The Mathematics Education into the 21st Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

**The impact of interactive whiteboards on classroom practice: examples drawn from the teaching of mathematics in secondary schools in England.**

**Derek Glover, David Miller and Doug Averis: Keele University, UK**

**Abstract:** *Two influences, the introduction of interactive whiteboards, and the exploration of cognitive processes in mathematics in the Cognitive Acceleration in Mathematics Education project, are affecting pedagogy in secondary mathematics teaching. Mathematics teachers from 12 schools working in partnership with Keele University have been funded to explore how learning can be enhanced through interactivity. Lessons being taught in connection with this work have been observed according to a structured format. Analysis shows that teachers were using the same materials in different ways to secure pupil fluency in the application of processes and the development of concepts. Early results suggest that lesson effectiveness hinges on the technological capability of the teacher in responding to divergent needs, and that the process of exposition, demonstration, exemplification and conceptualisation is best managed through the use of the interactive whiteboard as a means of revisiting earlier material.*

**Background**

There has been an increasing use of interactive whiteboards (IAWs) in schools in England in the last three years. IAWs costing about £3,000 per unit have been introduced in three ways (Glover and Miller (2001a; 2001b; 2001c)). As a start, a few are bought and used by 'missioners' (Glover and Miller, 2001b) to evaluate their use. Elsewhere subject departments are equipped to exploit the teaching value of the technology, whilst in other schools all departments are provided with one or more so that all can become familiar with its use before wider introduction. Early studies on their use have pointed to the need to develop a pedagogy that exploits interactivity if they are to be other than a passing interest enhancing element in the classroom. McCormick and Scrimshaw (2001) investigating effectiveness of their use have demonstrated the need for a rapid movement along a continuum from more attractive presentation of materials, through sustained pupil motivation, to the achievement of sustained and interactive learning approaches by the teachers involved.

The link between pedagogy and practice has led to further exploration of how interactivity can assist learning. Latane (2002) has demonstrated that interactivity with all technologies needs to be pupil-pupil as well as pupil-teacher. Glover and Miller (2002) have indicated the need for immediacy of response and the opportunity to explore ideas as an adjunct to enhanced presentation of material, and Iding (2000) working in initial teacher education for scientists has shown the need for the co-ordination of pictorial, textual and audio materials. There has however, been little attempt to develop sequentiality and extended coherence of understanding – interactivity has been seen as an aid to traditional teaching rather than as the driving force for understanding.

One innovation in mathematics teaching has been the Cognitive Acceleration in Mathematics Education (CAME) at Kings' College, London. The CAME approach involves mediating pupils' work through discussion. The interactive mechanisms (pupil-pupil and teacher-pupil) used to aid pupil development are based on theories of social constructivism. Such interactions are intended to give pupils time and opportunity to work and think on their own and to work towards development of formal operational thinking (Adhami et al, 1998).

Over two years CAME teachers work through 30 mathematics lessons designed to develop thinking skills and promote cognitive acceleration in pupils. Teachers learn about theories of constructivism and social constructivism and establish skills of interaction with pupils within a well-defined framework. A feature of CAME teacher-pupil interaction is the number of separate 'episodes' the teacher manages at different stages of the lesson. Early on the teacher introduces a mathematical situation, outlines something of interest, clarifies issues and terminology and suggests an idea to follow. As the lesson progresses, the teacher conducts more 'episodes' before collecting ideas for review by the whole group. Good ideas are kept while others are rejected. Often some of these ideas might be used by the teacher to promote 'cognitive conflict' and explore misconceptions.

Other episodes include: orchestrating pupils' working in groups (or at the IAW); extending the degree of difficulty (from the concrete to the formal); emphasising links with other topics/subjects (bridging); and reflecting on the thinking that has taken place (metacognition).

Our involvement with CAME has led us to adapt and adopt elements of this approach to our IAW research. In particular those aspects associated with teacher-pupil and pupil-pupil interaction.

The Mathematics Education into the 21st Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

Mathematics teachers from 12 comprehensive co-educational schools in the North West Midlands of England working with Keele University have been funded by the Nuffield Foundation to explore the way in which interactivity can be developed through producing and evaluating materials. Two members of the Department and a consultant are producing materials for teacher selected topics. The authors then write a programme that is demonstrated, modified and then used with pupils. Evaluation is by questionnaire-based pupil and teacher surveys, teacher measurement of enhancement in learning, teacher interviews and observed lessons. The aim of the evaluation is to establish whether, and if so, how, the use of the IAW promotes learning in mathematics.

**Methodology**

This paper reports on an early stage in the investigation and concentrates on the first six observed and filmed lessons which were then analysed according to an agreed structure as follows:

1. Note topic, age and ability detail of group
2. Brief note on sequential placing of lesson within the topic framework
3. Timeline for the lesson with brief note of content for starter, main element, plenary
4. Use made of IAW by teacher - continuous exposition and example, intermittent use in exposition and examples, use for examples only
5. Use made of IAW by pupils – working examples, demonstrating, developing ideas
6. Classroom management issues – pupil involvement, differentiation, extension, expectations, evidence of IAW impact on practice
7. Assessment of enhancement (or otherwise) arising from IAW use
8. Pedagogic issues – impact on conceptual development

All pupils observed were in the upper half of a normal ability spread. The first topic of six lessons was based on the mathematics National Curriculum for Year 7 (pupils aged 11-12 years) and involved fractions. Lessons one to three averaged 12 screens with teaching materials consisting of equivalent fractions, fractions of a quantity and combination of fractions. Interactivity included shading fractions of shapes, equivalent fraction problems, fractions on lines of varying length, and a revision exercise involving combination of fractions. A fully interactive fraction wall underpinned much of the work in lessons two and three. The detail of the lessons observed is as follows:

**Table 1. Availability of IAW during the early period of the project**

| Lesson | Lesson Title | IAW availability |
|---|---|---|
| A | Fractions of amounts | Always |
| B | Dice fractions on line | Teacher has to book |
| C | Fraction wall | Always |
| D | Fraction wall | Always |
| E | Fraction wall | Teacher has to book IAW |
| F | Fraction amounts and fraction wall | Always but not teacher's normal class |

Whilst the analysis was essentially subjective, comparison was possible by noting the time taken for each stage of the lesson, and through observation of 'on task' time of a pupil who remained visible while filming. That said, comparison is limited because the normal behaviour of the observed pupil is not known. No allowance could be made for teacher quality but all participants are known to be effective teachers within their schools. The use of the results for comparative purposes within a small sample can only be indicative but the data offers a starting point for further investigation.

**Classroom practice**

In five lessons pupils entered the classroom and were attentive. The teacher then started the lesson in a brisk way with recapitulation of earlier fraction work using either the IAW as a normal board with handwritten fractions or the screen from the prepared lesson sequence used in the last lesson. The late arrival of pupils caused the other lesson to be slower in gaining impact. A notable feature was that pupils were ready for IAW use and attentive as soon as the teacher spoke. This might have been because the pace of lessons was greater than that often seen with normal teaching technology, and because pupils were aware that they could be missing something. An immediate impression is that IAW based lessons allow little opportunity for pupils to move off-task. Overall the observed pupils were 'on task' for 96% of the total lesson time.

The lesson structures were tight demonstrating a variety of visual representations of concepts and examples. This was well managed in four of the lessons but in the other two there was evidence that slower pupils were being left behind. However, the teachers concerned were aware of this and they found an opportunity to help individuals during periods of group work or written exercises. In both

The Mathematics Education into the 21st Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

cases they referred back to earlier screens in the sequence to ensure understanding. In one lesson use was made of non-interactive pupil whiteboards for working out examples. These were then shown to the teacher to provide a quick check on progress. In the other five lessons exercise books were used. Whilst there were still times when pupils were slow to begin to work through examples in this way it seemed that this arose from inadequate understanding of instructions – remedied by one teacher by having these clearly shown on a screen inserted into the sequence provided.

In all lessons there was some attempt to use features of IAW technology. Three lessons were based on throwing dice to generate fractions that could be placed in the correct position on a line. In these pupils could interactively check the accuracy of their positioning. In the five lessons using the fraction wall at some stage there was a clear gain from the ability to see equivalent fractions moved around the wall. In only one lesson was the printer used to print copies from the IAW. Recall of earlier screens was used in working with the whole class in three lessons and with individuals in two others. In one classroom the IAW was used by one group of pupils to check the responses of others working in their exercise books. The teachers showed varying degrees of readiness to use the potential of over writing pre-prepared screens, and functions such as shading, moving and rotating that were dependent upon their fluency in using the software provided. Two teachers used the IAW with an adjoining ordinary whiteboard to help pupils' understanding.

There appeared to be some attempt by all six teachers to recognise and respond to varying learning style needs. In part this came from the use of visual, verbal and sequential material, but three of them used alternative representation of ideas. One showed fractions in three ways, another used fractions of a shape to illustrate a numerical statement, and the third used a game as an experimental approach. All the teachers using the fraction wall spoke of the meaning of a fraction, moved the fraction around the IAW and then asked pupils to do the same to reinforce the understanding of equivalence. Pupils then worked through examples using a copy of the fraction wall. In two lessons the fraction wall was used to help pupils who were having difficulties understanding the concept of equivalence. The flexibility of use and the combination of approaches suggests that all except one of the teachers are using the IAW as part of an enhanced learning strategy based upon the principles of accelerated learning (Smith, 1996: Caine and Caine, 1997 and Gardner, 1999).

In all filmed lessons teacher-pupil interaction was observed. All teachers appeared aware of the potential of the IAW to enhance this aspect of the learning process. At its simplest it was shown in the manipulation of fractions by giving pupils examples that were worked through on the IAW and then checked against known results. In three lessons this was further developed through pupils' software use. All lessons using the fraction wall were interactive (equivalence was shown and used by pupils). The use of superimposed handwritten examples, directional arrows and shading was fluent and fitted naturally into the lessons but further development of interactivity was dependent upon teacher understanding of software. Three of the observed teachers displayed the 'missioner' view of the potential of the IAW and had extended interactivity in some form reinforcing Bailey and Johnson's view (1996) that the IAW is only of advantage if this is possible.

### Inhibiting factors

The observed lessons were all well managed and productive as measured by pupil participation. This was 96% overall during the time when the IAW was the focus of teaching but the importance of teacher control was seen in that this varied from 86% in one lesson to 100% in the lesson showing fastest pace. By comparison, attention span appears less in those parts when the IAW was not the focus of teaching. Although this was cumulatively less than one fifth of the teaching time the observed pupils were 'on task' for between 72% and 94% with an average of 86%. This suggests that when the lesson is not driven by the IAW, pupils revert to a more typical classroom approach. This is an aspect explored by Elvers (2000) and Glover and Miller (2001a) as a motivating factor in learning with new technologies, but observation suggests that pupils expect there to be a break in the sequence of teaching in which they will be required to 'turn to your books'. In one lesson the use of pupil whiteboards maintained the interest and drive. We conjecture that use of the pupil whiteboards, instead of an exercise book, might maintain pupil engagement.

The other inhibiting factor was that teachers varied in their ability to manage the technology. All were competent in IAW use. One worked under some disadvantage with a portable unit in front of a window, another worked in a room that was not his room and in which pupils were not naturally facing the IAW. Minor technical problems impaired the flow of teaching twice in one lesson, and two teachers could not easily access previous screens. In four lessons pupils were being helped to use the

The Mathematics Education into the 21st Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

potential of the IAW by teachers who led them through software processes alongside their mathematical use of the IAW. In only one lesson was there an apparent concern with the IAW to the detriment of whole class control but overall teachers were making sustained efforts to work with all pupils and four made use of group organisation within the IAW lesson. Other research in this project will be directed at assessment of pupil enjoyment of IAW focused teaching but the level of responsiveness observed suggests that the IAW has enlivened and enhanced teaching also.

**Pedagogic development**

Analysis of the six lessons on the same topic suggests that the IAW is now being used more interactively than was initially the case. Teachers have moved from presentation to pedagogy and have developed teaching to match learning styles and differentiated learning pace. There was however, considerable variation in the way in which the IAW was being used. All the teachers were using materials provided to meet the prescribed needs of the National Curriculum and it might be thought that this would constrain flexibility in teaching. Our evidence is that all six teachers used the material in different ways and four inserted extension materials of their own devising.

Analysis of the lessons against a pedagogic framework suggests that there is need for greater understanding of the balance between four elements in teaching. These are :

    a.  Exposition – the outlining of a process or principle

    b.  Demonstration – the application of a process or principle

    c.  Exemplification – the use of process or principle

    d.  Conceptualisation – the development of concepts after the consideration of data.

**Table 2. Analysis of lessons against learning framework**

| Lesson | Exposition | Demonstration | Exemplification | Conceptualisation | Percentage of IAW use in lesson |
|---|---|---|---|---|---|
| A | Use of IAW with simple fraction | Effects of simplification without IAW | Use of programme screens to start exercise – IAW as illustration | Use of ordinary board as pupils explain numerator and denominator – IAW use minimal | 76% |
| B | Use of IAW to outline principle of numerator and denominator | Use of prepared material for interactive manipulation of figures on IAW | IAW use for fraction wall manipulation whilst other groups use exercise books | Return to IAW for plenary development of equivalence | 98% |
| C | Use of IAW to check understanding of fractions | Illustrating of fractions of shapes with some IAW use | Two examples on IAW, pupils then moved to exercise books | Return to fraction wall on IAW to move to ideas of fractions more than or less than | 86% |
| D | Use of IAW to introduce equivalence | Equivalence shown by using IAW fraction wall with some pupil participation | Exercises using IAW and own ordinary boards with results shown to teacher | Development of rules for adding and subtracting copied into exercise books. | 82% |
| E | Use of IAW to introduce fractions of amounts | Relationship between fractions demonstrated using IAW | Matched progress through examples on IAW with pupil use of own whiteboards | Use of adjoining whiteboard to summarise what has been found out in the lesson | 84% |
| F | Use of IAW to illustrate meaning of fractions | IAW illustration of building of fraction wall | Use of IAW to guide exercise using similar framework on IAW and in books | Use of IAW to ensure understanding. Exercise matched with IAW results | 96% |

As can be seen the use of the IAW varied greatly in the observed lessons when considered against this framework. The analysis suggests that teachers are currently using materials and the IAW for the structure and framework of their lessons. Introduction and demonstration are usually integrated with IAW use – often with interactivity as the demonstration moves into the exemplification phase. The greatest variation occurs during the exemplification phase as teachers make varying use of pre-prepared materials or the plain whiteboard to ensure understanding, reinforce learning and re-visit

The Mathematics Education into the 21<sup>st</sup> Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

principles. Some leave examples on the IAW but expect pupils to work in their books, others allow some to use the interactivity features of the IAW and others switch from individual whiteboards to the IAW with considerable fluency. Plenary sessions almost always make some use of the IAW to reinforce concepts drawn from the group but this varies according to the confidence that teachers have in accessing earlier work. It would seem that the key to enhanced IAW use lies in a deeper understanding of its contribution to the aim and structure of lessons.

**Conclusion**

Our experience is that teachers' use of IAWs is still in its infancy. This is not from the point of view of basic skills associated with using the IAW's functionality but rather with a framework of knowledge, skills and understanding related to interactivity (teacher-pupil and pupil-pupil), that can help promote future work. We believe that it is important that teachers working with IAWs remain flexible and open to ideas. We question whether it is appropriate to continue to apply traditional templates to lessons when initial evidence suggests that there is the potential for further gains if one adopts new approaches. One example is the opportunity to use the dynamic and 'replay' facility offered by the IAW to explore pupils' conjectures and misconceptions. We consider that the ease of use of these facilities means that teachers now have an opportunity to explore new ways to develop topics based on pupils' thoughts and ideas. This might have implications for pupil empowerment.

Our observations suggest that teachers are intuitively responding to opportunities for interactivity. Where it is clear pupils have understood material, they are being invited and encouraged to present their work and conjectures to the whole class. The use of questions by the teacher such as "Can you explain ….", "Why did you …", lets pupils clarify and confirm points in their own mind thereby increasing their own understanding. Additionally, when pupils need help, it is possible to revisit material to reconsider learning points from a different standpoint. Such experiences suggest that there is increased effort to match teaching method by the teacher to learning styles of pupils.

Finally, our observations also suggest that the focus and duration of lesson phases becomes more obvious as the use of the IAW increases. There is some evidence that each of these has appropriately structured 'episodes' of interaction within them. As we continue to collect evidence we anticipate that teachers will become more fluent in managing these 'episodes' and that this will allow us to develop a useful framework for interaction, pedagogy and learning.

**Bibliography:**

Adhami, M., Johnson, D. Shayer, M., (1998) Thinking Maths, Heinemann.

Bailey, C. and Chambers, J., (1996) 'Interactive learning and technology in the US science and mathematics reform movement' *British Journal of Educational Technology* 27 (2): 123-133

Caine R.N. and Caine, G. (1997) 'Maximising learning', *Educational Leadership* 54 (6): 11-15

Elvers, G. (2000) The digital whiteboard as a notes-taking aid. *Research report published on www.smarterkids.org*.

Gardner, H., (1999) 'Multiplicity of Intelligences', *Scientific American,* 9 (4): 19-23

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 for BEMAS Conference Newport Pagnell.

Glover, D. and Miller, D. (2001c) 'Running with technology: the pedagogic impact of the large scale introduction of interactive whiteboards in one secondary school' *Journal of Information Technology for Teacher Education* 10 (30: 257 – 275)

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

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

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

Smith, A. (1996) *Accelerated Learning in the Classroom,* Stafford: Network Educational Press