMMENTS

Data on changing expectations obtained from interviews with the seven teachers and their free comments at the end of the written questionnaire falls into three major categories.

All seven of the teachers specifically refer to at least some children working with and understanding larger numbers than previously expected - e.g. "They can be counting on their calculator with long strings of numbers, counting from zero by fives. They can get right up into the hundreds and anticipate the next numbers. Once they stop keying in the numbers, they get up to 505 and they will know the next number is 510". Teachers sometimes directly attribute the understanding to the presence of the calculator - e.g. "I think it enables them to do more difficult things. They will make up counting grids and count up into the hundreds and even into thousands and they wouldn't be doing that if they didn't have the calculator". Teachers frequently comment that they are no longer able to "limit" children to numbers less than 10 (or 50 or 100) - e.g. "I'm not conscious of staying within a given number range. Although I might start that way, I then leave it up to the children".

This last comment also suggests a change in the way in which teachers are approaching their mathematics teaching. Five of the seven teachers reported changes in their teaching of mathematics, while the remaining two denied any such changes. The most common changes were in the extent of open-endedness of the tasks and the extent to which children are able to lead the learning process. For example, one teacher reports that "I have changed the way I plan the sorts of activities I do and allow the kids to extend themselves. I think that's what the calculator has allowed." Several teachers compare the changes to earlier changes in their language teaching - e.g. "I am asking a lot more questions and allowing children to arrive at their own answers. I am giving them a lot more freedom to experiment with number and problem solving. I am not giving

approval or disapproval, I am just allowing children to share what they find out. So it's much more child-centred, as language has become".

There is considerable agreement that the calculator enables teachers to see what the children can do and hence affects their expectations. One teacher comments "Some things children are actually able to do might have been the same in previous years - but I may not have given them the opportunity to show me. Consequently past experiences and style of teaching have led to my end of year predictions". When asked whether they believed the calculator was causing changes in children's level of understanding or merely revealing what they already knew, three teachers believed that it was merely revealing what children knew, three believed it was both, while the remaining teacher answered by saying "I think we actually stopped children from going too far years ago - we [went] to 10 in prep and 20 in grade 1 ... I really believe it's causing a change in teaching rather than in children's levels of learning. I think teachers are changing because we are using the calculators now".

CONCLUSION

Teachers' expectations, as measured by the questionnaire, show a slight increase for most of the 21 items dealing with counting and "large numbers", with a greater increase for the 5 items dealing with negative numbers. In general, teachers' increased expectations reflected their observations of children's performance during the previous year. Nevertheless, teachers' predictions remained conservative compared to actual levels of performance.

One possible reason for these conservative expectations may be teachers' beliefs that the few children they observed being able to perform these tasks in their first year of involvement in the project were truly exceptional and that such children were unlikely to be present again in other years.

The items relating to counting which showed the greatest increase in expectations both involved counting backwards. Counting backwards on calculators has been cited by project teachers as leading many children to "discover" negative numbers – the area in which the greatest positive change in teachers' expectations was observed.

Previous studies have found that the unrestricted mathematical environment provided by calculators encourages children to explore concepts from which they may have previously been "shielded" and that, as a result, teachers reconsider their approach to teaching and begin to develop exploratory and investigative styles of teaching which allow children to take responsibility for their own learning (Open University, 1982, pp.49-51; Shuard, Walsh, Goodwin, & Worcester, 1991, p.44).

Classroom observations and other data as reported elsewhere (see, for example, Groves, 1991) suggest that teachers involved in the *Calculators in Primary Mathematics* project are changing their teaching practice in mathematics. These observations are now supported by data obtained from interviews and the free comments on the questionnaire, which suggest that teachers, at least at the preparatory level, are adopting a more open-ended approach to their mathematics teaching in order to cater for the increased level of understanding revealed by the presence of the calculator. In particular, teachers are allowing children to lead the learning process by presenting them with starting points which allow for extensions in many different ways.

Future reporting of research on project teachers' expectations will focus on other aspects of number, such as operations, and other grade levels. If teachers' conservative predictions compared to children's actual levels of performance persists, further data will be collected through interviews.

REFERENCES

Corbitt, M. K. (1985). The impact of computing technology on school mathematics: Report of an NCTM conference. *Arithmetic Teacher, 32* (8), 14-18.

Cockcroft, W.H.(1982). *Mathematics Counts* . London: Her Majesty's Stationery Office.

Curriculum Development Centre and The Australian Association of Mathematics Teachers (1987). *A National Statement on the Use of Calculators for Mathematics in Australian Schools.* Canberra: CDC.

Desforges, C. & Cockburn, A. (1987). *Understanding the mathematics teacher: A study of practice in first schools.* London: Falmer Press.

Groves, S. (1991, November). *Calculators as an agent for change in the teaching of primary mathematics: The Victoria College Calculator Project.* Unpublished paper presented at the Annual Conference of the Australian Association for Research in Education, Surfers Paradise.

Groves, S., Cheeseman, J., Clarke, C. & Hawkes, J. (1991). Using calculators with young children. In O'Reilly, J. & Wettenhall, S. (Eds.). *Whither mathematics?* (Proceedings of the 28th Annual Conference of the Mathematical Association of Victoria, pp. 244-250). Melbourne: Mathematical Association of Victoria

Groves, S. & Cheeseman, J. (1992, November). *Calculators in primary mathematics: Changing expectations and curriculum issues.* Unpublished paper presented at the Joint Conference of the Australian Association for Research in Education and the New Zealand Association for Research in Education, Geelong.

Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher, 15* (5), 5-13.

Hembree, A. & Dessart, D. (1986). Effects of hand-held calculators in pre-college mathematics education: A meta-analysis. *Journal for Research in Mathematics Education, 17,* 83-99.

Ministry of Education, Victoria (1988). *The mathematics framework: P-10.* Melbourne: Ministry of Education (Schools Division), Victoria.

Open University (1982). *Calculators in the primary school.* Milton Keynes: The Open University Press.

Reys, B. J. (1989). The calculator as a tool for instruction and learning. In P. R. Trafton & A. P. Shulte (Eds.). *New directions for elementary school mathematics* (1989 yearbook of the National Council of Teachers of Mathematics, pp. 168-173). Reston, VA: NCTM.

Shuard, H., Walsh, A., Goodwin, J. & Worcester, V. (1991). *Calculators, children and mathematics.* London: Simon & Schuster.

Wright, R.J. (1991). What number knowledge is possessed by children beginning the kindergarten year of school? *Mathematics Education Research Journal, 3* (1), 1-16.

Yackel, E., Cobb, P. & Wood, T. (to appear). The interactive constitution of mathematical meaning in one second grade classroom: An illustrative example. *Journal of Mathematical Behaviour.*

Young-Loveridge, J. (1989). The development of children's number concepts: The first year of school. *New Zealand Journal of Educational Studies, 24* (1), 47-64.