A Worthwhile Investment? The Interactive Whiteboard and the Teaching of Mathematics

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Abstract

There is increasing evidence that the interactive whiteboard contributes to understanding and application in the teaching of mathematics. At the same time there has been some comment that the technology may be a passing feature and that people are tending to invest without considering the implications of training and associated software purchase (both specially designed interactive whiteboard software and 'generic' mathematical software including wordprocessors, spreadsheet, graph plotters and geometry packages). Understanding of the nature of interactivity and the development of pedagogy to support this, points to a need for long-term changes in both teaching and learning if the technology is to be worthwhile. This paper outlines evidence pointing to the effectiveness, efficiency and value for money of investment in interactive whiteboard technology and pedagogy with illustrations from a widespread investigation of use in secondary mathematics teaching.

Background

The emerging evidence from research into the use of interactive whiteboards (IAWs – here meaning an IAW connected to a computer and data projector) highlights the need for a pedagogic change from a didactic to an interactive approach to learning and teaching, and from the use of the IAW as a visual support for lessons to the integration of the technology into lesson planning. This has been explored at length by Miller et al (2004). Greiffenhagen (2000) has shown that the use of the technology as an adjunct rather than as an integrated element in teaching minimises interaction and matching of teaching to learning needs. McCormick and Scrimshaw (2001) have developed this in their analysis of the contribution of ICT to pedagogic change in teaching mathematics and their contention that teaching can only be enhanced if interactivity is understood. There has been concurrent research into learning approaches and Jones and Tanner (2002) offer evidence to show that interactivity is most effectively sustained through effective questioning as well as a wider range of activity. As a result later literature is moving towards consideration of the technology and pedagogy of interactivity. Simpson et al. (1998), Cogill (2003), Robison (2000) and Damcott et al (2000) demonstrate the use of interactive technology within mathematics as a subject area with diverse ability groups. They stress the need for changed approaches to teaching to optimise the teaching and learning value of the technology.

A range of research reports including Glover et al. (2003) and Edwards et al. (2002) focus on the way in which presentation is improved, pupils are motivated and learning enhanced during the early stages of the use of the technology. However, other observers have raised concerns that the IAW could be another gimmick, see, for example, http://www.g2fl.greenwich.gov.uk/temp/whiteboards, Kennewell (2001) and Moore (2001) who question whether the investment is 'a luxury too far?' Early evidence from primary education sources (Smith et al, 2004) points to investment in both equipment and training in order to maximise the value of the technology. Overall the research literature points to effective learning where teachers have been convinced of the value of the technology and fully understand the nature of interactivity and its pedagogic implications.

Methodology

The initial work was with twelve mathematics teachers working with Keele University researchers on Nuffield Foundation funded research. Additional evidence arises from the same research team working on British Educational Communications and Technology Agency (Becta) funded research. This group met termly across two years and grew to a total of seventeen practitioners who were interviewed using a structured format during the research. This opened the way for discussion of practice in IAW use and led to the development of a structure for the observation of video-recorded lessons. A total of forty one mathematics lessons were video-recorded and analysed. The video-recorded lessons were analysed according to a set format with observation of the timeline and activity sequence in each lessons. There was a strong link to promoting cognitive development through the use of Cognitive Acceleration in Mathematics Education (Adhami et al.,1998) principles. This gave a normal sequence of a starter, followed by exposition and development of the lesson's theme, and then a plenary session to ascertain the nature of learning. The advantage of this was that participant teachers were fitting the use of the IAW into a clear structure and were prompted to think of the ways in which interactivity could enhance learning. There was also consideration of classroom management issues to ascertain the impact of the IAW on pupil management and to record lesson events such as technological malfunctioning.

The observation was also concerned with the enhancement from IAW use within a framework of establishing new principles, sequencing of learning, demonstration of processes, reinforcement through recall, revision and the use of examples. At the same time there was also recording of presentational and pedagogic techniques arising from the particular features of the technology including the use of colour, shading, movement, 'drag and drop', 'hide and reveal', and overwriting.

Further structured interviews were undertaken with ten teachers from a national spread of good practitioners known for their effective use of IAW technology. Overall forty six interviews were undertaken with teachers. The focus of each interview was a framework based on presentation, motivation and pedagogic advantages and disadvantages of IAW use. Two groups of ten pupils were interviewed in two schools to gain some triangulation with teacher opinion.

Outcomes

Analysis of the interview evidence alongside the video-recorded lessons led us to classify teachers as following one of three patterns of pedagogy.

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. An example of this was seen where the teacher used the fraction wall to demonstrate equivalence but did not then use any techniques to bring about interactivity. In this situation the teacher is the focus, following 'traditional' approaches with minimal pupil input except in response to questioning or when following normal written tasks. However, teachers often start to use their own materials 'traditionally' through PowerPoint, Excel or commercially produced programs. 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, this is marked by a tendency to further explore the potential of PowerPoint, Excel and the software tools that come with the IAW. The IAW becomes the focal point of pupil attention 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, is integrated into teaching and learning but its full potential has not been developed. This was seen in one lesson where the teacher used a program on vectors downloaded from the internet but then used an adjoining normal whiteboard to develop the processes involved.

c. Enhanced interactive. This is a progression from the previous stage marked by a change of thinking of the teacher who seeks to use the technology as an integral part of 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 to prompt discussion, explain processes, develop hypotheses or structures and then test these by varied application. This was demonstrated by the use of movement, colouring, shading and overwriting in teaching about angles on a line and at a point. Here teachers show enhanced understanding of the learning process, they talk about the ways that technology can support learning, and show ingenuity in developing materials to meet specific learning needs including differentiation of task for pupils, often focussed on the IAW. 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.
Further analysis of the data was undertaken by applying resource evaluation concepts to the range of practice seen in the video-recorded lessons and then linking this to the interview comment. In this way it was possible to ascertain the value of IAW use within mathematics.

Efficiency

Efficiency is concerned with the relationship between an institution's inputs and its outputs. Here, is the investment in IAWs having an effect on pupils' learning? If so this is usually measured in terms of pupil attainment. Whilst this is problematic because attainment results are only part of pupils' educational development, teachers will be aware if installation of the equipment has been worthwhile. In methodological terms it should be possible to measure the efficiency of IAW technology by equipping one class with the equipment and allowing another to function with a traditional pedagogy and then comparing results after completion of the same topic. This however, is dependent upon consistency in teaching and pupil quality and these cannot be guaranteed (Glover and Levacic, 2004).
Efficiency was illustrated by participant A, a 'Missioner' (Glover & Miller, 2001), within her school but who faced difficulties. The system in the school was portable and access for her was difficult. It had been in use for three months when a lesson was video-recorded but the teacher had had only limited time to gain confidence in the use of a complex technology. As a result pupils were not familiar with its use and coping with the practicalities of room darkening, furniture arranging and basic IAW board use inhibited thinking about interactivity.
A step-by-step exposition was used to teach how to bisect angles but then inadequate understanding of the software tools led to a demonstration on a traditional board. Whilst the IAW was in use in the lesson it was not used to advantage, especially in a room with poor blackout facilities. The approach was ***supported didactic*** and the board was the focus of teaching for only seventy percent of the lesson.
By contrast participant B, a fluent IAW user worked with pace and enthusiasm on equations. He made maximum use of the equipment by showing transpositions of terms using colour and movement. He asked pupils to work through examples and show their results on small whiteboards, and then asked them to demonstrate solving equations on the IAW. The IAW was used for ninety five percent of the lesson and the interaction between teacher and pupils was lively and continuous with enhanced interactivity the norm.
In our view the contrast is 'obvious' – efficiency was achieved only when the teacher was both fluent in the use of the technology and understood the nature of interactivity. Self-evaluation by teacher B was based on attainment evidence of the pupils and enhanced understanding of principles and practice. In his view 'this is an efficient way for us to teach and the pupils to learn because it stimulates learning and demonstrates the processes in an understandable way'.
Efficiency appears to depend upon: ***awareness*** of the investment involved and determination that it should make a difference; equipment ***availability*** so that it is used regularly and not seen as a

novelty; and ***understanding*** of the ways in which pupil progress can be stimulated, developed and assessed.

Figures 1 and 2 (Miller D. and Sherran P., 2003) show two pages from a unit on Equivalent Fractions. In Figure 1 a fraction wall is made from blocks representing fractions from $^1/_{12}$ through to $^1/_2$, each block retaining its own unique colour. In Figure 2 the sizes and colours for the blocks are retained but in this case only single copies of the blocks appear on the page along with a central working area (grey).

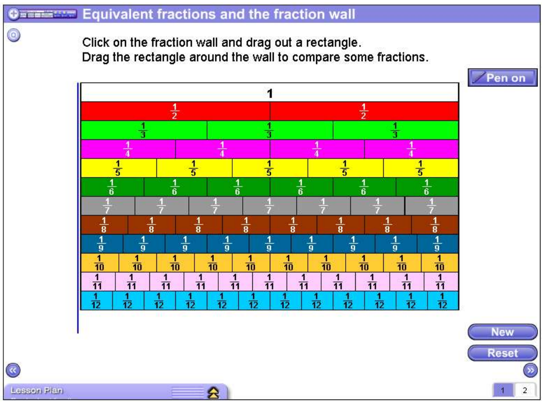


Figure 1: Equivalent fractions and the fraction wall

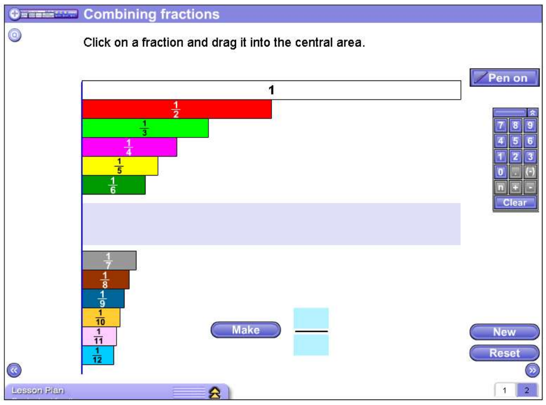


Figure 2: Combining fractions

IAW interactivity features such as '*drag and drop'*, *colour, shading and highlighting* can be used in a number of ways on the fraction wall. '*Drag and drop'* is used in two ways. In Figure 3 the vertical blue line to the left of the wall (the line to the left of the fraction wall in Figure 1) is dragged from left to right across the wall. As this happens, fraction blocks in the wall are highlighted, when appropriate, to show equivalence ($^1/_3$, $^2/_6$, $^3/_9$ and $^4/_{12}$ are shown in a grey colour when the vertical line is at the end of $^1/_3$). In Figure 4, an individual fraction block (here $^1/_3$) can be made by 'dragging out' an appropriate rectangle and then moved around the wall to be compared with other blocks. In each case '*drag and drop*' is used to help demonstrate that the fractions are equivalent.

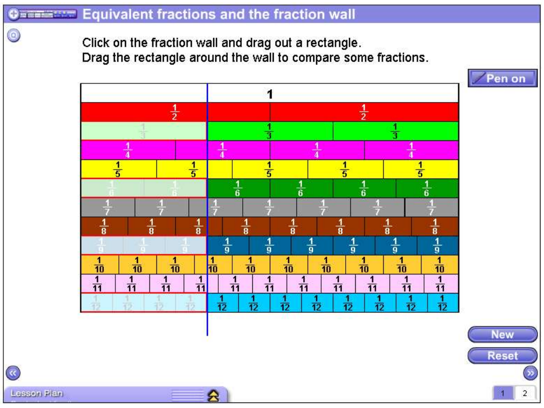


Figure 3: 'Drag and drop' of the vertical line

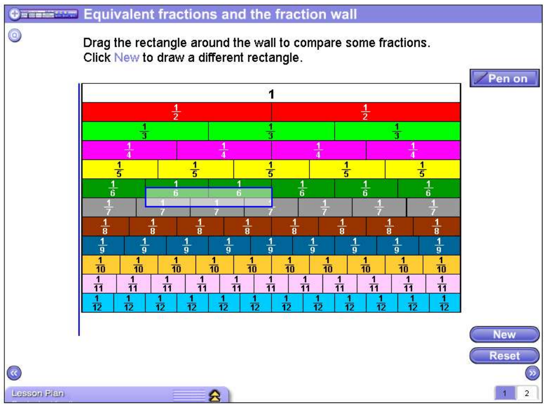


Figure 4: 'Drag and drop' of a rectangle

A teacher at the ***supported didactic stage*** would use the wall simply to demonstrate equivalence. The lesson would be teacher led with limited pupil response. At the ***interactive stage*** a teacher would engage in more dialogue and consider more demonstrations of the same equivalence and begin to rely on colour and highlighting for focus. However, at the ***enhanced interactive stage*** the teacher sets up and manages clearly structured episodes of interaction. Engagement is stimulated by questioning such as "Can you explain what happens as the line moves across the wall?", "What will happen if I move the line further?". At this stage the teacher is acting as mediator between the IAW and the pupils and manipulates classroom activity to allow pupils to explore the nature of equivalence of fractions according to their level of understanding. As a consequence of working in this way, pupils in one of the observed classes went on to compare fractions and so show that $^1/_4 + {}^1/_{12} = {}^1/_3$ and $^1/_3 - {}^1/_{12} = {}^1/_4$ whilst working themselves in a small group at the IAW. The resource intended simply to demonstrate equivalence could be used flexibly and appropriately at a different level. Encouraged by the teacher concerned, their use of the IAW's features enabled them to move beyond what the teacher had anticipated and had clearly allowed them to become independent learners.

In Figure 5, using '*drag and drop'*, two-fraction blocks are brought into the (grey) working area of the screen. In a carefully managed episode (conjecture, justification, verification) the teacher at the ***enhanced interactive stage*** and pupils are able to discuss the answer to the question $^1/_3 + {}^1/_4$. Figure 6 shows what is revealed when the pupils' response of $^2/_7$ is entered via the keypad and the 'button' '***Make***' is clicked. It then becomes possible using the IAW's features to explore why this common, but incorrect, response to the question arises.

In both examples, the teacher is able to appeal to both the constructivist and social constructivist models of learning. Encouraged by the clarity and accuracy of the presentation and further supported by the use of *colour and highlighting*, pupils (individually) are able to visualise what is being discussed and begin to make links with appropriate language. Furthermore, the use of '*drag and drop'* and *'reveal'* allows instant comparisons to be made in order to reinforce beginning understanding.

In an attempt to assess the efficiency of teaching using IAW resources three teaching groups took a short test on understanding of fractions at the conclusion of the lesson scheme. The mean mathematics national attainment level as assessed on the national key tests was four point six for one able group taught using the IAW (group one), and four for the other two groups, one of which (group two) was taught using IAW and the other (group three) taught conventionally. The test results were a mean of seventy eight percent for group one and sixty eight percent for group two. The test level for the third group was sixty five percent. Whilst we believe that the teacher working with the most able group was the most capable in encouraging interactivity, the results for those groups using the IAW were somewhat better – but possibly not sufficiently so to offer any compensation for less enthusiastic teachers. Pupil opinion offers a more optimistic view. In those classrooms with the IAW as the focus, all pupils in the class are able to share their understanding and discuss what is being presented. One pupil commented: 'We seem to get along so much better with the IAW and I think that that is because we enjoy the way in which we have to be ready to answer our teacher not just by words but by showing the class what we mean by moving things on the board' (boy, year seven).

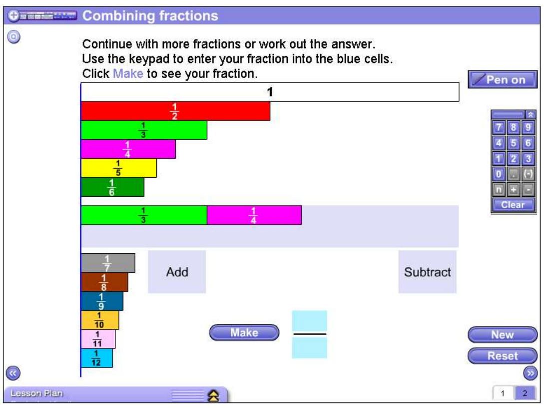


Figure 5: 'Drag and drop' of two fractions

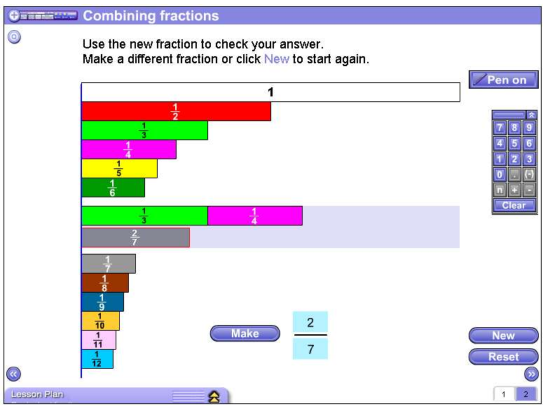


Figure 6: 'Hide and reveal' a sum of two fractions

The IAW provides the stimulus and the scaffolding to allow pupils in the classroom to learn in a way that social constructivists would suggest. Teacher comment suggests that they are now 'Made to prepare in advance so that we are on the ball all the while, made to think about the way in which pupils will learn and made to build in opportunities for interactivity at all stages – starter, development and plenary – it drives us to pull the youngsters along with us' (female, talking about a group of less able year eight pupils).
It may be that efficiency comes from teacher desire to maximise the impact of equipment that is known to be both expensive and innovative by being constantly aware of effective lesson planning with the IAW at the centre of activities . The ***enhanced interactive*** teacher would understand the implications of this model and plan her/his work accordingly.

Effectiveness

Effectiveness refers just to the extent to which resource use is judged to meet its objectives regardless of cost**.** It is not easy to define and analyse in the classroom but it is the relationship between the teacher's objectives for the pupils and the way in which these are best attained. The standard definition evolved by the UK Audit Commission in 1984 is 'how well a programme or activity is achieving its established goals or other intended effects'. With this in mind a teacher using IAW technology can be effective but not efficient if he or she makes wasteful use of its resources, either by using it as an add-on to the lesson or by failing to maximise the learning potential of interactivity in teaching.
A lower level of effectiveness in equipment use was shown by participant C. She was teaching volume and surface area of prisms to a group of year nine pupils. Although a fluent user of the IAW software she had prepared screens showing prisms and demonstrating the calculation of surface areas and then volumes. During the lesson she made effective use of the technology and linked her demonstration to '*hide and reveal'*, '*drag and drop*', colour, and overwriting. And yet there were periods when pupil attention wavered possibly because some were seated at right angles to the IAW, but also because the principles were taught in a didactic way – presentation, proposal and question in a routine manner.
Participant D was a late starter in the use of the IAW having waited until it was possible for the school to provide a full set of equipment for the sole use of all mathematicians. He described himself as 'initially willing but needing the support of others whilst I gained competence, I suppose you would say I was becoming more fluent and then confident' At an early stage in the research he had taught polygonal drawing without the IAW and then attempted to teach the same topic once the equipment was provided. The increased effectiveness arising from the IAW was shown in the brightness of presentation using the IAW tools, the stepped learning process and the use of rapid construction processes by him and then by pupils using the IAW. The time taken for the same topic and the learning was forty per cent less than in the conventional lesson where activities were based upon paper cutting and visualisation. He commented 'it has taken me time to think about the ways in which I can offer every lesson principle in a way that will stimulate the youngsters, without that stimulation the IAW is nothing more than a visual aid' (male, reviewing a lesson with less-able year eight pupils).
Although it is possible that participant C will always be more didactic in her approach than participant D there is a clear gain from IAW use where the drawing tools are flexibly used, where commercially produced software is brighter in presentation, and in the hidden capacity to demonstrate several examples in the time taken to prepare one manually. Effectiveness appears to depend upon: ***fluency*** in the use of technology; ***understanding*** of the ways in which tools can be linked to interactivity; ***availability*** of software programs to provide the necessary stimulation for pupil involvement; and ***experience*** of a range of training opportunities to enable teachers to move from the ***supported didactic stage*** to the ***enhanced interactive stage*** in their own analysis of the learning process.

Figures 7 and 8 from *My Pet Goat*, a locus problem, are used to demonstrate how an IAW can be used with pupils of all abilities to introduce complex concepts. Further, that teachers require 'coaching' in the skills of interactivity if the most is to be made of the resource.
Figure 7 sets the context and allows for concrete preparation by the pupils. Whereas teachers at the ***supported didactic stage*** would use the screen to define the obvious terms, ***enhanced interactive teachers*** would use the IAW's features to explore the context at a deeper level. Using '*drag and drop*' to position the tethering point and rotate the rope, it is possible for the teacher to build a continuous concept of the circle (or disc) in which the goat can move from a number of discrete points described by the pupils. Once this concept is established, the formal constructs of the circle (disc) can be drawn easily using the drawing tools from the IAW and later still with ruler and pair of compasses.
Having established the concept of a circle with the pupils and again using '*drag and drop*' the teacher can explore the various possible positions of the appropriate circle – see Figure 8. The IAW allows, through the use of colour and highlighting and the dynamics of the moving circle, scaffolding for shared exploration of locus properties. Questions such as "Which parts of the grass can/cannot be eaten?", "Where should we put the stake?" – each of which have a range of answers – become accessible to the pupils in a way that is not possible in a static chalkboard/whiteboard situation. Coaching in the questioning and technical skills involved with this are seen as important by those involved. The solution to the problem can be shown using '*drag and drop*' of the 'ropes' shown in the bottom left-hand of Figures 7 and 8.

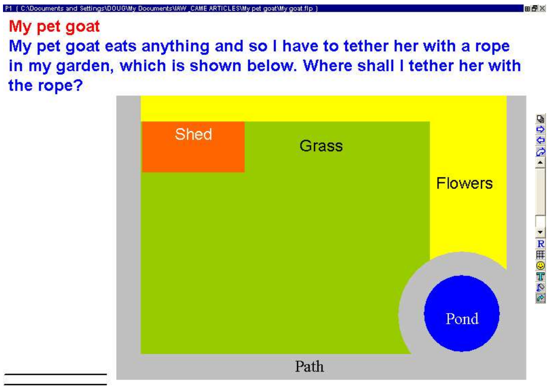


Figure 7: My pet goat – the problem

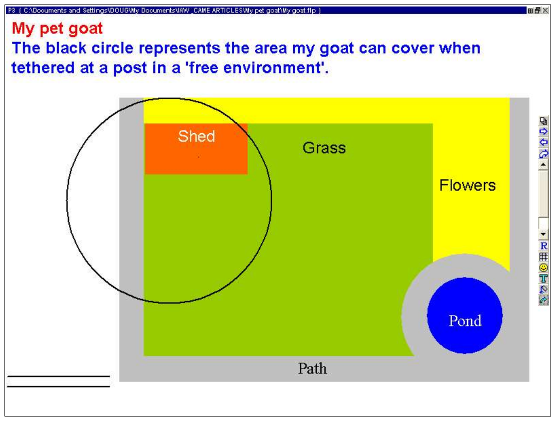


Figure 8: My pet goat – development

Economy and value for money

Economy is a much simpler concept that has underpinned some decision making in the purchase of IAW technology for mathematics teachers. It is defined as the acquisition of resources of the appropriate quality and quantity at the lowest possible cost, but this could mean that only part of the system is purchased e.g. the projector attached to a computer without the IAW that is so essential for new pedagogic approaches. Economy in practice often means just cutting costs and getting the cheapest. There is evidence from our research that this has sometimes been undertaken with insufficient thought about the cost and appropriateness of software, the need for effective teacher development and awareness of the use of associated materials. This may well not be efficient if poor quality is the result and the system is subject to frequent malfunction. This leads schools to look for value for money. If an activity or an organisation is both efficient and effective it is said to be providing value for money. This concept attempts to bring the measurable and the immeasurable, the objective and the subjective together. Glyn (1987) attempts to define this as 'a situation where those who strive to provide the service do the best they can with the resources that are available'. From the individual teacher's viewpoint this means a constant awareness of the ways in which

equipment is being used and an evaluation of the way in which technology and pedagogy are being used to maximum advantage.
It was shown at work by participant E who taught in a school where a decision had been taken to equip all mathematics rooms with a computer and data projector, but not an IAW, rather than one or two rooms in the department with an IAW, as had occurred in the rest of the school. The effect of this was that although demonstrations were lively and linked to PowerPoint and Excel interactivity was minimised and pupils were then using either normal 'slate' whiteboards or exercise books in a conventional way. The disadvantage was shown in the teaching of co-ordinates to year 7 pupils. The pupils followed a stepped process and communicated their understanding by using co-ordinates. However, there was no interactivity at the board and exercises were individualised rather than shared with the group.
Economy in the purchase of the best possible equipment at the lowest price was a matter of pride to participant F. She had then used the money released to purchase necessary tools and software so that 'we can maximise the teaching opportunities by drawing from on a really wide range of materials on the computer - it is a matter of being constantly aware of what is needed and where it is (needed) but it does support the starter, and the main point of the lesson and then I can use a range of ideas for the plenary according to progress made'.
Value for money is a subjective concept but the participants all felt that they had gained from the motivation and stimulation provided by good equipment that was fully used. Participants' comments indicate that gains are from the 'retention of a series of lessons ready for revision, and re-adaptation at one mouse click away'; 'the opportunity to record what is there for pupils who for some reason have been away'; 'the chance to go through things with those who are having difficulty without searching textbooks and old lesson notes'; and 'the opportunity to link IAW, computer, video clip and internet as teaching or learning demands'.
If equipment has been purchased with economy in mind and is then used to the full there should be evidence that expenditure has secured value for money. Pupil comment indicates that there are gains from the use of the IAW providing that the teachers are capable of using it with ease, and if there is planned learning and opportunity for revision. To secure these attention should be paid to: ***understanding*** of the way in which IAW equipment can add to conventional teaching; ***utilisation*** of associated techniques; and ***development*** of recording and resource management systems so that there can be ready recall of materials according to need.
The work with participant mathematics teachers led to discussion of the ways in which the IAW was integrated into teaching. Seven of the participants commended the concept of the fraction wall as something that would provide them with value for money and enhance their use of the IAW.

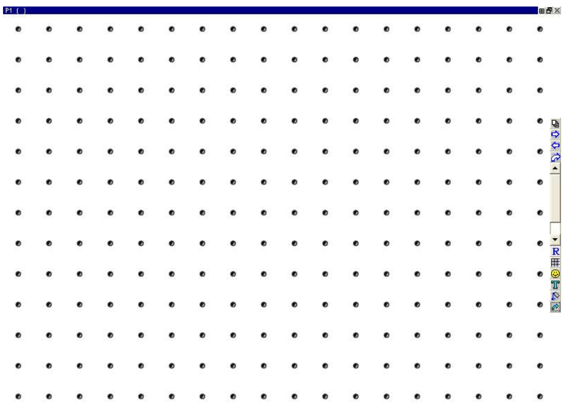
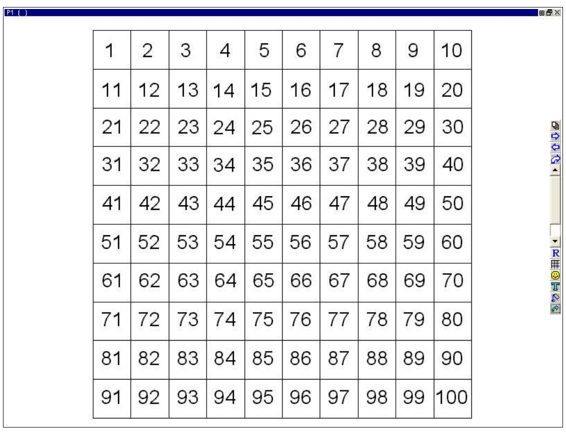


Figure 9: A rectangular dot lattice



1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

Figure 10: A hundred square

Most IAWs come complete with background pages or tiles, and these can easily be made by teachers with knowledge of, for example Word and Excel. The use of such background pages enables the teacher to produce effectively and efficiently appropriate resources for classroom use in order to meet local needs. In Figures 9 and 10 we see background pages that are completely open-ended in their use. They can be overwritten and saved. ***Enhanced interactive teachers*** use such pages in many different situations to tackle different topics. Figures 11 and 12 show one such use where a simple square grid is used to promote discussion of fractions. Overwriting on the grid allow the teacher to tackle equivalent and increasingly complex dissections of rectangular grids in a meaningful way, with Figure 12 showing one possible set of answers. Such opportunities allow teachers to develop and re-use materials, thereby improving cost effectiveness.

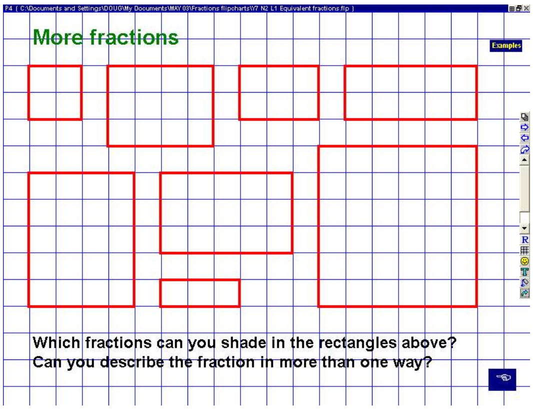


Figure 11: A fraction screen

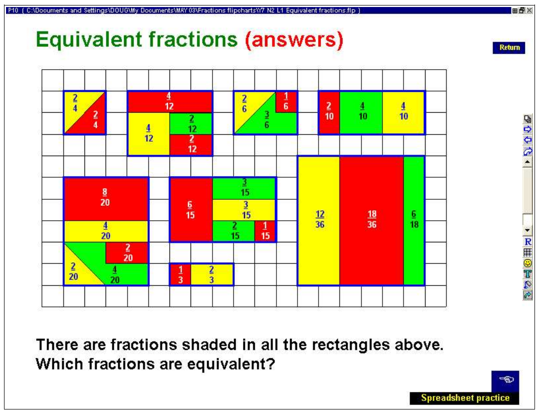


Figure 12: Answers for a fraction screen

Conclusions

It can be argued that teachers are only aware of the equipment they have at their disposal in a professional way. For them the important question was expressed by participant B as ‘does the IAW add to the quality of my teaching and pupils’ learning – if so, then it is worth the time taken to learn how to use it, to modify the approaches and the materials I use, and to change the way I work in the classroom so that the focus moves from me to the IAW’. For him there is limited direct concern with efficiency, effectiveness and value for money but the retention of the IAW as a force for good in enhancing teaching and learning is only possible if its capacity is exploited to the full.

This has the hidden qualities of securing efficiency by maximising outcomes through using the equipment in an effective way. Where this is achieved there will be both economy and value for money. This impacts upon the management of resources at both departmental and school level. This is something larger than the use of technology in the classroom and reflects attitudes and encouragement within the school. Where we observed effective teaching focused on the IAW it was evident that ‘Missioners’ within the staff had convinced colleagues of the advantages to be gained by using the technology and had sought senior management help in obtaining the technological resources and the professional development support necessary for successful introduction.

There were also teachers who spoke of the importance of understanding how pupils learn and in twenty six interviews teachers reported using teaching methods that catered for a range of learning styles and that they used the IAW as a means of offering a combination of pedagogic approaches in carefully stepped learning processes. In most of the schools where lessons were observed there were at least two IAWs in each of the subject departments concerned. This brought with it the opportunity for teachers to develop fluency in use, to share ideas, personal learning and technology with colleagues. The ability to network and share software resources within the departments was a factor in securing successful use of the IAW and the effective use of the technology was further enhanced because, in most cases, there were no issues of pupil behaviour. All these add up to a developing ‘culture’ of IAW use within schools. If teachers have moved to the point of ***enhanced interactivity*** it is unlikely that there could be a reversion to conventional approaches because both teaching and learning have gained from an integrated approach that brings together technology,

knowledge of the ways in which people learn, and of pedagogic approaches that cater for those needs. In this way current suggestions that there may be an element of 'luxury' in IAW availability and use will be rebuffed because their value for money is demonstrated by their constant use.
The fundamental requirement to offer efficiency in equipment use, effectiveness in its incorporation into teaching and value for money once the installation has been undertaken, is that teachers should recognise the need to move from didactic to adventurously interactive approaches to IAW use. Whether this can be achieved or not is dependent upon the provision of suitable training. Our evidence is that this is best undertaken on a one-to-one basis and within subject departments where all the mathematicians have a collective view of the value of the technology. In such environments sharing of ideas, corporate development of materials and software, and group review of pupil attainment supports those teachers who may be lacking in confidence and awareness of the potential being offered. Where teachers have not been provided with this level of support there is evidence to suggest that they revert to didactic approaches with minimal or limited use of the technology and pedagogy. In such circumstances the efficiency, effectiveness and value for money of the IAW is rightly called into question.

References

Adhami, M., Johnson, D. Shayer, M., (1998) Thinking Maths, Heinemann
Audit Commission (1993) *Adding up the Sums: Schools' Management of their Finances.* London, HMSO.
Cogill, J. (2003) The use of interactive whiteboards in the primary school: effects on pedagogy *Research Bursary Reports* Coventry, Becta
Damcott, D., Landato, J. and Marsh, C. (2000) Report on the use of the SMART board interactive whiteboard in physical science. *Research report published on www.smarterkids.org*
Edwards, J., Hartnell, M., Martin, R. (2002) Interactive whiteboards: some lessons for the classroom. *Micromath* 18(2) 30-4
Glover, D. and Levacic, R. (2004) Investigating effective resource management in Wallace, M. and Poulson, L. (eds.) *Learning to Read Critically: Educational Leadership and Management*, Chapter 4, 90-112. London, Sage.
Glover, D. and Miller, D. (2001) 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., Miller, D. and Averis, D. (2003) The impact of interactive whiteboards on classroom practice: examples drawn from the teaching of mathematics in secondary schools in England. *The Mathematics Education into the 21st Century Project: Proceedings of the International Conference The Decidable and the Undecidable in Mathematics Education, Brno, Czech Republic* 181-5
Glyn, J. (1987) *Public Sector Financial Control and Accounting* Oxford, Blackwell
Greiffenhagen, C. (2000) A report into whiteboard technologies; (unpublished) Oxford, Computing Laboratory
Jones, S, and Tanner, H. (2002) Teachers interpretations of effective whole-class interactive teaching in secondary mathematics classrooms. *Educational Studies* 28 (3), 265-274
Kennewell, S. (2001) Interactive whiteboards – yet another solution looking for a problems to solve? *Information Technology in Teacher Education* 39 (3-6)
McCormick, R. and Scrimshaw, P. (2001) 'Information and communications technology, knowledge and pedagogy. *Education, Communication and Information* 1: 37-57
Miller D., Sherran P, (2003) EXP Maths 7 Whiteboard CD-ROM and Activities for Interactive Whiteboards, Nelson Thornes
Miller, D., Glover, D., Averis, D., Door, V. (2004) *Research reports to the Nuffield Foundation, Becta and TTA,* Keele University, Staffs., Department of Education (in press)
Moore, A. (2001) Interactive whiteboards – a luxury too far? *Teaching ICT* 1 (2) 52-57
Robison, S. (2000) Math classes for the 21st century, Media and Methods, 36 (4), 10 – 11

Simpson, M., Payne, F, Munro, R and Lynch, E. (1998) 'Using information and communication technology as a pedagogical tool: a survey of initial teacher education in Scotland' *Journal of Information Technology for Teacher Education*, 7 (3) pp. 431-446

Smith, F., Hardman, F., Wall, K., Mroz, M (2004) 'Interactive whole class teaching in the National Literacy and Numeracy Strategies *British Educational Research Journal* 30 (3), 395-411