NEMP Probe Study Report

Children's Strategies in Numeracy Activity

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This NEMP Probe study was associated with the course, *TL835 Issues in Numeracy*, in the Master of Teaching and Learning of the Christchurch College of Education. In 2005 five students enrolled in the course were required to collaboratively and individually analyse NEMP data for a research assignment within this course. The students were fourth year primary teacher education students enrolled in the full-time BTchLn(Hons) programme at the Christchurch College of Education. In this report, these five students are collectively referred to as the 'research team' and individually as researchers, and the author is the course lecturer. This report discusses some background issues to the study, outlines the analysis design and summarises key aspects of the analysis of the data from the research team.

Further information about the process of incorporating experience with NEMP data within coursework is reported elsewhere.

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Introduction

The National Education Monitoring Project (NEMP) Mathematics studies in 1997 and 2001 provide information about children's achievement in a range of task items (Crooks and Flockton, 2002; Flockton and Crooks, 1998). The tasks that focus on numeracy are found mostly (but not exclusively) in the Items from the 1997 Number and Money chapters and from the 2001 Number chapter. There are also number-related items from the Measurement, Algebra and Statistics chapters. The current Numeracy Projects have a focus on children's strategies and is a topic of some discussion within mathematics education (Walls, 2004). This highlights a tension between knowledge and strategies in the Numeracy Framework used in the current Numeracy projects. The NEMP Mathematics Framework (Crooks and Flockton, 2002, p.10) also includes connections between areas of Knowledge and Process and Skills.

The *Commentary* section in each NEMP Report provides brief details about children's errors and strategies after each Item. Further analysis of the task items may provide greater detail about children's mathematical and strategic reasoning as well as errors or misconceptions within the context of the tasks and among groups of children.

This Probe Study report sets out the method used to further analyse four task items from a small sample of the 2001 NEMP Mathematics data. The results of the data analysis are set out for each task and include the categories of strategies and errors for each item. Finally, the findings for each item and implications for research are briefly discussed.

Background

Assessment tasks in mathematics are designed to provide children with opportunities to solve mathematical problems and to demonstrate their knowledge of mathematics. Yet research suggests that assessment of children's understanding in mathematics is complex. Tasks can be presented in written form or verbally, with or without equipment. Problems can also be posed in everyday contexts, referred to as contextualized problems. These are designed to make a link with children's experiences including cultural backgrounds and assumed to be motivation for engagement in mathematical tasks. Tasks set in a context, however, can be problematic for children and can pose either a distraction or barrier for children in their attempts to solve the task (Boaler, 1993: Sullivan, Zevenbergen and Moulsey, 2002: Zevenbergen, 2002).

The language of the task also poses difficulties for children whether in written or oral form. The description of a context situation usually requires more text for children to read, placing greater demands on children (Eley and Cargill, 2002). They must be able to decode both the specialized terms in mathematics as well as the linguistic forms embedded in the questions (Eley and Cargill, 2003). School mathematics involves words that are not necessarily specific for mathematics but are signifiers of the type of task requirement. For example a question that asks "how many more than …?" includes a signifier 'more than' that provides a cue for the child about the type of task and possible solution strategies (Cooper and Dunne, 2000; Zevenbergen, 2000).

In New Zealand, further analysis of NEMP items has raised questions about the context and/or format of mathematical tasks. For example, a station task set in a context did not necessarily promote recognition. Although it was a familiar context of a family pizza dinner, the Year 4 children in particular relied on a prompt from the interviewer to continue with the questions in the task (Anthony and Walshaw, 2003a). The year 4 children were also more likely to talk about the features of the pizza context rather than the mathematical structure (Anthony and Walshaw, 2003b). Written tasks were found to be less popular with children than the one-to-one or multichoice tasks (Eley and Cargill, 2002). Question formats were examined and found that students were less successful with 'short answer' formats as these provided the least support to children without teacher clarification or equipment (Eley and Cargill, 2002). Children's explanations in one-to-one tasks described their strategies and/or reasoning and were more extended responses, generally resulting in higher scores than for other kinds of task formats (Eley and Cargill, 2002: Eley and Cargill, 2003). The one-to-one tasks had drawbacks, however, because some children gave as many responses as possible rather than taking time to articulate their thinking. Children may have felt watched with an interviewer present and were less likely to check answers. The multichoice format was somewhat contradictory as many children used the choice of answers provided to work out or guess the correct answer yet it was not popular as a format with the children (Eley and Cargill, 2002).

The children's verbal responses to tasks provide information about their mathematical thinking. This has become a common research tool as children's strategies or reasoning can be identified or inferred from what they say. For example, some seven to twelve year old students were found to retain the use of counting strategies rather than using number facts for addition and subtraction (Gray, 1991; Gray and Pitta, 1996;). The less successful students were found to have an over-reliance on counting strategies which was inferred as a tenuous knowledge of number facts.

Errors in written tasks can also be a source of information about children's mathematical reasoning. Errors can be based on misconceptions, plausible beliefs about numbers but applied to inappropriate situations (Hart, 1981; Johnson, 1989; Maurer, 1987). Recurring stable errors are also known as bugs, from a metaphor used in computing. Errors with decimal numbers have been a topic of much research in both primary and secondary schools (Irwin, 1999; Moloney and Stacey, 1996; Steinle and Stacey, 2001). Decimal misconceptions have been attributed to a variety of factors: application of whole number knowledge to decimal numbers (Steinle and Stacey, 2001), differing interpretations of some real life situations such as money, emerging knowledge of place value, or not enough emphasis on multiplicative thinking (Irwin, 1999).

This probe study used four task items from the 2001 NEMP data to investigate the following research questions:

1. *What strategies are Year 4 children using within a particular task?*

2. *What are the common errors in the written Number tasks?*

3; *What is the range of strategies in a one-to-one interview task?*

4. *How might the identified errors and/or misconceptions relate to aspects of the written task, such as language and visual presentation?*

Method

NEMP Items selected

Five task items from the 2001 Year 4 NEMP were selected for analysis, in consultation with USEE. These were chosen to provide a focus on numeracy or number-related activity, a range of contextualised and de-contextualised tasks, and a mix of written and video data (all from Crooks and Flockton, 2002).

Three independent tasks were selected and provided written data. The tasks were:

Addition Examples	(p. 14)
Speedo	(p. 17)
Money A	(p. 37)

Two one-to-one tasks were selected, providing video data.

36 and 29	(p. 20)
Number Line Y4	(p. 23)

Addition Examples was a Trend Task and *Number Line* was an Access Task.

These five tasks plus the survey data were available for each child.

Sample

The national sample for mathematics of 1440 year 4 children was divided into three groups of 480 (Crooks and Flockton, 2002, p. 5). Each group of 480 were given different tasks, so in order to track tasks for the same children, tasks from one of these groups were selected. The data sample provided by NEMP was 47 and the final sample analysed by the research team was 40 (representing 8.5% of the sample group of 480). The extra data sets from seven children were used for trial analysis before the researchers each took responsibility for the data sets of their eight children.

Changes made to the Method

On viewing the video data, the Number Line Y4 task was eliminated as it was not always possible to read the fraction on each card in order to identify where each card was placed. This illustrated how the interviewer in situ was better placed than the video viewer to accurately record the children's actions. Some of this task data was also compromised due to inconsistency of interviewing. Consequently, the research team decided to omit the Number Line Y4 task from this study.

Analysis of Data

The process of data analysis centred around immersion in the data, category generation, refining category analysis and peer review. These aspects were considered important course experiences for the researchers.

The research team familiarised themselves with the marking schedules for each task supplied by NEMP. They examined the task, became familiar with the marking approach, and generated further analysis categories guided by the course lecturer. Further categories focused on errors, and associated possible misconceptions or perturbations in mathematical activity. The research team refined the analysis protocol for each of the three written tasks, outlined in the next section. Each researcher used the analysis protocols for their sample of eight children, recording results in a grid for each task. This was followed by peer review of the analysis in order to check for consistency and to add further clarity to the analysis. Peer review involved a member of the research team analysing another's data set and recording their results. This process of comparing analysis decisions and discussing similarities and differences provided opportunities for clarifying and 'sharpening' the analysis protocols, resulting in greater consistency between researchers.

One of the constraints of analysing children's written work is that researchers are unable to use direct observation or ask children to self report their strategies. Children's strategies can only be inferred from the written record and, while inferences are influenced by research, interpretations can still be somewhat speculative. When known strategies could not be inferred or peer review revealed multiple interpretations, then the research team resolved to categorise these items as *unknown*.

For the video task (*36 and 29*), the researchers generated a transcript of what was said by the child and the interviewer, adding supplementary information observed on the video. The transcripts were analysed using the NEMP marking protocol and peer reviewed for one child. Finally, the research team put together a profile for each of their eight children based on the survey data and the analysis of the four task items.

Results

This section sets out the results of the data analysis for the sample of 40 children in each of the four tasks. All page references are from Crooks and Flockton (2002).

Task 1   Addition Examples

The five addition tasks are examples of the following types of addition found in school mathematics programmes and materials; (p.14)

1. vertical addition, two addends of single digits (5 and 8)
2. vertical addition, five addends of single digits (6, 3, 8, 7, and 4)
3. vertical addition, two addends of double digits (42 and 35) without renaming
4. vertical addition, two addends of double digits (87 and 56) with renaming
5. vertical addition, two addends of three digits (327 and 436) with renaming

The focus of the task was "adding without a calculator" (p. 14) and the instructions to the children were to write their answers in the designated boxes and to use the shaded area for their working. The number of correct, incorrect and no responses for each addition question is set out in the table below.

Question	Correct	%	Incorrect	%	No response	%
1	33	82.5	4	10.0	3	7.5
2	27	67.5	8	20.0	5	12.5
3	28	70.0	6	15.0	6	15.0
4	22	55.0	12	30.0	6	15.0
5	19	47.5	14	35.0	7	17.5

Table 1 Results of *Addition Examples*

Within the sample of 40, the percentages of correct answers were similar to the NEMP 2001 data. Similarly, there was a fall off for correct responses in questions 4 and 5 as noted in the commentary section that children "struggled when required to rename" (2001, p. 14). In our sample there was a relatively high percentage of no responses.

A further analysis of the incorrect answers revealed the following errors in strategies.

(i) Renaming: the errors associated with renaming were

- the 'carried' number added to incorrect column/place, often the left hand column regardless.

- having carried to correct place but then calculated as a larger number, eg renaming 1+2 as 12 rather than 3 (possibly using a subtraction form of renaming).

(ii) Mixing addition and subtraction, particularly in questions 4 and 5.

(iii) Adjusting the answer to have the same number of digits as addends (NB this is often the case with subtraction)

(iv) Other errors identified were

- misread numbers in the addends
- incorrect basic fact with addition in one of the columns
- Possible missed addends with adding more than two numbers (eg task 2)

The errors identified were examples of errors in addition and in the use of the addition algorithm. The addition of two digit or three digit numbers appeared to compound errors in renaming. The presentation of addends in a vertical form was also identified as problematic. This vertical format may cue children to use other operations such as subtraction including bugs in the renaming process.

Task 2 Speedo

New to the NEMP study in 2001, this series of questions used a visual representation of an odometer common to cars and referred to as a speedometer. This task is an example of a traditional place value task set in a context of a speedometer. The information provided in the tasks was as follows:

> A trip meter on a speedo shows how many kilometres a car travels. (p. 17).

The first four questions required adding respectively one, ten, one hundred and one thousand more kms to a benchmark number, 1996. The addition of ten and one hundred required renaming of one or more place. The final four questions required subtracting respectively one, ten, one hundred and one thousand kms from 3402. Only the subtraction of 10 required renaming. The number of correct, incorrect and no responses for each *Speedo* question is set out in the table on the following page:

Question	Correct	%	Incorrect	%	No response	%
1	18	45.0	19	47.5	3	7.5
2	4	10.0	31	77.5	5	12.5
3	4	10.0	31	77.5	5	15.0
4	12	30.0	21	52.5	7	17.5
5	14	35.	18	45.0	8	20.0
6	3	7.5	30	75.0	7	17.5
7	7	17.5	26	65.0	7	17.5
8	9	22.5	23	57.5	8	20.0

Table 2 Results of *Speedo*

Note that the percentages of correct responses were very similar to the results from NEMP 2001. There was less than 20% of ‘no response’ for all questions and there were indications of uncertainty such as evidence of some children rubbing out many of the answers or writing the benchmark number 1996 as their answer for all 4 questions. The three questions requiring renaming (questions 2, 3 and 6) had a high percentage of incorrect responses. One common renaming error was carrying the digits to the left hand ‘place’, correct for renaming two digit numbers but not for larger numbers. Other strategies to avoid renaming were to include an extra place, transposing some of the places when adding to the ‘nines’ place, or to add on numbers at both ends.

The nature of this task may have been problematic for year 4 children in a different ways. The context may have assumed some prior familiarity with a trip meter that changes as kms are traveled. An odometer is a dynamic system that shows the number changing, with two places changing when a 9 changes to a 10. Yet the visual presentation was a static image. The language load in this question may also have posed difficulties as the terms ‘more than’ and ‘before’ are possibly confusing for some Year 4 children.

Task 3 Money A

This was another contextual word problem and the context of money is often assumed to be more familiar and therefore more accessible for children of this age. The tasks were: (from p. 37)

1. In a sale 1/4 is taken off the price of everything. How much will you save on something which used to cost $2.00?
2. $2.50 is divided equally between 2 children. How much will each child get?
3. Sonny bought 3 Play Station games at $98 each. How could he work out how much he spent?
   A 3 x $100, minus $2
   B 3 x $100, minus $3
   C 3 x $100, minus $6
   D 3 x $100, minus $12

The number of correct, incorrect and no responses for each *Money* question is set out in the table below.

Question	Correct	%	Incorrect	%	No response	%
1	6	15.0	25	62.5	9	22.5
2	20	50.0	14	35.0	6	15.0
3	8	20.0	27	67.5	5	12.5

Table 3 Results of *Money*

Overall, in our sample, 5 children (12.5%) did not respond to both questions 1 and 2, with 3 of these children not responding to all questions. In the first question, 8 of the 25 incorrect answers were $1.50, the discounted amount for the problem. This is similar to the finding in the commentary that "many students in both years gave the discounted price, not the amount of the discount." (p. 37). Another common incorrect response was $1.00 which halved the original dollar amount. There were a few errors that seemed to be generated by doing something with the numbers presented ie 1 and 4 from the fraction. For this question, there were 9 errors that were classified as unknown.

For the second question, the most common incorrect response was $1.50 (4 instances), generated by dividing the dollar amount but leaving the cents intact. Similarly, there were 2 instances of doubling the dollar amount and leaving the cents intact. The remainder of incorrect responses were classified as unknown although all except 2 were answers that suggested the dollar amount was shared equally but the cents amount had been divided in idiosyncratic ways.

The third task was a multichoice question and the four options included the distributive property for this calculation. The results were: (No responses were 5)

A	10	25.0%(leaving the 2 dollars from 100-98)
B	2	5.0%
C	8	20.0%(correct answer) cf 21% from NEMP
D	15	37.5% (less obvious – using 96 instead of 98?)
(no response		12.5%)

Word problems set in a context can pose language demands of key signifiers and terms. This was evident in these three questions; for example, *equally*, *divided*, *between* (qtn 2), and *minus* (qtn 3). Year 4 children may not have been familiar with multichoice tasks or with the process for dividing quantities of less than one (ie the cents amount).

Task 4 36 and 29

The task was presented verbally to each child as:

> Here are two numbers, 36 and 29. If you had to add the two numbers, and you didn't have a calculator, how would you work it out? Try to think of **one** way you could work it out, and **explain** it to me.
> Encourage student to think of, and explain a way of working it out. They are not asked to work out answers. If the student succeeds in explaining one way ask: is there another way you could work out 36 plus 29? Explain to me how you would do it. (p. 20)
> (the students are also shown a card with 36 and 29 written horizontally.)

Task Four is an example of a decontextualised mental addition task where the interviewer asks the child to explain how they worked it out. The child 'thinks aloud' and their explanation is assumed to be the calculation strategy. This particular example a more complex task than 29 plus 36 because the larger number is the first addend. This was a one-to-one task and analysed from the transcript of videotaped interview.

The researchers used the NEMP marking schedule to categorise the first strategy provided by each child. The most common strategy (35%) was the conventional algorithm of adding the units first and carrying the ten. Two transcripts are set out below to illustrate the use of this strategy.

If it’s two numbers, first I take, because tens and ones. In the one’s column there’s 6, and in the other one, which is 29, in the one’s column which is 9 so I add 9 and 6 which is 15. Then I just have the one, the ten in my mind and then it’s 15, so I take the 10 off 15 and I just think 5. So in the one’s column it’s 5 when it’s added together. And 3 and 2 equals 5 plus one more ten is 60, so it’s 65.

Easy. Am I adding it?
(Interviewer: Yes that’s right.)
I’d go, write 29 up here (writes with finger on table), 36 down there. Put the plus sign here and draw the line underneath. Then I would go 9 plus 6 equals 15. I’d put the 5 down there and the one up here. Then 2 plus 3 plus 1 equals 6 and it would equal 65 … I think.

The next most common strategy (22.5%) was to add the tens first (30 plus 20) and then to add the units, often referred to as ‘front end’ addition. An example was:

Get two first numbers, the tens.
(Interviewer: You mean the 3 and the 2?)
Yes put them together and that makes 50 then add the 9 and the 6 and that makes 65/

There were some other number-related strategies such as the one below.

Well I would take 1 off the 6 and put it on the 29 which makes it 30 and 35 and then I would add the 30 and 30 together which makes 60 and seeing I’ve also got 5, it would be 65.

This strategy is an example of recomposing 29+1 as 30 and followed by front end addition (Sowder, 1988). 37.5% of responses were categorised as other and included methods that were often descriptive (eg counting, count on a ruler, use fingers, use equipment such as pencils, sticks, coins, a calculator) rather than an explanation of a number related strategy. A few children used other operations such as subtraction and division.

Conclusions

The analysis of the Year 4 sample for three independent written tasks revealed a range of strategy use. The *Addition Examples* were found to produce errors in renaming and in mixing the algorithms for addition and subtraction. The presentation of these examples in a vertical format was found to be problematic and may have cued children to use alternative calculation strategies. At Year 4 level, many children are still developing confidence with more that two addends or adding two or 3 digit numbers. Renaming was also a problematic aspect of the examples in the *Speedo* task with many children carrying the digit to the left hand place regardless. There were a significant number of no responses and incorrect answers indicating a high level of difficulty for this item due to the unfamiliar and contrived context and possibly some of the signifier terms used in the questions. The third written item was *Money A* that indicated difficulties with finding a fraction of a decimal, division of decimals and contextual difficulties posed by a task related to finding both discounts and a new discounted price.

The one-to-one task of *36 and 29* provided a rich source of verbal solutions. Children responded in many different ways and transcripts revealed a variety of solutions, of language, further detail about strategies, and opportunities for children to self-correct. This was an example of an assessment task where children could verbally express their thinking with the aid of an experienced other, the interviewer.

It is interesting to note that all four tasks are not included in the latest NEMP mathematics results (Flockton, Crooks, Smith and Smith, 2006). Some similar tasks appear such as subtraction and division algorithms rather than addition, place value questions are part of *Number A* (p. 14); and *36 and 29* is similar to the item *Beans* (p. 22), which is now a contextualized word problem. *Money A* has been transformed into an item called *Super Sale* (p. 39) where there are now two parts to the question, to find the savings and to find the new sale price. This new item is only for Year 8 children.

The research team also put together ‘assessment profiles’ for each of the eight children that they analysed. The profiles included the analysis of the four items plus the information from the survey data. Although these profiles have not been reported here, two issues arose that could lead to further investigation. Firstly, in our sample of 40, there were 4 children (10%) who consistently identified the *strongly dislike* category in most questions of the survey. Such strong reactions to mathematics at Year 4 concerned the researchers. In tracking through these four children’s profiles, they found that the children had been assessed as incorrect or no response for most questions in each item. In the transcripts of the one-to-one tasks, *36 and 29*, the children were found to use a counting strategy, counting on from larger (first addend), using fingers or equipment. Within the NEMP population, the data from the Year 4 children who identified a strong dislike of mathematics would be worthy of further investigation.

Secondly, the researchers returned to the children who were assessed as ‘incorrect’ or ‘no response’ for many of the questions in the task items, and included the four children identified above. These children (around 20%) appeared to have little success with questions in the written Items and would be an interesting group to study further. A more in-depth examination of the one-to-one tasks would provide information about their strategies and reasoning for a greater range of task items. Given current concern about the children who are underachieving in mathematics, a focus on the group of the least successful children at year 4 level could provide further detail about their mathematical activity.

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