Interactive Whiteboards for Education:
Theory, Research and Practice

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Chapter 6

The Impact of Interactive Whiteboards on Classroom Interaction and Learning in Primary Schools in the UK

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ABSTRACT

The UK Government's Primary National Strategy undertook a pilot programme "Embedding ICT in the Literacy and Numeracy Strategies" where interactive whiteboards were installed in the classrooms of teachers of 9-11 year old students in more than 80 schools in six regions of England. Research to evaluate this project collected multiple sources of data, including students' attainment, structured lesson observations and the perceptions of teachers and students. Results suggest that the use of the interactive whiteboards did lead to significant changes in teachers' practices in the use of technology and in aspects of classroom interaction, and that the perceptions of those involved were overwhelmingly positive, but that the impact in terms of students' attainment on national tests was very small and short-lived. This raises questions about the integration of new technologies into classroom teaching and how such technologies might improve teaching and learning.

INTRODUCTION

The aim of this chapter is to present a critical analysis of the findings from a large-scale research project in the UK where electronic or interactive whiteboards were introduced into over 200 classrooms of the teachers of 9-11 year olds in England (Higgins et al., 2005). The initiative was explicitly designated as a national pilot project with the key goal of raising levels of attainment in the pilot schools in literacy and mathematics, which are the central curriculum focus of the UK Government-funded Primary National Strategy (i.e. strategy for raising standards in primary or elementary schools across England). Some aspects of the project have been published elsewhere, such as the initial literature scoping to identify likely issues with the evaluation

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(Smith, Higgins, Wall & Miller, 2005), changes in patterns of interaction identified through systematic observation over the course of the research (Smith, Hardman & Higgins, 2006), two analyses of students' perceptions using different methodologies (Hall & Higgins, 2005; Wall, Higgins & Smith 2005), an analysis by gender of the impact on classroom interaction (Smith, Higgins & Hardman 2007) and a discussion of the limitations of analysis of question types without investigating the subsequent discourse moves (Smith & Higgins, 2006). This chapter therefore aims to synthesize key aspects of the findings in relation to the overall objectives of the research in terms of its national policy objectives and to identify key issues for wider research into the use of interactive whiteboards in education. The process of the research also raises wider questions about the way that educational research is valued and used at policy level in the UK and more general challenges in evaluating the impact of technologies on education.

BACKGROUND

The UK has invested heavily in promoting the use of educational technologies in primary or elementary schools. Initiatives such as training for teachers in the use of information and communications technology in the late 1990s aimed to offer a course of training to all serving school teachers in the UK at a cost of about $800 million. Additionally investment in hardware, software and networking (such as the development of a "National Grid for Learning") have similarly seen considerable sums (over $3 billion up to 2008).

At the policy level, the introduction of interactive whiteboards was seen as a way to integrate technology into teaching in primary or elementary schools and at the same time support the development of "whole class interactive teaching" (Reynolds & Muijs, 1999) in order to improve standards of attainment. Other goals were informally identified, such as greater engagement of boys in lessons to address their perceived underachievement. These aims were discussed with the funders of the research and this helped to shape the development of the research methodology.

The implementation of training and the support for the teachers involved was also studied as part of the research. A model was developed in the project where one full-time specialist teacher supported groups of about 20 teachers in each region. Training materials were developed centrally, then revised as they were used locally. A temporary website was created to exchange ideas and teaching resources (used mainly by the specialist teachers, but also by a number of classroom teachers in the project). In addition, most regions established support groups which met more informally on a regular basis. The approach to supporting teachers in using the technology effectively was a key part of the pilot programme.

RESEARCH APPROACH

The research team adopted a pragmatic approach to the evaluation of this major national initiative working within the limitations imposed by the sponsors and the funding available. The main driver of the research was to evaluate the impact of the initiative on national test results with an implicit rationalist paradigm (Young, 1999) but influenced by post-positivist approaches such as scientific realism (Pawson & Tilley, 1997) and responsive evaluation (Stake, 2004). Working with the sponsors of the pilot project, the team planned a multi-method approach to the evaluation using complementary qualitative and quantitative methods. The model of impact the research team used involved short-term indicators (participants' perceptions and changes in patterns of classroom interaction) as well as outcomes (students' attitudes and attainment). A review of the available evidence at the outset of the project indicated that the perceptions of those involved in the introduction of such technologies is generally positive, but that information about the impact in terms of changes of patterns of classroom interaction or measures of attainment were scarce (Smith et al., 2005). This remains the trend in research in this area (Higgins, Beauchamp & Miller, 2007).

The research approach was influenced by this existing evidence about the use of interactive whiteboards in education. The team attempted to design the research to address some of these shortcomings similar to the approach advocated by Blatchford (2005) in terms of the balance of evidence types. The evaluation also took into account aspects of the process of the initiative (such as technical and logistical issues) which were fed back to the sponsors and participants as the research developed. The main focus of this chapter, however, is the perceptions of the teachers and students involved of the impact of the technology, the actual changes found in classroom interaction through systematic observation and then the analysis of attainment data for literacy and mathematics, first after one, and then after two years of use.

The research team therefore used a multi-method approach to the evaluation of the impact of the technology on teaching and learning. Quantitative data was collected about aspects of classroom discourse and interaction and about students' attainment using national test data. In addition the perceptions of teachers, students and others involved in the initiative were included as an important aspect of the project methodology (van den Berg & Ros, 1999). In the sections which follow, summaries are presented of some of the data published elsewhere (Hall & Higgins, 2005; Higgins et al., 2005; Smith et al., 2005; Smith et al., 2006; Smith & Higgins, 2006; Wall et al., 2005) to provide a background for the discussion of issues concerning the synthesis of evidence in relation to the impact on students' attainment which has not been previously integrated into the overall analysis.

Daily Use of Interactive Whiteboards for Literacy and Mathematics

Descriptive data about the day-to-day use of the whiteboards was collected for two six-week periods one year apart using online diary forms. The weekly records contain data for about 100 teachers' self-reported use of the interactive white-boards (about half of the participating teachers) representing about 8,800 lessons in literacy and mathematics. These teachers were volunteers and this may therefore over-estimate the actual usage (assuming the volunteers were more willing participants in completing the online forms and in participating in the project overall). The records indicate that the teachers reported using their interactive whiteboards in just over two thirds of their lessons (66%) in the first year of the project and nearly three-quarters of their lessons (74%) one year later. Interactive whiteboards were used slightly (and significantly) more often during mathematics lessons compared with literacy in the first year of the project. This had evened out a year later (with a 6.3% increase in reported use in mathematics and a 9.7% increase in literacy), resulting in no significant difference in reported use by subject after two years. This suggests that either the teachers were initially more confident to use the IWBs for mathematics teaching or that there were more activities or software available in this area of the curriculum at the start of the project.

Consistent patterns of use were reported over the course of the week, with a steady decline in reported use from Monday to Thursday (from about 80% of lessons at the beginning of the week to about 73% of lessons on a Thursday) and significantly fewer teachers reporting using IWBs on Fridays (about 67% of lessons).

Use increased in all parts of lessons (whole class introduction, group and plenary phases) and patterns of software use indicated that teachers were involved in developing or adapting resources more in the second year of the research, suggesting greater levels of confidence and skill in using the technology (for further details see Higgins et al., 2005). These data indicate that the pilot project was successful in developing use of the technology to a point where it was being used in nearly three-quarters of lessons of the teachers who completed the weekly records.

Changes in Patterns of Classroom Interaction

Structured observations of classroom interaction were undertaken in early 2003 and again a year later in early 2004. A total of 184 lessons of a random sample of 30 teachers were observed; the research focused on differences between lessons where teachers taught literacy and mathematics with and without an interactive whiteboard and on any changes in patterns of interaction a year later. This enabled us to investigate potential differences in classroom interaction between those teachers when using whiteboards and when they were not. Our sample size was also large enough to compare literacy and mathematics lessons and to examine any interaction effect between lessons with and without an interactive whiteboard and subject area (literacy or mathematics). The structured observation system was developed from that of Mroz, Smith and Hardman (2000) and Smith, Hardman, Mroz and Wall (2004), based on earlier classroom observational research (Croll, 1986; Flanders, 1963; Galton, Hargreaves, Comber, Wall & Pell, 1999; Good & Brophy, 1991). Full details of the findings from this aspect of the research are published elsewhere in terms of general patterns of interaction (Smith et al., 2006) as well as an analysis in terms of gender (Smith et al., 2007), and a summary of these findings is presented below.

Overall the interactions in lessons were fairly typical of the kinds of patterns in primary schools identified in this earlier research. For example, the most frequent discourse moves were *explaining* by the teacher (135 'moves' per hour, each lasting on average 12 seconds and accounting for 28% of lesson time), *closed questions* by the teacher (62 per hour, each lasting on average only 3.5 seconds), *evaluation* by the teacher (62 per hour, on average 4.7 seconds long and accounting for 7.5% of lesson time), and *direction* (51 per hour, lasting 8.1 seconds on average and comprising 9.4% of lesson time). A typical *pupil answer* lasted for 4.4 seconds and such answers accounted for about 17% of the duration of a lesson overall.

The use of interactive whiteboards did seem to make a difference to aspects of classroom interaction. Some of these were relatively short-lived, others appeared over time as the use of the technology became embedded. From both years of observations, there were fewer pauses and uptake questions in interactive whiteboard lessons; but an embedding effect was observed in the second year of the project whereby there were also more open questions, repeat questions, probes, longer answers from students, and general talk in these lessons. There was almost twice the amount of evaluative responses from teachers in interactive whiteboard lessons. Teachers using interactive whiteboards after a year of use tended to focus their uptake or follow-up questions on the whole class rather than on an individual student.

There was a faster pace in the interactive whiteboard lessons (as measured by total number of discourse moves) in 2004 compared with the non-whiteboard lessons in 2003. Nearly 100 more discourse moves were found per lesson (such as explanations, questions, evaluations and answers). However, answers from students were also longer in whiteboard lessons compared to non-whiteboard lessons. The initial decrease in the amount of explanation by the teacher was short-lived (it increased again in 2004).

There were a number of statistically significant differences between mathematics and literacy lessons. For example, closed questions made up 9.5% of an average mathematics lesson but only 3.4% of a literacy lesson. Open questions constituted 3.1% of a literacy lesson but only 0.9% of a mathematics lesson. Presenting from pupils and uptake questions by the teacher both had larger percentage contributions in literacy lessons; and teacher direction (such as giving instructions) had a larger percentage contribution in mathematics lessons. These differences were consistent, however, between whiteboard and non-whiteboard lessons suggesting a strong subject pedagogy with clear patterns of interaction associated with the different lessons in literacy and in mathematics.

In the first set of observations, interactive whiteboard lessons contained about five minutes more whole class teaching and five minutes less group work than lessons without an interactive whiteboard. This difference was found in both literacy and mathematics. After a year the amount of group work had decreased further (this time a difference of nearly seven and a half minutes). This difference was found in the classes of 9-10 year olds (Year 5) and of 10-11 year olds (Year 6) classes.

The patterns of interaction in lessons by boys and girls remained consistent across both interactive whiteboard lessons and lessons where such technology was not used. There was no difference in who initiated or who received questions and answers between interactive whiteboard and non-interactive whiteboard lessons. Although there are clear differences in patterns of interaction and response between boys and girls (Smith et al., 2007), particularly in terms of the greater amount of attention boys receive, the introduction of the interactive whiteboard did not make a significant difference to these patterns.

Interpretation of these findings is challenging. Some of the changes suggest an increase in the kinds of interaction associated with more effective teaching (e.g. Muijs & Reynolds, 2001; Nystrand & Gamoran, 1991), although the relationship between observed teacher and learner behaviors and teaching effectiveness is an elusive one (Rex, Steadman & Graciano, 2006). In particular the increase in open questions, length of answers and use of "probes" or follow-up questions indicate a more interactive style of classroom discourse (Galton et al., 1999). Others may or may not be so beneficial. Pace of lessons is an example of this (Muijs & Reynolds, 2001, p. 9) as pace of interaction must be balanced with students' level of understanding. Inspection reports in the UK often comment favorably on one of the benefits of information and communications technology as enabling a faster pace of lessons (e.g. Ofsted, 2005, p. 16). The research reported here confirms that the use of interactive whiteboard technology is indeed associated with faster pace (at least in terms of the number of interactions in lessons). However, overall it is difficult to determine from the observational evidence alone whether the introduction of IWBs had a positive impact on interaction in these classes.

Teachers' Perceptions

Structured interviews were undertaken with a random sample of 68 teachers to determine their perceptions of the impact of the technology on their teaching and their views of the training and support they had received. Checks were made to ensure that the sample was broadly representative of the group of teachers as a whole (Higgins et al., 2005). These interviews were conducted by telephone and covered areas such as teaching and ICT experience, training and more detailed exploration of their use of the technology and their perceptions of its impact.

Overall, the teachers interviewed were extremely positive about the impact of interactive whiteboards on their teaching. They were also positive about the training and support that they had received as part of the pilot project with the majority of teachers reporting that using the interactive whiteboard had improved their confidence. All of them felt that the interactive whiteboard helped them to achieve their teaching aims and cited a number of factors such as the wealth of resources available, the stimulating nature of the presentation and the flexibility that the technology offers. The overwhelming majority (99%) believed that using the interactive whiteboard in lessons improved students' motivation to learn. Eighty-five percent thought that interactive whiteboards would lead to improvements in student attainment, though some felt that this would be dependent on how the interactive whiteboard was used and that such impact might not be evident immediately.

In terms of patterns of working, the teachers were asked how the interactive whiteboard had affected their teaching and just over 70% reported that they were doing more teaching of the whole class together (as opposed to setting group or individual work) and a greater majority (81%) thought that their workload had increased since the introduction of the interactive whiteboard, one of the few negative comments in relation to the new technology, though about one third of these believed (or hoped) that the increase would be only temporary in nature as they developed, stored and shared their digital resources.

Fifty-six percent of respondents said they had not noticed any differences between boys and girls in relation to interactive whiteboard use while 44% said they had noticed differences, usually commenting on a positive impact on boys such as that they were more motivated and interested or more focused and involved.

Overall the responses were overwhelmingly positive about the introduction of this technology in the classroom, with by far the majority of teachers commenting that they believed that the interactive whiteboards helped them to achieve their teaching aims and to improve students' motivation.

Student's Views

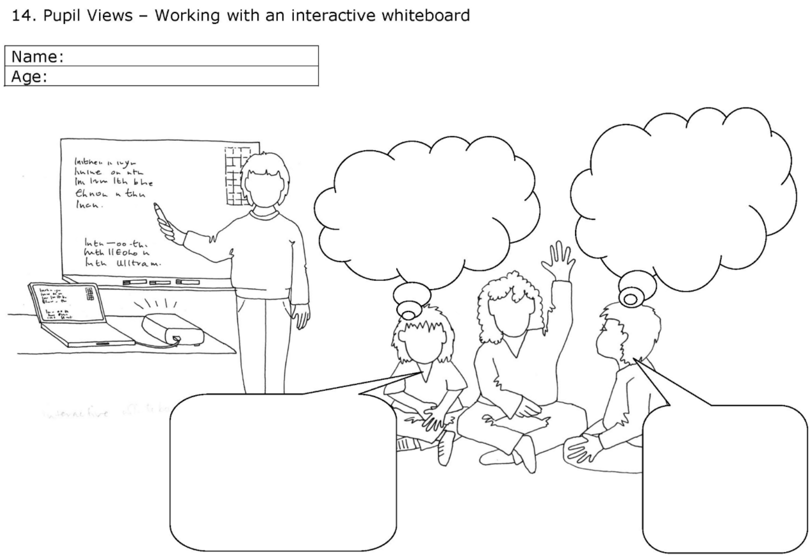
Twelve sets of student interviews were conducted between March and April 2004 with groups of students who had been in classes where interactive whiteboards had been used for two years. The schools were chosen at random, but each school selected the group to be interviewed. In total, 72 students were involved in the group interviews. The interviews were taped and transcribed, then analyzed for the responses to each of the questions as well as for any further themes which emerged (Hall & Higgins, 2005).

The students were very positive about the use of interactive whiteboards, they particularly liked the multimedia potential of the technology and believed that they learned better when an interactive whiteboard was used in the classroom. In particular, most of the student groups interviewed believed that the interactive whiteboard helped them to pay better attention during lessons. Their reasons for this appear to revolve around the opportunities for a wider range of resources and multi-media being used, though they generally also liked having their work shown on the interactive whiteboard. It was widely seen as an opportunity to learn and to improve their work. Students also said that they would like to use the interactive whiteboard themselves more than they currently had opportunities to and that they would like it if their teachers used the interactive whiteboard more in lessons. The consensus seemed to be that mathematics was the most popular lesson among those students interviewed although students also readily identified other lessons that they enjoyed when an interactive whiteboard was used.

Students identified a number of common problems which were encountered by their teachers. Apart from the interactive whiteboard breaking down entirely or having to be recalibrated (which they universally found frustrating), students mentioned difficulties seeing the interactive whiteboard when sunlight shone through the windows. They also noted that sometimes moving objects on the board could be difficult to manipulate or to see clearly and that some colors of text were hard to read.

Asking pupils whether there were any differences between boys and girls in connection with interactive whiteboards sparked off a level of rivalry between them (all of the groups were mixed), which made it difficult to tease out whether

Figure 1. The IWB pupil views template



there are any real differences in their perceptions. Student responses fell into four distinct themes: specific pupils are chosen more than other pupils to answer questions; boys use the interactive whiteboard more than girls; girls use the interactive whiteboard more than boys; everyone gets an equal chance to use the interactive whiteboard. There was no clear consensus over this theme.

An innovative methodology was also used to record pupils' views using templates of a classroom scene with an IWB and showing children with speech and thought bubbles (see Figure 1) to try to elicit their thoughts about learning with IWBs (Wall et al., 2005; Wall et al., 2007) as opposed to simply what they thought of them. Eighty pupils (46 boys and 34 girls) in three LEAs completed the pupil views templates.

The responses were broken down into 1,568 individual statements for analysis, ranging from single words to whole sentences. The split between responses in the thought and speech bubbles was approximately equal (51% and 49% respectively). The statements were then categorized according to whether they were positive, negative, or neutral, with the majority positive (56%) and neutral (32%).

The use of the cartoon structure seemed to facilitate discussion and recording of thinking processes such as remembering, understanding and concentrating in relation to the use of the IWB. Other areas recorded corresponded more closely to the findings from the focus group discussions such as enjoying the variety and the multimedia features of the boards as well as some of the challenges and difficulties in their use (such as technical difficulties, frequent recalibration, visibility of text and the like).

The overall impression from both sets of interviews was of a positive reaction to the technology, particularly in terms of their motivation and learning, but of informed and critical comments about the use of the technology more generally. These findings are broadly consistent with the wider research on students' and teachers' perceptions of interactive whiteboard use in education (Higgins et al., 2007).

Impact on Student Attainment

Data at student level from the national tests in English, mathematics and science for 11 year olds were provided by the UK's Department for Education and Skills (DfES) for 2003 and for 2004. Data were provided for both the project schools and a further matched control group of schools in the same Local Education Authority (LEA) as a comparison. These data were then analyzed to identify any impact of the use of interactive whiteboards in the project schools and to see if there was any difference in impact according to gender or for high or low attaining students.

The group of the pilot project schools and matched control group consisted of 67 of the schools in the six LEAs who participated in the project, while the control group consisted of 55 schools from the same LEAs. As the use of interactive whiteboards started in most schools early in 2003, the schools were matched on the basis of their 2002 national test performance, using both mean points score and mean percentage of students achieving level 4 and above (this is the target level for 11 year olds). As the interactive whiteboard schools had test scores about five points above the national average, it was not possible to constitute a control group of the same size as the interactive whiteboard group, nor to include all project schools in the experimental group. Schools were also included only if test data were available for all three years from 2002-2004. The matching was carried out so as to ensure similar proportions of schools in each of eight percentile bands and where there were more potential control group schools than required in a band, the selection was carried out using random numbers. Checks were made so that the two groups were well matched on the following additional criteria: mean number of students on roll in 2002, mean proportion of students with Special Educational Needs, patterns of attendance in 2002 and national test performance in 2001. In all cases the two groups were seen to be equivalent, with no differences approaching statistical significance.

The 2003 national tests were taken in May, after approximately five to seven months of use of interactive whiteboards in the project schools. This is a relatively short time for any effect to become apparent, but as shown in Table 1, the mean raw test scores in the interactive whiteboard schools are slightly higher than in the control schools, with statistically significant margins for mathematics and science. However, the effect size in each case is very small.

A year later, in 2004, raw test scores were again made available by the DfES and the overall comparison of interactive whiteboard and control samples is presented in Table 2. Here it can be seen that there are no significant differences between the two groups and the effect sizes are negligible. The small benefit for the interactive whiteboard schools seen in mathematics and science test results in 2003 was not sustained. Analysis of teacher assessments in 2004 yield a very similar set of results, with non-significant between-group differences and very small effect sizes of 0.06 for English, 0.04 for mathematics and 0.01 for science.

When the 2004 Reading and Writing test components for English are compared separately, the effect sizes for between-group differences are -0.01 for Reading and 0.05 for Writing.

Although some of the initial differences were statistically significant the extent of the difference (the effect size) was small. The early improvement seen after the first few months may have been a novelty or Hawthorne effect of some kind (Gillespie, 1991). It did not lead to further improvement in the following year, which might have been expected on the hypotheses that students were taught more actively, and therefore perhaps more effectively, in interactive whiteboard classes. The initial small improvement in mathematics and science did not seem to provide a platform for continued improvement for students the follow-

Table 1. Comparison of 2003 student attainment data

Subject	Group	No of students	Mean test score	s.d.	t	p	Effect size (Cohen's d)
ENGLISH	IWB Controls	2879 2085	58.69 58.09	16.39 16.32	1.28	n.s.	0.04
MATHS	IWB Controls	2892 2094	63.93 61.75	21.00 21.06	3.62	<0.001	0.10
SCIENCE	IWB Controls	2921 2108	59.42 58.10	11.94 12.30	3.79	<0.001	0.11

(Raw national test scores: interactive whiteboard and controls - student level)

ing year. It therefore appears that, after two years, the impact of the use of interactive whiteboards is not identifiable in the levels of attainment of students, at least as measured in national tests. While the nature of the evaluation design (without random allocation) means it would not have been possible to claim a clear causal inference had a significant and substantial difference been found (there may have been systematic bias in the allocation of schools to the IWB intervention for example), the absence of a clear difference is indicative (or at least strongly suggestive) of a *lack* of direct effect.

Issues and Challenges

The analysis indicates that it is important to consider the multiple sources of data in evaluating the impact of the introduction of educational technology on this scale. The teachers involved all rated the introduction of the interactive whiteboards, the training in its use and the support from the specialist teachers very highly. There can be no doubt that the technology had a real impact on the primary or elementary school classrooms where they were introduced. The response of the teachers and students involved in the project was overwhelmingly positive. Both of these groups reported that they were convinced that these changes were improving the teaching and learning in lessons where they were used.

The observations confirmed that there were significant differences in patterns of classroom interaction, both as the teachers learned to use the technology and a year later as the use of interactive whiteboards became more "embedded" in literacy and mathematics lessons. Overall interactive whiteboards did seem to make a difference to aspects of classroom interaction. Some of these were relatively short-lived, others appeared over time as the use of the technology became embedded. For example, there were fewer pauses and uptake questions in lessons where an interactive whiteboard was used and an embedding effect

Table 2. Comparison of 2004 student attainment data

Subject	Group	n students	Mean test score	s.d.	t	p	Effect size
ENGLISH	IWB Controls	2763 1965	55.36 55.08	15.08 14.89	0.63	n.s.	0.02
MATHS	IWB Controls	2824 1980	66.53 66.47	21.41 21.20	0.09	n.s.	0.00
SCIENCE	IWB Controls	2850 1944	57.29 57.71	12.45 11.99	1.16	n.s.	-0.03

(Raw test scores: IWB and controls - student level) was observed in the second year whereby there were also more open questions, repeat questions, probes, longer answers from students, and general talk in these lessons. This suggests a stronger lesson "flow" (Jewitt, Moss & Cardini, 2007; Kounin, 1970). There was almost twice the amount of evaluative responses from teachers in whiteboard lessons. The indications from these observations also suggested that the changes in questioning by the teachers and the responses from their students were consistent with the kinds of interaction associated with effective teaching and in particular teacher questioning (e.g. Muijs & Reynolds, 2001; Nystrand & Gamoran, 1991). The enthusiasm of the teachers and the early data from the evaluation convinced policy-makers that the approach was successful and plans to widen the pilot began before the final analysis of national test data were available.

This analysis of students' performance in literacy, mathematics and science tests at first suggested that the impact of the introduction of interactive whiteboards was associated with some small improvements in children's learning. The aggregated national test results show that after one year the pilot project schools made slightly more progress overall than a matched group of schools not involved in the project, with a rather small effect size of 0.09. However, these differences were not found after the second year of the project, suggesting that the early improvement was due to the initial intervention or that sustained improvement is harder to achieve, especially in relatively high performing schools and as measured by national tests.

Implications and Issues for Future Research

This chapter has presented findings from a major national policy initiative in the UK where educational technology was introduced to improve standards of attainment. The research findings indicate that caution is needed in introducing such new technologies, if the aim is to improve student's levels of tested attainment. Initial indicators from the innovation were positive, yet the final outcomes of the research suggest that the overall impact on standards was negligible. The technological validity (Strassmann, 1974) of the study is demonstrated through similar findings being repeated both in other similar evaluations of IWB technology and in more general implementation studies of educational technology more broadly.

As in the US, current political pressures on the educational research community are such that research should meet the demands of evidence-based and scientifically-based inquiry, however the policy drive by the Primary National Strategy in England has been to continue to promote the 'embedding' of such technologies in schools, despite the lack of convincing evidence of impact on student attainment or more developmental research into how teachers' can best be supported in getting the best from the technology. This raises questions about how educational research is valued and used at policy level and more broadly about educational research and its utility.

THE FUTURE OF IWB RESEARCH

One direction for further research is in the nature of the technology itself. Interactive (single-touch) surfaces to control a computer and to display information are clearly welcomed by both teachers and students. Multitouch interfaces are the focus of much current development (such as Microsoft's Surface™ or even Apple's iPhone). The development of multi-touch interfaces for computer displays for use by both teachers and learners is likely therefore to be motivating and productive. If the lessons from the introduction of IWBs are learned, then educational impact will be achieved by identifying a match between the affordances of the technology with the pedagogical affordances of its introduction into educational settings. The stage after this is perhaps the development of multi-user, multi-touch environments, such as the prototype SynergyNET environment (see http://tel.dur.ac.uk/) where networked multi-touch tables are the basis of a classroom environment supported with interactive technologies. Here again the emphasis must be on the pedagogical possibilities, rather than the technological capabilities.

A clear indication from the findings from this project is that research in embedding new or developing technologies in education needs a pedagogical design phase as well as a technological one. The levels of enthusiasm for the technology suggest that this could have been achieved with the support of the teachers (and students) involved. The pedagogical intervention in this project could be described as negligible in that the technology was used to support existing approaches to teaching literacy and mathematics. There was no exploration or evaluation of how the technology might have supported changes or improvement to teaching and learning approaches, such as through improved modeling or the use of dynamic images for example. This is an area which still needs further research (Higgins et al., 2007).

It may be, of course, that the introduction of the technology was beneficial for learning, but that the indicators used to assess outcomes did not capture the changes that resulted. Certainly national test performance represents only a limited assessment of learning in mathematics or literacy (see, for example, James & Brown, 2005). It focuses impact narrowly on a range of quantifiable outcomes, usually with a particular curriculum content focus (often heavily weighted towards the knowledge domain). The use of digital technologies may be beneficial because it develops deeper knowledge, more positive attitudes or learning dispositions, more creative and flexible learners, or better social learning situations; indeed there is evidence that such approaches are associated with higher attainment in specific subjects of the curriculum (Voogt & Knezek, 2008).

There is a general assumption that new technologies can (or even will) improve learning; however on occasion the different enthusiasts seem to talk over each other without exploring how their different conceptions of learning are affecting their interpretation of the existing evidence and current use of technology in schools. From the learner's point of view, there are those who see the availability of technology as a means to altering the curriculum and certainly the means of accessing the curriculum (Loveless, DeVoogd & Bohlin, 2001; Nachimias, Mioduser & Forkosh-Baruch, 2008). This stance can perhaps be identified as aligned with the "pupil-empowerment' dimension and connected with primary or elementary school teachers' thinking about educational technology and learning (Higgins & Moseley, 2001). From this viewpoint ICT offers a way to enable children to learn by giving them access to information (Law, 2004), tools (Jonassen, 2000) or to take control of aspects of their learning (Smeets & Mooij, 2001) in a way that is educationally more desirable. The introduction of IWBs in the UK was clearly not aimed at achieving this goal.

ASSESSING THE IMPACT OF TECHNOLOGY USE ON LEARNING

It is therefore possible to conceptualize new approaches in terms of their view of pedagogy (or pedagogies) for educational technologies. Most advocates of digital technologies see them as a way of altering aspects of teaching and learning, particularly in terms of empowering pupils through the use of technology as Scrimshaw's (2004) analysis identifies. This could perhaps be characterized broadly as having a view of a prospective pedagogy (Higgins & Moseley, 2001) in which technology is used to develop or re-shape aspects of teaching and learning. This position is hard to counter as it takes the view that technology can support the development of a more effective curriculum (e.g. Loveless et al., 2001). Since it implicitly advocates changes in the curriculum or pedagogy, the use of outcome indicators from the current position form only part of the case (or perhaps the "cause" more accurately): it may be that the effectiveness of the introduction of technology, for example in developing more independent learners, can only be judged after a longer period of time. It is therefore possible to take up a position that the use of technology in this way cannot be effectively evaluated until its impact upon the curriculum or upon the learners is complete. Others may see this as a dangerous position (e.g. Cuban, 2001) as criteria to judge the effectiveness of ICT are always in the future and the promise is always of "jam tomorrow" (Blamires, 2004).

It is therefore necessary for those of us who advocate the use of technology in schools to be clear about what it might achieve and to identify some indicators to assess its impact. These might be characterized as follows:

1. **The technology will help do what you have to do now, but better (either more efficiently or more effectively).** This could be evaluated by pupils' achieving either greater success on conventional outcome measures or achieving equal success, but with less teaching, or with greater understanding, or with more positive attitudes or dispositions towards learning. This rationale should identify the means by which the technology will improve upon existing pedagogy, such as through more effective feedback as simply replacing current practices with technology is unlikely to provide benefits.
2. **The technology will help you achieve other things that you value educationally and be as effective or more effective on conventional measures;** or, if less effective on conventional outcomes, it should be possible to justify why the benefits outweigh the disadvantages. This might be through developing more effective patterns of talk or collaborative skills or better understanding.
3. **Technology will help you develop the curriculum and its assessment to something that you value more**. The development of new approaches such as digital portfolios for incremental or ipsative self-assessment by learners may be considered to be of sufficient benefit that the impact of their introduction is worth pursuing to achieve long-term aims of improving important aspects of teaching and learning. In this position it is incumbent on the proponents of such a change to argue clearly what the likely impact is to be and to be clear about the costs and benefits (human as well as financial) of such change at each stage of the process.
4. **Technology will help you explore how teaching and learning may be changed.** The process of change offers the opportunity to explore how ICT can affect pedagogy (e.g. Loveless et al., 2001). The main issues here are moral ones about how those involved in such an exploration understand and have given consent to be involved. Again the onus is on the advocates to be clear about their theoretical and practical rationale as to why such changes are likely to be beneficial (and then in what way they are actually beneficial) as well as what the disadvantages might be.

CONCLUSION

The challenge of this evaluation of the introduction of interactive whiteboards into primary schools in the UK was in integrating the data and findings from the various sources over the course of the evaluation. The short and medium term indicators were positive. Teachers' and learners' perceptions were overwhelmingly positive with very few negative points raised in the interviews and were supported with what appeared to be positive and quantifiable changes in patterns of classroom interaction which might be associated with more effective teaching. Use of the technology increased, again suggesting a positive trend. The initial impact on tested attainment was small, but positive. However, there was no sustained improvement in test scores once the technology was embedded in the classrooms of the schools where it had been introduced.

Of course the study also had significant limitations. There was no random assignment of schools or teachers to the intervention with interactive whiteboards. The schools chosen were already above the norm in terms of their test results. The pedagogic model of use was determined by the Primary National Strategy and involved direct translation of the existing approach to teaching advocated by the former Literacy and Numeracy Strategies without interactive whiteboards and without any exploration of how learning interactions might be enhanced by the new technology such as by applying aspects of multimedia learning theory (Mayer, 2001). Exploration of such variation in use is essential to explore in any variation of impact of new technologies. We need to know not just whether they are more effective (in some way) than what went before, but also the ways in which the range of ways they can be used is related to aspects of learning. The policy adoption of the technology and its subsequent uptake in the UK made it impossible in a relatively short time to evaluate the contribution that interactive whiteboards make to learning. There are now an average of 18 interactive whiteboards in every primary school in England, at least according to recent figures (Smith, Rudd & Coghlan, 2008, p. 19).

Technology on its own does not change pedagogy. It is clear from the observations that the characteristic patterns of interaction in primary school classrooms remain constant in whole class teaching with or without interactive whiteboard technology. These patterns of interaction are led by teachers with largely responsive behaviors by both boys and girls (though with boys getting more of the teachers' attention). There are also characteristic patterns of interaction in mathematics and literacy lessons (such as the pattern of open and closed questions) which are also affected very little by interactive whiteboards. Both the classroom and subject pedagogies are more robust that the opportunities offered by technology. Though there were some changes in teachers' practice in terms of the balance of lessons between whole class and individual or group work and in an overall increase of 'pace' (the number and type of questions and responses) these were not sufficient to bring about identifiable changes in students' learning as measured by national standards.

Future studies of technology implementation need to have a clear hypothesis about *how* technology is likely to improve learning. This could include increased time spent on learning, or the development of better understanding through more effective modeling. Moreover, it would require researchers to undertake a design which investigates this hypothesis within the evaluation or research, such as by investigating correlations between increased time spent learning with greater knowledge acquisition or an association between the assessment of richer understanding with increased use of modeling or visualization activities. Evaluation of pedagogical change is at least as important as evaluation of technological change.

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