Using spreadsheets with 8 year olds: Easy to visualise?

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ABSTRACT: Despite the prominence information and communication technology (ICT) receives in resource allocation and teacher professional development, little is known about the extent it actually enhances the learning process.

A recent study investigating the link between integrating spreadsheets into a primary mathematics programme, and the development of some specific numerical skills, suggested exploring number patterns and spreadsheet templates did enhance their understanding of additive strategies.

*This paper discusses the role of **visualisation** of number patterns in fostering learner progression from relying solely on concrete materials, to abstract thinking.*

Introduction

Information and Communication Technology (ICT) is frequently touted as the catalyst for innovation in education. Teachers and children have generally embraced various ICT medium as tools for research, conceptualisation and presentation. Various world wide agencies and curriculum associations have recognised the vast capacity of technology and its potential to revolutionise the learning process. NZAMT (New Zealand Association of Mathematics Teachers), AAMT (Australian Association of Mathematics Teachers) and NCTM (National Council of Teachers of Mathematics) have all included specific statements regarding the positive effects of ICT on learning in mathematics. This has been formalised in curriculum statements. For instance, Mathematics in the New Zealand Curriculum (MiNZC) states: "...computers are learning tools which students can use to discover and reinforce new ideas" (Ministry of Education, 1992, p. 14).

Schools and communities have invested vast amounts of resource, both monetary and human, in hardware, and professional development in the use of the computer has also been a major focus. There are some exciting developments, and much interest from children, teachers and communities in the integration of ICT into classroom programmes, and the need to prepare children to be effective participants in a technological world that hasn't yet been conceived. However, little is known about the actual effect of ICT on the learning process. While there has been much anticipation, positive discussion and anecdotal evidence, research into the potential of ICT to enhance learning is relatively limited.

This paper discusses aspects of research undertaken with two year four classes (predominantly 8 year olds) at a school in a provincial New Zealand city. Working in pairs in a computer suite, the children explored number patterns and spreadsheet templates that facilitated their understanding of additive strategies. While the research explored the understanding of additive number strategies in general, this paper focuses on whether children's inclination to visualise number patterns assisted their bridging the concrete to the abstract.

In attempts to alleviate problems in the development of understanding in numeracy, it is important not to neglect the potential that technology might have in enhancing that understanding. The facility of the spreadsheet environment to connect numerical, tabular and graphical forms of data gives the learner opportunity to visualise patterns. This, combined with its rapidity of response, creates a unique situation to explore mathematical problems or concepts. They also have the capacity to compute, and maintain, vast amounts of data simultaneously, enabling complex problems to be solved by different approaches. These aspects, when considered in conjunction with other mathematics educators more generic research into the way children learn mathematics, indicate the vast potential of the spreadsheet to enhance the understanding of mathematics.

In particular, strategies associated with addition and subtraction, investigations exploring place value, and problem solving in contexts conducive to the use of spreadsheets were elements of the research. The paper explores how the visual nature of spreadsheets, used to consider number patterns in an interactive environment, assisted some learners to reconstruct their strategies when doing addition and subtraction.

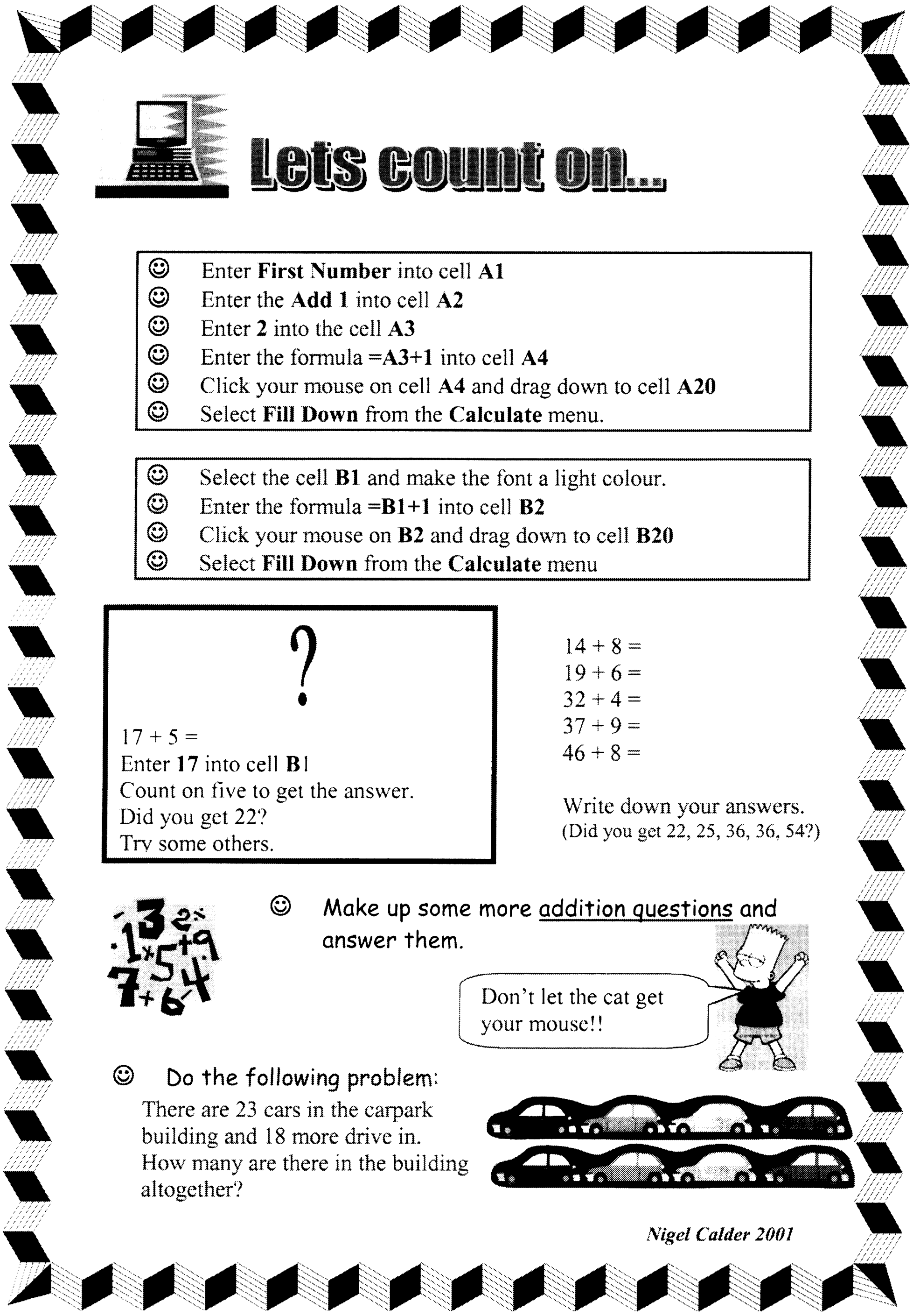
Method

Two similar classes of year four students $N = 28$, $N =2$ 6 from a medium-sized school in a New Zealand provincial city were given two instruments to assess their level of number understanding. The school has three year four classes of similar size, ability and behaviour profiles.

Two instruments were used for assessment. The first, 'Where Do I Start?' is a written, diagnostic assessment tool, covering number sense, operations, estimation and application of skills. It is based on the achievement objectives for levels one to three of MiNZC, and gave information on the children's content knowledge. The second instrument, a refined form of the Advanced Numeracy Project (ANP) was used to indicate the number strategies they were utilising. This assessment placed them on the numeracy project's framework for strategies.

The classes followed their usual number topic unit for four weeks, but with a similar approach. This approach was planned collaboratively, after a professional development session, and occurred simultaneously with regular consultation, to maintain some consistency. One of the classes had an enhanced programme. This involved using the spreadsheet to do number activities during one of its maths sessions per week.

These spreadsheet sessions included working, in pairs, through a series of worksheets that developed number patterns based on various addition and subtraction strategies. e.g.,



Lets count on...

☺ Enter **First Number** into cell **A1**
☺ Enter the **Add 1** into cell **A2**
☺ Enter **2** into the cell **A3**
☺ Enter the formula **=A3+1** into cell **A4**
☺ Click your mouse on cell **A4** and drag down to cell **A20**
☺ Select **Fill Down** from the **Calculate** menu.

☺ Select the cell **B1** and make the font a light colour.
☺ Enter the formula **=B1+1** into cell **B2**
☺ Click your mouse on **B2** and drag down to cell **B20**
☺ Select **Fill Down** from the **Calculate** menu

?

17 + 5 =
Enter **17** into cell **B1**
Count on five to get the answer.
Did you get 22?
Try some others.

14 + 8 =
19 + 6 =
32 + 4 =
37 + 9 =
46 + 8 =

Write down your answers.
(Did you get 22, 25, 36, 36, 54?)

☺ Make up some more <u>addition questions</u> and answer them.

Don't let the cat get your mouse!!

☺ Do the following problem:
There are 23 cars in the carpark building and 18 more drive in.
How many are there in the building altogether?

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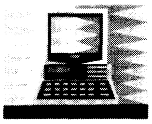
The worksheet material was introduced to the whole class in an interactive session, followed by the children working independently through the material. A consistent approach to format and terminology was taken through the series of worksheets, so that the children needed successively less explanation and support in interpreting the requirements of the activities. Initially, the activities required step by step instructions for setting up the templates for the various strategies, but as the children's skills and experience with working in the spreadsheet environment developed, this needed less emphasis.

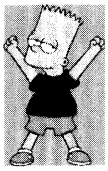
e.g.,Make a SPREADSHEET the same as the one below



Looking at PATTERNS

Make a SPREADSHEET the same as the one below

	A	B	C	D
1	1	11	=A1*B1	
2				
3				
4				



INVESTIGATE the pattern formed by the 11 times table by:

→ **Changing the number in cell A1, predicting what the answer will be, then pressing RETURN to see the answer.**

→ **Trying some 2 digit numbers.**

☺ **Are you still able to predict?**

☺ **Can you come up with a rule?**

☺ **Are there any tricky ones that need their own rule?**

→ **Trying some 3 digit numbers.**

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They also had some class sessions where the investigative tasks they were given were conducive to using the spreadsheet as a tool for exploration of number.

Care was also taken to ensure that spreadsheet skill enhancement was developmental and occurred as seamlessly as possible in the mathematical contexts. One objective was to have problems suitable for exploration and solving using the spreadsheet in the last sessions, but giving the children a range of options for them to utilise such as pencil and paper, and equipment. There is certainly an imperative to teach basic skills that allow the student access to the environment, but the aim is to use ICT as a tool for mathematics learning, not mathematics as a context for ICT learning.

For this age group it was expected that the children would use a variety of strategies including counting on, doubling, and making up tens to solve number problems. Moving from counting on to early additive strategies requires a degree of abstraction, so the spreadsheet activities required the children to develop a visual representation of a number pattern involved with each particular strategy.

Twelve weeks from the initial assessment (and seven weeks after the completion of the number topic unit), the two classes of children were reassessed using the same two assessment tools. The change in content level and strategies the children used were analysed. Statistical tests were carried out to see if there were significant differences between the classes that could possibly be attributed to the spreadsheet activity intervention.

Children from the class that used spreadsheets to explore number patterns and strategies were also surveyed in regard to attitudinal changes through using the spreadsheet activities, and to gain further information about their understanding of numeracy and the effect of using the spreadsheets.

Over this period observations and some informal individual interviews took place during each of the spreadsheet and the in-class learning sessions. These were recorded as field notes. Examples of children's work were also recorded.

Findings

The research indicated some general findings regarding the children's learning experience in the spreadsheet environment, as well as those of particular interest for this paper. The nature of the data collected, that is ordinal level data, dictated the use of a non-parametric test. While this constrains any extrapolation of the findings to children in general, it does allow us to make statistical inferences, of relative development between assessments, for each class. The Wilcoxon signed ranks test indicated a significant improvement, between testing times, for the enhanced class in their content score, MiNZC level and addition/subtraction strategies ($z = -2.828, p < 0.01$). This was particularly marked for addition/subtraction strategy ($z = -3.308, p < 0.01$).

The class that had their number programme enhanced with the spreadsheet activities, made statistically significant improvement in their concept knowledge and their development of strategies, whereas the improvement of these aspects was not significant with the control class. This implies that the use of spreadsheets to explore number patterns seemed to enhance the children's understanding of concepts and appeared to facilitate the advancement of their repertoire and employment of mental strategies to solve numeracy problems. As well as the development of understanding indicated by the assessments and interviews, observation also revealed children effectively using strategies they had not used prior to the spreadsheet activities.

Collation of the survey responses from the enhanced class indicated clear attitudes to the use of spreadsheets in the mathematics programme. All the pupils felt the activities with the spreadsheets had helped them understand some of the maths and all enjoyed doing the work on the spreadsheets. There were also comments in the interviews that indicated their enjoyment of, and motivation stemming from, the actual use of spreadsheets:

> Even numbers was pretty cool. The spreadsheet did a lot of the easy bits for you quickly.
>
> It was fun going on the computer. Way better than working in my book. Made me want to do it more.

The teacher also commented on their enjoyment and motivation:

> They were really enthusiastic. They were really motivated. Some of the brighter kids really buzzed about the challenge.

The two particular strategies that the students indicated using spreadsheets helped them most with, were counting back and doubling; these areas were also commented on significantly in the in- depth interviews. With the counting back template, for example, the children followed instructions to set up the spreadsheet, then investigated various number problems using the number patterns generated by the spreadsheet.

e.g., the following template was used for the question: There are 23 children in the choir. If 8 of them are boys, how many are girls?

First Number	23
Subtract 1	22
2	21
3	20
4	19
5	18
6	17
7	16
8	15
9	14

The children had to enter the first number (in this case 23), which generated the number pattern. They then counted back 8 from that first number to get 15.

The visual aspect of generating and seeing a pattern (in the approach or process, as well as the actual number patterns) was reported by students.

> Counting Back (the worksheet activity) helped me to learn to do it in my head better. Usually I count it on my fingers instead of in my head, but it helped me to see it in my head better.
>
> The doubling machine was most useful. You could see the numbers, see the pattern. Before I couldn't double my numbers but (after the spreadsheet work) I saw how it worked.
>
> It was easier to see it, to see what's happening. I'm kinaesthetics and visual and found it easier to learn this way. Its cool, helped me to learn well.

The visual number pattern also facilitated strategy development. One student who used a count all approach commented discretely to me that you "... could cheat by just reading off the number". The fact that he was now selecting the initial number, entering it into the spreadsheet, then using the number pattern, was the significant gain for him. He had moved seamlessly to a counting on strategy by utilising the visual number pattern.

The teacher also commented that it helped to develop their strategies for counting on and counting back, and that the effect on their ability to double was, "...huge, awesome."

Analysis

The use of spreadsheets was conducive to developing activities suitable for particular strategies. The counting on and counting back activities included forming a visual pattern for them to physically or mentally count through. It was obviously more efficient to do so mentally and the children quickly realised this (within their partnership anyway) and adapted their strategy. With, for example, "17 + 6 =" they used the tabular image to count on 6 mentally, from the entered value of 17, rather than counting through each number while physically indicating them. Critically, the activity also emphasised identifying the starting point for the counting on/back procedure. The children had to mentally identify this initial value, and they could instantly verify their choice. This is consistent with Beare's (1993), Chance, Garfield and delMas' (2000) and Calder's (2001) assertions that the opportunity to immediately test, then verify in an interactive situation, is a vital element in learning facilitated by ICT.

For both these and the doubling activities, the capacity to develop, then reflect on, the visual pattern offered, not only provided a means and support to explore this strategy, but allowed the students to mentally predict, then confirm, what the doubled value would be. This facilitated a sequential progression from using a physical model through to using the mental strategy exclusively. The use of a visual approach, in itself, may have been advantageous, not only from the perspective of providing for an alternative learning style (Baker & Biesel, 2001), but also because this visualisation provides an essential link between an approach based on concrete materials, to utilisation of a mental strategy.

As one of the students put it:

> Counting back (the activity) helped me learn to do it in my head better. Usually I count it on my fingers instead of in my head, but it helped me to see it in my head better. Count back and count on (the activities) helped me to get it in my head. It was easier to see it, to see what's happening.

The capacity to edit easily was another practical aspect noted by students. This also facilitates their willingness to explore and take risks, particularly when coupled with the speed of response and the intimacy of working with a partner on a task, rather than in a whole class situation. Risk-taking and relatively unrestrained exploration of mathematical ideas are key features of effective problem solving. This investigative approach, fostered through the points above, encouraged the students to experiment with different strategies. The teacher also commented that "...their approach to strategies changed; they thought more about what they were doing."

It is not clear whether this transition was directly related to the actual medium itself, however, or the change of approach, which gave the students an opportunity to reconstruct their strategies.

The interviews shed light on a further perspective. One student commented on the envisaging of the pattern, after counting back in tens on the spreadsheet. The connection between the visual scaffold of the generated pattern, and the mental visualisation required at the transition from advanced counting to early part/whole strategies, seems to be a critical feature of the spreadsheet work. Another student felt that "to be able to visualise the pattern or what was actually happening" was the most useful aspect of the spreadsheet activities. Two others talked about the activities enabling them to visualise the pattern.

> I could see the pattern with the numbers. My counting on is better now.
>
> You could see the numbers, see the pattern. The doubling machine was most useful. Before I couldn't double my numbers but [after the activity] I saw how it worked.

Giving the learner the scope to visualise both in tabular and graphical form definitely gives the spreadsheet a major advantage as a learning tool. Baker and Beisel (2001) found some advantage to a visual instruction style, modelled by spreadsheet usage, in their investigation of how children best understand averages. The NCTM also advocated the use of spreadsheets for their support of a visual instructional style. Lemke (1996) maintained that visual-graphical representations available in software such as spreadsheets, have the potential to allow students to develop mathematical concepts and relationships. McRobbie, Nason, Jamieson-Proctor, Norton, and Cooper (2000) contend that "[a]s computers are able to represent information in both textual and visual forms, they have the potential to provide the multi-media environments for more effective learning (p. 188)." Seeing an immediate change to a graph when a table value is altered, is certainly a powerful method of imaging the relationship between the two.

Several students and the teacher commented positively on the motivational effects of both the medium and particular activities. Their enthusiasm for the activities was also an obvious and frequent occurrence observed. The children's self-identification of the motivational aspects suggests it had a positive impact on the learning process.

The intervention appeared to be beneficial to a wide range of students. One of those identified by the teacher as requiring consistent support for mathematics learning, commented on the benefits gained from the activities: "I'm pretty good at maths now, since doing it on the computer. It makes more sense." The teacher also remarked about the extension and incentive the work provided some of the brighter students. This breadth of appeal and effectiveness, can possibly be attributed to the structure of the activities, but is also symptomatic of the medium and its propensity to engender risk-taking and investigative skills, that allow learners to explore and reflect at their own conceptual level. To some extent it helps to personalise the learning process.

I also noticed the maturity of the language used by several interviewees. They seemed very comfortable using correct spreadsheet terminology by the interview stage, as well as being conversant with words such as "visualise". Only the spreadsheet language could perhaps be attributable to the work undertaken, but using the language in appropriate situations indicates understanding.

The results indicate the use of spreadsheets enhanced the development of strategies to solve number problems. However, this must be viewed with caution; to extrapolate from this limited sample to give a definitive answer to what is a generic, encompassing question could not be justified. Nevertheless, the research gives insights into the question, allows generalisation in terms of year four children in a New Zealand provincial city, and provides clearer understanding of how children make sense of numeracy content and processes.

Conclusions

There were a number of significant features to emerge from the results and analysis. A critical, and consistent, aspect of the findings was that the spreadsheet provided a visual environment to effectively explore the mathematical ideas. This capability, not only enhanced understanding, but the development of approaches less dependent on concrete materials. The visual nature of the spreadsheet work, and its capacity to enable children to explore number patterns and strategies for processing numbers easily, for example, doubling, appears to facilitate the bridging of the gap between the use of materials and mental imaging. The transition from matching physical objects into pairs, to mentally doubling numbers requires intermediary development. Creating, then investigating number patterns produced by the doubling machine appears to assist that transition.

The student is able to generate, visualise, then manipulate number patterns with an almost instantaneous response, allowing for the clear linking of the action they have thought through, to the reaction they see on the screen. They can observe the transformation of the number (in tabular or graphical form) and site it within the context of other transformations they have initiated. Most of the students interviewed remarked that this ability to see the pattern and the process was particularly valuable. This visualisation is identified as a critical developmental stage, necessary for the progression through the stages from count all, to advanced counting, to early additive part/whole in the New Zealand numeracy framework (Ministry of Education, 2001).

One aspect of the findings was the motivational effect derived from the spreadsheet activities. All the students found the spreadsheet activities enjoyable and useful. This positive attitude, in itself, would have impacted on their confidence and conceptual development. The rapidity of response, coupled with the less threatening, more personal environment that working with an associate on the computer provides, fosters the exploration of mathematical ideas in problem solving and the stimulation of mathematical thinking since the results of prediction or conjecture are viewed very promptly.

The interactive quality of working on the computer, and with the spreadsheet activities in particular, provided an additional approach to processing the conceptual knowledge or strategies that some learners probably benefited from. This might also provide opportunity for some students to conceptualise aspects of the classroom programme as well. For instance, if the student in the class programme was using equipment and mental visualisation to develop the strategy of doubling in the addition of two digit numbers, then setting up the spreadsheet to perform that task, interacting with the computer by prediction, trial and confirmation of output, and conjecturing about the cause of unexpected results, would certainly help advance understanding. Several students indicated this aspect.

This is consistent with the findings of other researchers; Beare, for example, concluded:

> Spreadsheets...have a number of very significant benefits many of which are now apparent. Firstly they facilitate a variety of learning styles, which can be characterised by the terms: open-ended, problem orientated, constructivist, investigative, discovery orientated, active and student centred. In addition they offer the following additional benefits: they are interactive; they give immediate feedback to changing data or formula; they enable data, formula and graphical output to be available on the screen at once; they give students a large measure of control and ownership over their learning; and they can solve complex problems and handle large amounts of data without any need for programming. (Beare, 1993, p. 123)

These attributes Beare identifies, coupled with appropriate teacher intervention, enable the learner, to not only explore problems, but to make links between different content areas that may otherwise be developed discretely. They allow students to model in a dynamic, reflective way. Funnell, Marsh, and Thomas (1995) contend that "[b]y interacting with a computer programme which, as well as showing some of these different algebraic, linguistic and graphical representations, actively encourages students to relate one to the other through investigation, may assist them to construct linked mathematical cognitive structures" (p. 231).

In my considered opinion, children progressing in their approach to solving number problems from counting concrete materials (including fingers), to visualising number patterns, to using strategies that require mental imaging, is a desirable outcome of a mathematics programme at this level. It appears spreadsheets provide a unique and valuable tool for visualising number patterns, that enhances children's numerical understanding and their development of strategies to solve number problems, and allows them to conceptualise in abstract ways.

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