Not everyone talked about cats: learning from Year 5 learners' responses to lessons using Numicon (a visual concept manipulative)

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In upper Key Stage 2 (KS2) English mathematics classrooms, written work produced in response to questions in textbooks features prominently. Individual output,, is emphasized and mathematical artefacts, present in earlier school life, are absent . Through a piece of action research, the responses of 90 Year 5 children to one such artefact, Numicon, during and after 3 lessons about number, were considered. Though quantitative data was collected from the children, this paper focuses on conclusions drawn from the verbal responses of individuals, articulated immediately after each lesson, in semi-structured small-group interviews: these show Numicon use could still benefit Year 5 children. Crucially, its limited availability necessitates sharing of equipment thereby stimulating partnership and talk. Here, there is the potential for verbal thought exchange about mathematics which can enhance learners' understanding. The complexity of enabling this to occur between pairs of learners in upper KS2 mathematics classrooms is discussed.

Keywords: Numicon; primary; Key Stage 2; Year 5; talk; pairs; visual concept manipulative; division; bus-stop method

Introduction

Differences exist in the way pupils encounter maths at opposite ends of primary school. In Reception, children who have just passed their 4th birthday are surrounded by concrete representations of number, both formal and informal, and everything is a problem to be solved. In contrast, in upper KS2 (Years 5 and 6, children aged 9 to 11), maths is experienced through textbooks or question sheets and the resource that the children have to help them is likely to be their own brain. Whilst working with a group of Year 5 children (aged 9 to 10) who found maths difficult, I realised that their needs were not met by the structure of typical upper KS2 maths classrooms, in particular through the absence of practical equipment; in fact, the Reception classrooms seemed to provide a better fit. Furthermore, writing that "education often results in making far too many people look 'dumb' because they are not allowed to use resources, whereas outside of education we all use resources", Pea (1993, p.73) highlights that resources have potential relevance to everyone, not just those labelled as low attainers. Recalling that in Reception concrete representations are used by all not just to develop understanding of number but also to aid exploration and problem solving, I began to question their absence in upper KS2.

Initial theoretical background

Piaget (1964) suggested that stages exist in child development with a concrete operational stage occurring between the ages of 7 and 11 (KS2), the age when most English schools currently actively move children away from use of concrete objects

and towards test-based national assessment in Y6 (SATS). Though this implies some disagreement as to when concrete resources should be used I am sure most primary maths teachers would agree that there are points where concrete objects help learners to gain understanding of, even access to, the number system. Pea's quote hints that here age is as unimportant as prior attainment. One aspect of this project, then, was to see whether such objects might still hold relevance for children in upper KS2 learning about number, irrespective of their prior attainment.

In trying to narrow my focus to a specific 'manipulative', I noticed that in much of what I read this term was being used generically implying that such objects are equal. However Pea (1993) recognised an intelligence inherent in them by virtue of their design: the easier an "artifact" is to use, the easier it is to understand and the more intelligence it therefore holds. Hence, the most intelligent manipulatives would allow the learner to understand, and develop their understanding of, abstract concepts for themselves without intervention. In some ways, these tools have the potential to fulfil the role of a more able other (Vygotsky, 1978). Building on these ideas, and also those of Lakoff and Nunez (2000, pp. 39-52), I developed terminology to take account of this (Skevington, 2016) and to allow me to home in on a specific type of artefact that I define as a "visual concept manipulative". This is a concrete tool which provides the learner with a bridge between physical and visual representations and mental constructs because its visual imagery enables those who handle it to explore, and make inferences about, fundamental concepts of our number system independently. Out of Cuisenaire rods, Dienes apparatus and Numicon, I chose to focus on the latter as the children I worked with were most familiar with it.

Methodology

As a practicing classroom teacher, I aimed to improve my practice for learners by improving my knowledge and understanding of their perspectives. This steered me towards action research and heavily influenced my research question: How do Year 5 children respond to Numicon in maths lessons about number?

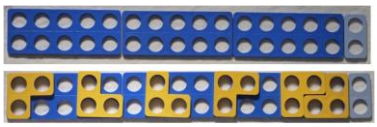
The fieldwork was carried out with a cohort of 90 Year 5 children in a three-form entry school in North London. A pilot had been carried out with 19 children at another school before finalising the study design. I taught each of three mixed ability classes 3 consecutive maths lessons about number: the first concerned multiples and factors and enabled the children to familiarise themselves with key terminology and Numicon; the second looked at solving division using Numicon; the third focussed on division using the bus stop method (the children's first school experience of this written method) and encouraged learners to choose whether to continue to use any Numicon. A short A5 pupil self-response sheet gathered individuals' feelings immediately before and after the lessons. Facial Likert scales were used to understand: attitudes to maths; enjoyment of the lesson; responses to partners. Pre-coded multiple choices gathered data about perceived understanding and resource use. A 2-point difference in a facial Likert scale assessing attitudes pre and post lesson acted as a screener for a semi-structured small group discussion immediately after each lesson. All 9 of these groups had a mix of gender and attainment and were recorded. The verbatim transcriptions were especially rich and formed the basis of my conclusions and the focus of this paper. A rough codeframe based on more than 1 mention of an idea by children in separate groups was created. From these, themes representing different core responses emerged. The resources and time at my disposal were limited: inevitably, my conclusions are, to a degree, subjective.

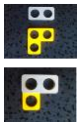
Results and discussion

The verbatim transcriptions highlighted three main areas for discussion: the Numicon supported some children's understanding of written methods of division; children's responses to the Numicon differed according to their prior attainment; the Numicon provoked verbal interaction between children which hugely affected the lessons.

Did the Numicon help them to understand the maths?

Numicon's visual imagery gave the children an understanding of core concepts behind, and within, the process of division before employing a written method. The second lesson focused on remainders as whole numbers and as fractions. Figure 1 shows 32 being made using three 10s and one 2 and 32÷3 being solved by alternating pieces and gaps of 3s until 2 remains. Children were then led to understand a remainder of two-thirds by thinking of the 2 remainder as part of a whole 3 (Figure 2). Developing understanding was reflected in self-corrected written work (Figure 3).


(Figure 1)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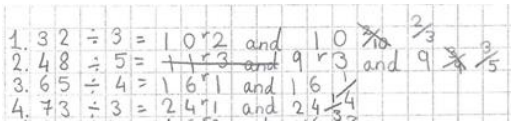

(Figure 3)

In the group discussions following the first two lessons, many children highlighted how Numicon supported them. In their words, it helped them to "understand the question", to "see what remainder you have" and to "understand how you found the remainder". Seeing what was happening and understanding the process as a consequence was repeatedly referenced. Additionally, a lack of available equipment steered children towards relying on their internal visualisations to solve the divisions. Transitions from concrete to more abstract thinking were inferred in multiple verbatim similar to this one: "…we imagined having 4s there and counted and then we ended up having 10 4s and 5 imaginary 4s, so we added it together."

Did the Numicon help everyone?

However, the verbatim show a polarization of opinion between children with different levels of prior attainment. Those who traditionally struggled with number saw Numicon as an equalizer; without it they wouldn't have understood the work. By comparison, many of those who were confident and secure in their times tables viewed it as irrelevant. Not all such children expressed this view but all those who did fell into this group. Ultimately, this response led them to reject a tool which could still have been useful to them: within each lesson there was an extension activity, designed specifically with these children in mind. All would have been easier to solve using the Numicon however the children trying these activities were unwilling to do so, even after verbal encouragement. Responses indicate some believed it was for younger children leading to feelings of embarrassment at the thought of using it. Some felt it was just for those who found maths hard. Others suggested that because what they were doing was different to what the core group of children were doing, it wouldn't be relevant. All had undertones of being beyond needing to use a tool to help them and yet none were able to solve the problems without it. They viewed Numicon, and perhaps tools generally, as something to aid core understanding not as a problem-solving resource that could be applied elsewhere.

Did the Numicon affect the lesson?

Typically, a lack of sufficient equipment necessitated sharing affecting the classroom environment and the lesson and causing learners to have a high awareness of, and dependence on, the actions of others, particularly those of their immediate partners. Pupils' responses to these interactions were heavily represented in the verbatim.

Some felt that having a partner had been good because: it felt more secure and less risky; or they felt it was exciting; or because they could use their respective knowledge to help each other. Others had a less positive experience and here, as Cobb (1995) has suggested, relative prior attainment mattered. Power struggles developed where children who were more secure in their understanding had taken control thereby annoying their partner. Others felt they had to take control because their partner hadn't. Some felt that with a more knowledgeable partner, they would have fared better. Others suggested existing social relationships were an affecting factor.

The resultant noise level was a problem. Some clearly worked very hard:

> ...if we didn't have enough 2s to put down onto the 34...we might have...spaced it out or put a 4 on it...or put down all the 2s and have left a space and see if we had enough or we...put them all down next to each other and then use maybe put some 4s or a 6...

However, "other people were talking about cats". Several children observed that conversations around them caused them to talk louder. The raised noise level hindered some: "if I…had a number in my head and I was trying to…sort it out and the noise would kind of get it out of my head and…I'd have to start all over again."

Some didn't want a partner: two children chose to work on their own. Others worked independently in the final lesson to see if they could do the work themselves and know for certain their thinking was correct. That said, their self-response sheets still show a preference for working with a partner: essentially, they preferred to work with someone else but saw some benefits to working independently.

The Numicon itself caused some problems. How the equipment was being shared, or not, formed the basis of several children's comments; how some were playing inappropriately with it was at the root of others. Moyer (2001) discusses the impact that familiarity with tools, or the lack of it, can have on lessons and how this affects the viewpoints of teachers and learners and their subsequent actions. Here it was clear that novelty was an issue for some and core etiquette needed to be developed in others. That said, most were on task and socially responsible responses were being triggered: some cited getting their partner back on task; some highlighted their own conscious choice to focus either because they didn't want to get into trouble or because they didn't want to fall behind; others highlighted ways to overcome the problems of sharing equipment. Independent of adult input, they had begun to negotiate their own way around the complicated dynamics of paired and shared work.

Conclusions and implications

Overall, the children's responses do not suggest that Numicon use in upper KS2 maths lessons should be avoided. This is not to say that it should be used in every maths lesson but more that it does still have some relevance.

Although this work focussed on Numicon and the subject area of division, I suspect similar responses would have been generated by lessons using a different tool or with a different focus. An important by-product of the use of any limited resource is the opportunity for dialogue created between pupils: not everyone talks about cats!

Howe (2010) notes multi-learner interaction is less likely to be seen in maths classrooms in comparison to other subjects presenting this as a negative. However, use of a limited resource in a KS2 classroom will inevitably provoke verbal interaction as a consequence of sharing. Vygotsky (1962, p.47) conjures a picture of thought and speech as 2 overlapping circles with verbal thought occurring at their intersection and representing a distinct, and particularly important, part of speech: not all talk is 'learning' talk. If interaction between pupils becomes a necessity, then opportunities for verbal thought exchange must arise: how do we change this from a potential occurrence into a reality? Houssart (2009) notes that expectations about when it is appropriate to hear learners' voices in school can stem its flow and Davis and Williams (2011) find positives occurring in unrestricted talk. Further clues exist in the responses of the children in my research to their immediate partners and to the lesson environment. Taken together, these suggest directions for further research.

Where teachers control pairings, matching children by their general level of mathematical understanding may ensure equality of contribution and participation and avoid resentment and a lack of understanding and engagement. Strongly targeted task differentiation may also be highly relevant. More notably, the children in this study recognised effective and ineffective partnerships themselves. The complexity of understanding ever-changing personalities and friendships, and the self-regulating responses of some in this study, suggest that the effects of pupil autonomy in partner selection may be particularly worthy of exploration.

Physical rearrangement of the classroom may be advantageous. KS2 classrooms I have seen seat children in rectangular groups of 6. However, other configurations may reduce noise level in a class of talking pairs because of relative positioning: pairs sat immediately opposite one another can maintain better eye contact and hear each other better than children sat side by side or across a table.

Some children suggested that the third lesson was the most valid because more written work was produced; equally, teaching the first two lessons I worried about reduced 'evidence' in books. Yet the verbatim show clear evidence of learning and development. It may be useful to consider how jottings, meaningful to the learner, could become more acceptable in primary workbooks.

Finally, at conference, I was asked whether encouraging use of concrete resources in later primary years was wise given SATS expectations. I recall replying that this was no reason to adversely affect learner's maths self-esteem in the preceding years. On reflection, I want to add to this. In these lessons, there were 3 broad but clear groups: those who were moving themselves away from the Numicon when they were ready to do so; those who weren't ready to do this but who were accessing the core task and developing their understanding; those who placed pressure on themselves to solve problems mentally and actively discounted using the resource. More normalised access to such resources in upper KS2 classrooms would help all three groups and would remove the stigma associated with them that first sparked my interest in this area, that my questioner highlighted, that Pea describes and that those who perceived themselves to be competent at maths displayed. Such tools can be applied in different ways and are potentially relevant to all. Further work should focus on ways to ensure it is viewed as such by teachers and pupils alike in order to help develop the latter's understanding and ability to apply skills to solve problems.

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