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PRESENTATION AND PEDAGOGY: THE EFFECTIVE USE OF INTERACTIVE WHITEBOARDS IN MATHEMATICS LESSONS

Dave Miller, Derek Glover and Doug Averis

Department of Education, Keele University

There has been a considerable investment in the use of interactive whiteboards in mathematics teaching in England. A research team from Keele University has worked with 12 partner school mathematics departments to evaluate the use and effectiveness of teaching when the technology is used to advantage. Evidence suggests that the presentational advantages of interactive whiteboard use are considerable and that the consequent motivational gain is to be welcomed. However, it is also clear that neither of these add to teaching effectiveness unless they are supported by teachers who understand the nature of interactivity as a teaching and learning process and who integrate the technology to ensure lessons that are both cohesive and conceptually stimulating.

The increase in the availability of interactive whiteboards (IAWs) to teachers in the secondary sector has come about because 'Missioner' teachers have persuaded senior leaders in schools to use resources to purchase the technology, or because external funding has been used to prompt senior leaders to promote the wider use of IAWs (Glover and Miller, 2001a, 2001b). However, availability alone is not sufficient to ensure continuing, consistent and effective learning (McCormick and Scrimshaw, 2001; Glover and Miller, 2002). Indeed, Greiffenhagen (2000) has shown that the use of the technology as an adjunct rather than as an integrated element in teaching minimises interaction and the matching of teaching to the learning needs.

The emergent factor in effective use of IAWs in mathematics teaching (as illustrated by Greiffenhagen, 2000, Edwards et al., 2002, Ball, 2003) appears to be that learning should be interactive – although the nature of this has been subject to considerable debate (Birmingham et al., 2002; Buckley, 2000; Jones and Tanner, 2002).

Working directly with 12 local secondary schools on a Nuffield Foundation funded research project, and collecting evidence from a further 6 schools in England on a British Educational Communications and Technology Agency (Becta) funded research project, members of the Keele University Department of Education IAW group have instigated extensive research to ascertain the rationale, practicalities, pedagogic implications and outcomes of the use of IAW in secondary mathematics.

METHODOLOGY

The fundamental aim of the research was to ascertain, analyse and evaluate practice in the classrooms of those teachers who were making extensive use of IAW technology. To this end a total of 37 mathematics lessons were video-recorded and all teachers who were video-recorded were interviewed using a semi-structured interview schedule.

The video-recorded lessons were analysed according to a set format with observation of: the timeline and activity sequence in each lesson; classroom management issues; the nature of IAW techniques used within the lesson and their perception by pupils; an assessment of the teaching style used in the lesson; teacher and pupil technological fluency; identification of practical and pedagogic issues; enhancement resulting from IAW use within a framework of pedagogic elements; the extent of 'on task' work when the IAW was the focus of attention; the percentage of the lesson when the IAW was the focus of teaching and learning; the contribution of IAW use to conceptual development; and the contribution of IAW use to cognitive development.

The 'Nuffield' teachers involved in the research took part in five discussion sessions based upon summaries of evidence collected. This enabled grounded analysis and led to two sets of findings that prompted changes in classroom practice: sharing of 'what works' and gains in the classroom experience for pupils.

FINDINGS

This paper looks to consider the use of the IAW use in secondary mathematics lessons in terms of presentation and pedagogy.

Presentation

In looking to identify and evaluate techniques and approaches being used to maximise the generic presentational gains of brightness of image and enhancement of interest for pupils this paper builds on the findings of Harler (2000), Iding (2000), and Latane (2002) and on the extensive practice reports offered by Becta (Becta 2003), the SMARTerkids Foundation research website (2004) and reports offered by other IAW manufacturers such as Promethean. Associated work linking presentation and motivation by Clemens et al. (2001) describes the gains from the IAW when used in learning enhancement for slower learners, and Bell (2000) and Blanton and Helms-Breazeale (2000) have also considered the gains from the use of stimulating technology from which enhanced presentation develops.

One of the gains of IAW technology is that teachers have access to many presentational techniques or '***manipulations'***, that can enliven understanding and learning. In some lessons teachers used several of the commonest manipulations, in others they used just two or three but exploited them to the full as a spur to learning. Most of the mathematics teachers using 'supported didactic' (Miller et al., 2004) approaches were using a limited number of manipulations. This approach is typified by lessons where the teacher makes some use of the IAW but only as a visual support and not as integral to supporting the conceptual development of pupils. Broadly speaking teachers who had consistently used the technology for at least the past year were inclined to use manipulations to foster interactivity rather than enhance presentation, i.e. they had moved beyond lessons using a '*supported didactic'* approach.

The six most common manipulations used for securing interactivity were:

drag and drop, where an on-screen item was moved for purposes of, for example, classification, processing, comparing items, ordering terms, testing hypotheses etc., often causing another action from software or expecting a further action or comments from pupils

hide and reveal, for example, hiding and then opening a response once a pupil had understood an idea thereby allowing ideas to be stepped in a particular way so that conceptual development takes place, and stepping the development of hypotheses

colour, shading and highlighting used, for example, for emphasising similarities and differences, enhancing explanations, and allowing reinforcement through greater emphasis

matching items, for example, equivalent fractions, a straight line with its graph and an equation with its solution

movement or animation, to demonstrate principles and to illustrate explanations

immediate feedback, from teacher, pupil or software, often arising as a direct consequence of one of the other five manipulations

In each case, observed best practice in the use of these manipulations included discussion between teacher and pupil based on focused questioning and appropriate follow up responses. In addition pupils were also observed using over-writing to annotate as they explained a process on the IAW. In all of these an aim of the teachers was to '*maximise the number of children working at the board so that they could develop their own self-esteem in use, and to stimulate the rest of the class to take part in what was happening at the board*'.

Drag and drop and *hide and reveal* appear particularly appropriate and relevant in mathematics lessons. Demonstrating equivalence or fitting and working through solutions to problems respectively clearly benefit from these manipulations. *Immediate feedback* from software was observed and proved to be particularly powerful, offering a 'neutral' comment. *Colour, shading and highlighting* was used extensively and effectively in, for example, graph work and work on fractions.

Just under half of the interview respondents commented upon higher standards of their presentations as a result of the use of IAW software and pupils referred to the way in which writing on the board had improved. It was '*sort of professional looking*' and '*much easier to read than the writing we used to have*'.

All except two of the observed lessons made use of commercially or professionally produced materials all of which incorporated *colour*, *shading*, *drag and drop* with *movement and animation*. By contrast those screens developed from the teacher's own work, often from Excel or PowerPoint programmes appeared to be less effective

– either because of minimal movement or because the standards of presentation (font, colour use, and highlighting) appeared comparable with 'old whiteboards'.

In lessons in which teachers were working with a 'supported didactic' approach there were fewer activities in the lesson period, the pace was more limited and there were longer periods of associated textbook or exercise work. In these lessons there were also fewer manipulations used and teachers tended to make use of *drag and drop* or *hide and reveal* more than in those lessons where interactivity was more highly used. In the lessons characterised by 'enhanced interactivity' (Miller et al., 2004), which is characterised by the development of teaching and learning strategies to shift the focus from the teacher to the IAW and pupil centred learning, there was a tendency to use more activities with several techniques and a combination of commercially or professionally produced materials with those developed by the teacher. These lessons had greater pace and tended to use the IAW as the focus of all activity including IAW based exercises and extension work.

Pedagogy

The learning context changes markedly when the IAW becomes the focus of exposition and development. Our evidence showed that the major features that encourage learning can be classified in three ways: ***intrinsic stimulation*** provided by the combination of the visual, kinaesthetic and auditory paths to learning; second the ***sustained focus*** maintained throughout the lesson by the teacher's management and 'orchestration' skills; and third ***stepped learning*** through constant challenges with frequent assessment of achievement as a stimulant to further involvement. The potential gains do not arise simply from an enhanced learning context but stem from the way in which teachers, who understand the nature of enhanced interactivity, structure the learning process so that the IAW is harnessed to effect.

All participant teachers were attempting to harness three underpinning pedagogic principles of: a lesson structure based upon an introduction or starter, a developmental phase and a plenary; the learning of concepts, as a basis for cognitive understanding; and a recognition that pupils learn in different ways. This awareness appeared to give teachers a framework for lesson preparation driven by planning to '*take advantage of what the IAW has to offer and link that to the way in which kids learn*'. Additionally, teachers were conscious of the need to maximise interactivity between themselves, the pupils and the learning materials. This they achieved through: exploiting opportunities for manipulation by teacher and pupil during lessons; the extended use of immediate feedback from software; using strategies for shared evaluations; the opportunity for differentiation of materials on the IAW and using the IAW as a focus and catalyst in lessons.

Two thirds of the observed lessons could be characterised as having pace – recognised by teachers as a hugely significant consequence of IAW use - with pupils actively learning in a planned progression with frequent checking of fact and understanding by teachers relying heavily on IAW manipulations already discussed.

When the pupil groups were asked to identify why they thought that they were learning more effectively they identified the inherent interest of colour, shading, dynamics, hide and reveal and demonstration; the sequential development of ideas and exemplars resulting from pre-prepared and commercial software; the availability of games that support learning, requiring responses that can be immediately assessed and then linked to a scoring system with team races or, e.g., noughts and crosses; and the 'fun' arising from the use of tools such as compasses, grids and lines; the immediacy of any feedback or interaction built into the programs; and the opportunity to revisit earlier concepts and examples in underpinning understanding. All these stem from presentation but reflect the planned structure and pace of learning.

There was also evidence of changes in the way in which lessons were being managed and these were shown to great advantage in developing differentiated approaches to the learning of similar concepts. All except one of the teachers interviewed maintained a full record of the materials they had developed and the way in which they had been used. Nine of the twelve schools had developed departmental 'sharing' systems so that materials were readily available to all groups with IAW access. The ready availability of earlier materials facilitated teacher awareness and prompted visual recall from lesson to lesson either as part of a staged learning process or as the basis of revision. In three of the observed lessons learning was stimulated through IAW specific software prompts as a means of sustaining both individual and group understanding and achievement. Teachers were increasingly adept at recalling materials to show the same concept in different ways to ensure understanding and retention as shown in the use of some year 7 (age 11-12) and 8 (age 12-13) materials with those who were having problems in coping with year 9 (age 13-14) equation work. There were personal gains for the pupils in that interactivity required a higher degree of attention (often stimulated through the use of associated 'slates' - non electronic mini-whiteboards), and as a result there appeared to be increased effective participation and enhanced self-esteem as frequent checks on progress were used to minimise the gap between assessment stages in conventional teaching.

Teachers were all conscious of the need to maximise interactivity between themselves, the pupils and the learning materials. This three way link was achieved through:

- the opportunity to use 'virtual manipulatives', such as a fraction wall, so that concepts could be illustrated and worked upon by the pupils. One teacher said '*this led to some profound moments in learning because we were able to use moving rather than static software, and pupils began to understand things like 3D co-ordinates and loci'*
- the use of the IAW as the focus of the lesson with pupils working on their own mini-whiteboards, and coming up to the IAW to provide answers, to illustrate concepts and to explain processes

the possibility of immediacy of feedback either through programmed software or through the use of presentational tools such as right and wrong answer symbols

the use of materials in a way that can be differentiated on the same IAW screen although not perceived to be obviously so by the pupils

There was also much debate about the place of traditional textbooks, exercise books, homework and other data sources for teaching. Analysis of the lessons suggests that at the time IAW use was within a traditional framework and that few teachers were 'brave' enough to rely on IAW based learning alone. One teacher made use of pupil based mini-whiteboards to check understanding as the lesson progressed and then used homework to consolidate learning – '*but in a way that makes them use it, think about it and then move on so that we can make steps in the next lesson – and with much less traditional marking.*'

Awareness of the need for cognitive development and the place of concepts within lessons were shown in the frequent reference by both teachers and pupils to sequencing of ideas, the availability of a range of pre-prepared examples appropriate '*to age and ability*', and adaptability of materials to allow for '*alternative approaches and the use of different ways of learning*'.

In pedagogic review the teachers also drew attention to the clear match of objectives to activities and the need for pupils to use the IAW to help in their evaluation of progress. The interviewees were asked to outline the criteria by which they selected materials for use with the IAW. Responses included the view that the materials should offer '*sound mathematics*', '*a maximisation of knowledge*', '*an avoidance of gimmicks*', '*the need for quality that can give more than we can give on the IAW*' and '*enhanced interest and visual impact*'.

CONCLUSIONS

Overall the evidence points to an increased understanding of the presentational and pedagogic gains from IAW use in mathematics lessons. The research offers evidence of the need for generic skills and competencies if the technology is to be used to maximum learning advantage.

Teachers need time to develop their technological fluency, apply pedagogic principles to the available materials or to the development of materials, and then to incorporate the IAW seamlessly into their teaching. Few teachers base all their lessons on the IAW all the time, and over half those interviewed stressed that the IAW has to be seen as part of the equipment available but that there was still a need for the use of texts, exercises and other media. As teachers become more experienced users it appears that they become more aware of the nature of interactivity and its stimulation as the basis for conceptual development and cognitive understanding. Pupils also need to have a range of skills if they are to take part in lessons without loss of self-esteem as technologically incompetent. Even so good practitioners ensure that all pupils have access to the IAW, and are given help if there are signs of unhappiness with the medium.

It is only when basic technological fluency and pedagogic understanding have been achieved that teachers can then overcome the novelty factor. Our evidence suggests that there is an initial period where interest is stimulated by the cleverness of the technology, but after a period pupils are more aware of three great gains: brighter and clearer presentation of material, stepped learning and the ability to recall earlier material, and, rapid responses to interactive examples so that learning is reinforced or revisited.

Where pupils have reached this stage, they accept the IAW as part of the battery of learning resources offered to them and progress beyond novelty to enhanced learning. At this stage any possible behavioural problems are usually overcome because pupils are caught up in the sequence and pace of learning and appear to '*take off*' in their understanding, achievement and consequent self-esteem.

It is not sufficient to argue that the use of the IAW will, of itself, bring the classroom into the 21st century and the visually stimulated environment. Effective teaching requires that the technology and the pedagogy are directed towards enhanced and structured understanding. '*I love my board because it gives so much to the kids*' may be the clue that enthusiasm can be regenerated not just in the pupils but also in staff. However, in order that the IAW might bring about substantial national gains in mathematics teaching we believe that there are implications for the professional development of teachers in order that the presentational and pedagogic advantages might be recognised and then realised.

REFERENCES

Ball, B., (2003) Teaching and learning mathematics with an interactive whiteboard. *Micromath* Spring 2003, pp. 4-7

British Educational Communications and Technology Agency (2003) *What the research says about interactive whiteboards*, British Educational Communications and Technology Agency

Bell, M.A. (2000) *Impact of the electronic interactive whiteboard on student attitudes and achievement in eighth grade writing instruction*. Research report published on www.smarterkids.org.

Birmingham, P., Davies, C. and Greiffenhagen, C. (2002) Turn to face the bard: making sense of the three way interactions between teacher, pupils and technology in the classroom. Education, *Communication and Information* 2 (2-3) 139-161

Blanton, B. and Helms-Breazeale, R. (2000) *Gains in self-efficacy: using SMART board interactive whiteboard technology in special education classrooms*. Research report published on www.smarterkids.org.

Buckley, B.C. (2000) Interactive multimedia and model-based learning in biology. *International Journal of Science Education* 22(3) 895-935

Clemens, A., Moore, T. and Nelson, B. (2001) Math intervention "SMART" project (student mathematical analysis and reasoning with technology). Research report published on www.smarterkids.org.

Edwards, J.A., Hartnell, M., Martin, R. (2002) Interactive whiteboards: some lessons from the classroom. *Micromath* 18 (2) 30-34

Glover, D. and Miller, D. (2001a) *A report to Blackburn and Colne EAZ on New Technologies*, Keele, Department of Education

Glover, D. and Miller, D. (2001b) 'Missioners, tentatives and luddites: leadership challenges for school and classroom posed by the introduction of interactive whiteboards into schools in the UK'. *Paper delivered at BEMAS Conference* Newport Pagnell, October.

Glover, D. and Miller, D. (2002) 'The interactive whiteboard as a force for pedagogic change: the experience of five elementary schools in an English education authority' *Information Technology in Childhood Education* Vol. 2002 Issue 1: AACE Digital Library

Greiffenhagen, C. (2000) Interactive whiteboards in mathematics education. *Paper presented to ICME 9*, Tokyo, 2000

Harler, C. (2000) Supporting the technology-enabled classroom, Journal of *Telecommunications in Higher Education*, 4 (4), 8 - 11

Iding, M. (2000) 'Is seeing believing? Features of effective multimedia for learning science' *International Journal of Instructive Media* 27 (4): 403-416

Jones, S, and Tanner, H. (2002) Teachers' interpretations of effective whole-class interactive teaching in secondary mathematics classrooms. *Educational Studies* 28 (3), 265-274

Latane, B. (2002) 'Focused interactive learning: a tool for active class discussion' *Teaching of Psychology* 29 (1): 10-16

McCormick, R. and Scrimshaw, P. (2001) 'Information and communications technology, knowledge and pedagogy. *Education, Communication and Information* 1: 37-57

Miller, D., Averis, D., Door, V., & Glover D. (2004) From technology to professional development: how can the use of an interactive whiteboard enhance the nature of teaching and learning in secondary mathematics and modern foreign languages? Unpublished report to the British Educational Communications and Technology Agency

SMARTer Kids Foundation research website (2004) http://www.smarterkids.org/research/index.asp