Keele University Department of Education

Enhancing Mathematics Teaching through New Technology

The Use of the Interactive Whiteboard

A Report to the Nuffield Foundation, Reference EDU/00272/G

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Background

Between April 2002 and March 2004 members of the Keele University Department of Education Interactive Whiteboard (IAW) group took part in extensive work to ascertain the rationale, practicalities, pedagogic implications and outcomes of the use of IAWs in mathematics teaching in secondary schools within the Keele Partnership of schools associated with initial teacher education.

Methodology

In accordance with the methodology outlined in the application for this grant, plans were made to undertake the research in the following way.

- A team of mathematics teachers from associated schools was to work with the project leader and the university staff to develop software and the appropriate pedagogic guides for ten topics the secondary years 11-18.
- These materials were then to be used in the schools and evaluated by the research team
- Participants were to be asked to allow members of the research team to video-record at least one lesson using the developed materials with IAW technology.
- Participants were also to be asked to complete two evaluation sheets during the period of the investigation and invited to use pupil questionnaires. In addition, the impact of the IAW and pupil progress were to be assessed using other attainment tests.

Practicalities led to some changes in the methodology. These were matters of scale rather than fundamental change because it was not possible to recruit sufficient school groups prepared to offer traditional teaching as a comparator for those lessons being taught with new technology. Rather, all schools wanted to be able to use and evaluate the new materials although two of them allowed limited comparisons by groups using traditional and newer mathematics teaching technology.

We decided therefore to place more emphasis upon the development of a structure for lesson observation analysis than was originally intended and this contributed to the research in a way that had not been originally envisaged. In total 40 lessons were recorded, observed and analysed and this formed the basis of much of the pedagogic analysis that follows. There were full interviews with 10 mathematics teachers and outline interviews with 10 others. About 80 pupils in each of two schools took part in attainment tests to provide data on enhanced learning based on IAW use.

In total 17 mathematics teachers from 12 secondary schools had some involvement with the project, though only 10 of these teachers were fully involved for the entire project. The team met either once or twice per term for a full day of discussion, practice in the use of materials and pedagogic development. These meetings provided an opportunity for discussion of issues of philosophy and practice and led to considerable cross-fertilisation of training approaches that are reported to have been of benefit to all participating schools.

Video recording of lessons started in 2003 and the recordings were given to each of the research team members and the teachers themselves. In most cases the video camera remained static and was focused on the IAW allowing observation of the teacher at and around the IAW and all activities

on the IAW. In all cases some pupils were in view of the camera. For some of the recordings the camera 'followed' the teacher when the teacher was not using the IAW.

The video-recorded lessons were then analysed according to a set format with observation of the following:

- the timeline and activity sequence in each lesson
- classroom management issues
- enhancement from IAW use, considered within a framework of revision of past work, establishing new principles and data, sequencing of information and learning, demonstration of processes and reinforcement of learning through recall and the use of examples
- the contribution of IAW use to cognitive development
- the contribution of IAW use to the conceptual development of discrete elements in the lessons
- the nature of IAW techniques used by teachers within the lesson and the way in which these were perceived by pupils
- an assessment of the teaching style used in the lesson
- identification of practical and pedagogic issues arising from the use of IAW technology in its contribution to effective learning
- assessment, through identification of one pupil in the group to establish the extent of 'on task' work when the IAW was the focus of attention and when other work was being undertaken
- measurement of that percentage of the lesson when the IAW was the focus of teaching and learning

This structure is given in some detail because it forms the basis of our recommendations for improved teacher practice in IAW use.

Development of materials

In this work we originally planned to develop two topics per year over each of five school years (years 7 to 10 and year 12). As we worked through the project our plans changed to allow for school factors (a curriculum taught in a prescribed sequence) and the individual needs and experiences of the group of teachers. We therefore developed fewer topic materials to be used in the research than originally planned but instead developed more materials that would last for single lessons or parts of lessons. In addition we spent more time adapting and changing the materials based on the advice of the teachers who had used them. This allowed us to look in more depth at pedagogic issues as the teachers discussed how the materials had been used and how improvements could be made.

At an early stage it became evident that we needed to consider the design of IAW screens and templates for IAW screens looking at where to place various 'components' of the screens so that they might be seen and used by pupils, how many and which colours to use, and how to use colour and other features of IAWs to enhance teaching.

It also became clear that we would need to focus on 'concrete' materials and to make sure that lessons would be enhanced by the use of such materials. Considerable time was spent on two components - a 'fraction wall' and a 'toolbox' containing a protractor, compass and a ruler. These were developed, tested, refined and then re-tested and refined again. Ideas for starter activities were considered and developed and we established a number of different 'templates' that were tried and then refined.

Monitoring and evaluation
Throughout the period of grant aid the day meetings with the teachers involved provided an opportunity for continuing internal evaluation of the process and impact of the work being undertaken. Particular gains were:

- the opportunity for all materials to be scrutinised and refined by potential professional users
- the involvement of users in the planning of the content of programmes of work
- regular reporting of gains and inhibitors from material use
- the opportunity for users to systematise and conceptualise their practice
- the rapid dissemination of practice and materials to the teams in their schools with potential change of practice in over 50 mathematics classrooms.

Internal evaluation was undertaken by one of the team who maintained structured and informal interviews with the school participants at all except two of the termly meetings. Questionnaires were used at the start and finish of the programme and all participants were asked to report back to the project leader on the completion of programmes of work involving the materials. This evaluation evidence forms the basis of the first publications arising from the work.

External evaluation was undertaken by Pat Perks of the University of Birmingham School of Education. She worked alongside the group for all except three of the termly meetings and met on other occasions with the project leader to discuss the use of IAWs. Her particular contribution was to question both the mathematics content and the way in which the IAW technology was exploited in order to facilitate pupil understanding. She also contributed to the discussions on effective teacher development in understanding the technology.

Findings
There was a continuous development of understanding of the technology and pedagogy of IAW use in supporting mathematics teaching. In the early terms attention focused on the practicalities of IAW use but once the practitioners had systematised their approaches and techniques there was a move towards ensuring effective use of the particular features of IAW supported learning. From this, and in the final two terms, the emphasis moved towards a deeper conceptualisation of the pedagogic gains from IAW use. This progression underpins the findings that follow.

a. Presentation of materials
Observation and interview evidence was also used to explore the processes by which IAW use promoted interactivity, as teachers understood it, in the lessons. In the use of techniques the six most common methods of securing interactivity were:

- drag and drop, matching a response to a stimulus and used for classification of data, matching, sequencing, processing of data
- hide and reveal, opening a hidden response when the stimulus was understood
- colour, shading and highlighting used for e.g. the collection of like terms
- matching equivalent terms, e.g. fractions
- movement, to demonstrate principles, e.g. angles on a line
- providing immediate feed

Many of the mathematics lessons observed also made use of commercially or professionally produced materials incorporating these elements of interactivity but to a varying degree. This was particularly welcomed in fractions work where seven staff spoke of the way in which coloured segments could be moved round a fraction wall to demonstrate equivalence, the effect of adding and subtracting, and establishing rules for handling numerators and denominators. By contrast those screens developed from the teacher's own work, often from Excel or PowerPoint programmes

appeared to be less effective, especially in the early stages, – either because of minimal movement or because the standards of presentation (font, colour use, and highlighting) appeared comparable with 'the old whiteboards'.

b. Motivation

The effect of brighter and dynamic presentation resulted in an increased pupil interest in what was happening and in good teaching the focus of learning moved from the teacher to the IAW.

Our evidence suggests that the major features that encourage pupil motivation can be classified in three ways:

- The intrinsic stimulation provided by the combination of the visual, kinaesthetic and auditory paths to learning.
- Those aspects of classroom management that lead to a focus on the IAW throughout the lesson.
- The stepped learning that characterises much IAW teaching and which offers constant challenges with frequent assessment of achievement as a stimulus to further involvement.

In those lessons where the IAW was used only as a support there were clear changes of pupil attention and attitude when the IAW was replaced by the teacher as the focus of activity – interest waned, and there was evidence of a return to behavioural management comments in a way that did not exist during the previous period of IAW based activity. Pupils gained from the IAW because they appreciated the visualisation of structures more readily than through verbally dominated approaches.

Another factor in the motivation of pupils stemmed from the way in which teachers exploited a 'different type of contact with the lesson in the pupils hands'. Good practice obviously builds upon knowledge of particular groups and of individuals within the groups and a realistic assessment was that 'the IAW still doesn't mean that we shall have a lesson where all the pupils are paying attention all the time'. There were some gender related issues that had motivational effect. Boys were generally more ready to demonstrate or complete work at the IAW than females of the same age. Older boys were more ready to demonstrate in part because it provides an opportunity for them to show their superiority in technological fields when teachers commented upon inadequacies of programmes or available tools, whilst girls were more concerned about 'being right' before they would commit themselves to the IAW. Evidence from pupils showed that they thought that 'lessons (using IAWs) had less wasted time', and that 'they moved with more pace so that they didn't want them to come to an end'. If there was one single motivational factor during lessons it appears to be that the immediacy of response ensured maintained interest.

When the pupil groups were asked to identify why lessons were of greater interest than in traditional teaching 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, require responses that can be immediately assessed and then linked to a scoring system with team races or, for example, noughts and crosses
- the 'fun' arising from the use of tools such as compasses, grids and lines
- the immediacy of any processing built into the programmes
- the opportunity to revisit earlier concepts and examples in underpinning understanding
- the ease with which multiple examples could be used from certain types of commercial software

Motivational influences thus became integrated with the pedagogic aims of IAW use. Revision, new work and metacognition were all apparently stimulated where interactivity underpinned learning.

c. Pedagogy

There were three underpinning pedagogic principles:

- Emerging from the earlier work in mathematics associated with the Cognitive Acceleration in Mathematics Education project, (CAME) the technology was being used, in all, except four observed lessons, to support a lesson structure based upon an introduction or starter, a developmental phase based upon a sequence of learning incidents, and a plenary to review learning and contribute to metacognitive learning of the subject.
- Most teachers were undertaking lesson planning that had discernible cognitive aims and a series of activities to explore, develop, explain and reinforce subsequent understanding.
- There was a high level of teacher recognition that pupils learn in different ways and the IAW was used to promote diversity of aesthetic, verbal, numeric and kinaesthetic experiences.

Awareness of the three elements appeared to give teachers a framework for lesson preparation. This ensured that each lesson was planned for IAW use. This was explained by one participant as planning to

> *'take advantage of what the board has to offer and link that to the way in which kids learn, and so although it has taken longer to plan the lessons I am sure that they are now properly planned because I ask myself five questions: what is my aim, what are my objectives, how can **I** use the whiteboard, how can **they** use the whiteboard, and how can I build in principles, practice and subsequent assessment?'*

To support this work 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 'visual manipulation' so that concepts could be illustrated and worked upon by the pupils. The interview evidence suggests that many schools are now developing strategies for joint preparation of materials and then for saving this within school networks.
- The growth of shared evaluation as well as shared material is leading to an enhancement of teaching and learning amongst people in a way that would not grow naturally within schools.
- The use of the IAW as the focus of the lesson with pupils working with their own mini-whiteboards, and coming up to the IAW to produce 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.
- The use of materials in a way that can be differentiated on the same board although not perceived to be obviously so by the pupils by a range of staged examples.

Integration

When the findings were analysed it emerged that teachers passed through three stages as they developed competence in and an understanding of the use of IAW technology and associated software in the mathematics classroom.

For our investigation we used the following descriptors and criteria:

a. Supported didactic

This approach was characterised by the teacher making some use of the IAW but only as a visual support to the lesson and not as an integral strategy for conceptual development. In this situation the

teacher is the focus of the room following traditional approaches with minimal pupil input except in response to teacher questioning or when following conventional written tasks. However, teachers often start to use their own materials traditionally through PowerPoint, Excel or commercially produced mini-programmes (such as Smile or the Key Maths ICT software). The effect is that pupils see the use of the IAW as a novelty in the lesson but in pedagogic terms it illustrates, rather then develops concepts.

b. Interactive

This approach marks progression from the supported didactic stage because the IAW is used to incorporate elements of the lesson that challenge pupils to think by using a variety of verbal, visual and aesthetic stimuli. During the phase when teachers are becoming conversant with the technology and its uses this is marked by a tendency to further explore the potential of PowerPoint and Excel and to look for ways of using the tools that come with the IAW software. The IAW becomes the focal point of pupil attention whilst it is in use usually to illustrate, develop and test discrete concepts. With this approach there are times when the teacher makes use of conventional approaches to ensure cognitive development and there is evidence of occasional lack of confidence in the technology or its teaching power. The IAW is no longer a novelty to the pupils, and is integrated into teaching and learning but its full potential is not developed. However, teachers at this stage show evidence of searching for new approaches and there is evidence of considerable co-operative activity between teachers who are learning from each other. There appears to be greater sharing and enthusiasm for development where there is a 'missioner' within a department, or where the head of department supports planned co-operative activity.

c. Enhanced interactivity

This approach is a progression from the previous stage marked by a change of thinking on the part of the teacher who seeks to use the technology as an integral part of most teaching in most lessons and who looks to integrate concept and cognitive development in a way that exploits the interactive capacity of the technology. As a result teachers are aware of the techniques that are available, are fluent in their use and structure the lesson so that there is considerable opportunity for pupils to respond to IAW stimuli either as individuals, pairs or groups, with enhanced active learning. The IAW is used as a means of prompting discussion, explaining processes, developing hypotheses or structures and then testing these by varied application. At this stage teachers show considerably enhanced understanding of the learning process, talk about the ways that technology can support learning, and show ingenuity in developing materials to meet specific learning needs with much more evident differentiation of task for pupils, often focussed on the board. Such teachers are aware of the contribution made by the IAW to kinaesthetic learning and seek to use this in two ways – through pupil movement in active learning with much increased use of pair and group work, and through movement of data on the board in a similarly active way so that the verbal and visual is linked to spatial changes that impact on the pupil. This stage is also marked by considerable teacher-teacher interchange.

Conclusions

1. Effective mathematics teaching occurs where the technology is part of the normal equipment for the classroom, where lighting and furniture arrangement have been used to advantage and where the teachers have had the time or access to a range of materials to exploit fully the potential of the equipment.

2. We believe that pupils learning will be enhanced if teachers work at the ***enhanced interactive stage***. Since there appears to be a learning curve for both teachers and pupils, mathematics departments (and schools) need to consider appropriate continuing professional development (CPD), that includes technical, technological and pedagogic elements, for staff using IAWs and to plan for this as they purchase the equipment. This should help provide teachers with guidance and 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 with effective interactivity. The support of coaches within schools would do much to enhance this.

3. Teachers are more likely to move more rapidly to the ***enhanced interactive stage*** if at least two teachers work together planning, preparing and using materials for IAWs.

4. Given workload constraints we believe that teachers should also invest in appropriate materials that have been specifically designed for IAW use **and** that also allow teachers to work at an ***enhanced interactive*** level. However we expect that teachers will still want to create their own materials and share these with colleagues.

5. 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 they are more likely to progress with enhanced understanding. At this stage behavioural problems may decrease and this is likely to arise 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.

6. This is not to suggest that the IAW is a panacea for all ills in mathematics teaching. Our evidence suggests that teacher progression from ***supported didactic*** to ***enhanced interactive*** in classroom and pedagogic management will occur, but it is not necessarily automatic nor rapid. Without such movement, in particular where a teacher remains at the ***supported didactic*** level the use of an IAW may not result in any gains.

7. Further work is required in two areas:

   - establishing evidence that pupil understanding is enhanced when teachers use IAWs in mathematics classrooms
   - developing appropriate CPD so that teachers might move more rapidly to an ***enhanced interactive*** stage

Outcomes
Whilst it is not possible for the group of teachers to continue to meet in the same way they have established a network linked to the university department and will continue to receive materials and information about the enhanced use of IAWs in mathematics classrooms.

The findings have been incorporated into many training sessions and research seminars organised by the research team. They also now inform the planning for sessions incorporating the use of the IAW for trainees undergoing initial teacher training in mathematics at Keele and more widely.

The findings have informed further research work in the teaching of modern foreign languages and provide a framework for good practice in the use of IAW technology for all initial teacher trainees within the Department.

The Training Schools associated with Keele University (Alsager School, Cheshire and Blurton High School, Stoke-on-Trent) are working with the research team to help disseminate the results through the network of Training Schools.

The research group continues to meet on a regular basis and has developed a conceptual framework which underpins further practical and conceptual research.

The following list our interactive whiteboard research, materials, articles, conference presentations and CPD some of which is directly attributable to our Nuffield work, but all of this will have been informed by our Nuffield work. This list will continue to be added to as our work progresses.

Research
Dave Miller with Derek Glover, Doug Averis and Victoria Door (2003-4). BECTA research bursary. *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?*

Dave Miller with Doug Averis and Victoria Door (2003-4). TTA research bursary. *From technology to professional development: How can the use of an interactive whiteboard in initial teacher training change the nature of teaching and learning in secondary mathematics and modern foreign languages?*

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Curriculum materials
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Interactive whiteboard website for mathematics that will be extended
http://www.keele.ac.uk/depts/ed/iaw/