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Embedding interactive whiteboards in teaching and learning: The process of change in pedagogic practice

Cathy Lewin · Bridget Somekh · Stephen Steadman

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Abstract This paper draws on research carried out for the UK government during 2004–2006 to evaluate the impact of interactive whiteboards for teaching and learning in primary schools in England. Multilevel modelling showed positive gains in literacy, mathematics and science for children aged 7 and 11, directly related to the length of time they had been taught with an interactive whiteboard (IWB). These gains were particularly strong for children of average and above average prior attainment. Classroom observations, together with teacher and pupil interviews, were used to develop a detailed account of how pedagogic practice changed. Results from the multilevel modelling enabled the researchers to visit the classrooms of teachers whose pupils had made exceptional progress and seek to identify what features of pedagogy might have helped to achieve these gains. It was also possible to examine possible reasons for the lack of impact of IWBs on the progress of low prior attainment pupils, despite their enthusiasm for the IWB and improved attention in class. The IWB is an ideal resource to support whole class teaching. Where teachers had been teaching with an IWB for 2 years and there was evidence that all children, had made exceptional progress in attainment in national tests, a key factor was the use of the IWB for skilled teaching of numeracy and literacy to pairs or threesomes of children. Young children with limited writing skills, and older pupils with special educational needs are highly motivated by being able to demonstrate their skills and knowledge with the tapping and dragging facilities of the IWB. These effects are greatest when they have the opportunity, individually or in small groups, for

C. Lewin (✉)
Manchester Metropolitan University, Crewe Green Road, Crewe, Cheshire CW1 5DU, UK
e-mail: c.lewin@mmu.ac.uk

B. Somekh
Manchester Metropolitan University, 799 Wilmslow Road, Didsbury, Manchester M20 2RR, UK
e-mail: b.somekh@mmu.ac.uk

S. Steadman
University of Sussex School of Education, Falmer, Brighton BN1 9QQ, UK
e-mail: s.d.steadman@sussex.ac.uk

extended use of the IWB rather than as part of whole class teaching. The IWB is in effect a mediating artefact in interactions between teacher and pupils, and when teachers use an IWB for a considerable period of time (at least 2 years), teachers learn how to mediate the greatly increased number of possible interactions to best aid pupils' learning. The IWB's use becomes embedded in their pedagogy as a mediating artefact for their interactions with their pupils, and pupils' interactions with one another, and this is when changes in pedagogic practice become apparent.

Keywords Interactive whiteboards · Pedagogy · Change · Evaluation

1 Introduction

In 2003–2004 the Primary Schools Whiteboard Expansion project (PSWE), a UK Government initiative, provided £10 million for the acquisition and use of interactive whiteboards (IWBs) within 21 local authorities in England. An IWB has a large touch sensitive screen, linked to the classroom computer, which is visible to a whole class. Thus it can be used by teachers to access still images, moving images and sound, providing a multi-modal portal enabling the needs of whole classes, groups, and individual learners to be addressed. The PSWE funding had a strong pump-priming effect and, with large-scale procurement, many schools were able to fund additional IWBs (approximately double the number funding through the initiative). PSWE also funded an extensive training programme. This included technical training from manufacturers, national training for local authority consultants, and a portal offering resources, forums and additional guidance. Local authorities took responsibility for training staff in their schools and adopted a range of approaches (Lewin et al. in press) but there was no additional funding for this.

The initiative was launched at a time when the UK Primary National Strategy mandated a particular approach to literacy and numeracy: a daily lesson of approximately 1 h for each, with 15–20 min of whole-class teaching, 30 min of group or individual activity and a 10 min plenary session. In addition, all primary classrooms at the time had additional adult support in the form of at least one teaching assistant. These additional staff were not all involved in training but were of course able to observe the classroom teacher's practice. Finally, for the majority of the school day primary school teachers are based in the same classroom and teach most, if not all, of the curriculum to a single group of pupils. This meant that teachers, their teaching assistants and the pupils had exclusive and sustained access to the IWB.

The aims of the evaluation included: assessing the impact of IWBs on attainment, attendance and behaviour; and identifying the effects of such technology on ICT pedagogies, the embedding of ICT across the curriculum and staff professional development. These were addressed using a mixed methods design, which used Multilevel Modelling to look at the impact on attainment and case studies to explore changes in practices. This offered a more sophisticated statistical approach which was sensitive to different contexts and accounted for the shared experiences of pupil cohorts at class level. At the end of the first period of evaluation (after 18 months) there was some tentative evidence to suggest that the IWBs were making an impact

but it was clear that an extension would be worthwhile and beneficial. Thus a second phase of quantitative and qualitative data collection and analysis was instigated, extending the evaluation by a further 18 months. The Government, as sponsors of the evaluation, were primarily interested in the impact on attainment. However, it is notable that they also had a strong interest in the development of pedagogy and embedding ICT across the curriculum. This together with a willingness to extend the evaluation represents an enlightened policy, although there were still some naïve expectations of how quickly changes could occur and measurable effects become apparent.

This paper focuses on the process of pedagogical change. We define pedagogy as being the interactive process that goes on between teachers and children, in this case in planned learning. Often evaluations of Government initiatives are too short to reveal evidence of impact; the length of time that it takes for new tools to become embedded in pedagogical practices is not always realistically taken into account. The extension to this evaluation enabled the team to follow the process of change, and investigate the impact of the technology on formal assessments, over a 2 year period. In addition, the design incorporated a substantial element of classroom observation which was digitally recorded. The video data proved to be beneficial for the researchers involved as it facilitated a richer analytical approach. The collection of both quantitative and qualitative data provided opportunities for exploring phenomena in different ways, and for both illuminating and challenging findings. Moreover, it enabled an integrated approach such that qualitative and quantitative strands interacted, each data set informing enquiry and analysis of the other.

The potential of IWB technologies for supporting teaching and learning has been noted by many (Kennewell 2001; Kennewell 2004; Smith et al. 2005). There is a need to provide both technical and pedagogical training (Beauchamp 2004). However, there has been little empirical evidence to date suggesting pedagogical change (e.g. Smith et al. 2006) although IWBs are used effectively to support existing pedagogical practices (e.g. Gillen et al. 2007).

2 Methodology

The mixed methods approach adopted in this research provided further insights and fresh perspectives for explaining the impact of IWBs on teaching and learning, enhancing knowledge about phenomena and strengthening the findings (Greene and Caracelli 1997; Teddlie and Tashakorri 2003). We agree with Greene and Caracelli (1997, p12) that "[c]ontrasts, conflicts and tensions between different methods and their findings are an expected, even welcome dimension of mixed-method inquiry, for it is in the tension that the boundaries of what is known are more generatively challenged and stretched." As the objectives set by the funders demanded different research approaches, some confirmatory and some exploratory, mixing methods was the only means of achieving this simultaneously (Teddlie and Tashakorri 2003). This could have been achieved by dealing with the questions individually but this would have been foolish; a missed opportunity to extend the analysis and interpretation.

Multilevel modelling (MLM) was used to analyse data on pupils' progress in Mathematics, English and Science at ages 11 and 7. This drew on National

Curriculum test data from 100 classes with a total of 2,000 pupils from across the 21 Local Authorities. Multilevel modelling has developed from multiple regression. It takes account of the inevitable 'nesting' that occurs in the school system. Because children in a particular class have the same experience of teaching, particularly in a primary school, than pupils in another class in the same school, their attainment within the group is likely to be similar, and probably different from that in other classes in the same school. Furthermore, there will be differences between schools. There is a need to take this 'non-independence' into account. Otherwise the analysis relates to fewer observations than anticipated (classes rather than pupils).

The MLM analytical approach examines the between class variation and between school variation more explicitly. Prior to MLM, researchers either aggregated data to school level (not accounting for individual variation) or worked with pupil level data but did not take account of contextual variations (thus oversimplifying). MLM enables more statistically efficient estimates of regression co-efficients to be made, but more importantly, standard errors, confidence intervals and significance tests will be more conservative, meaning that findings are more reliable (Goldstein 1983). Moreover, the data can be used to rank classes in relation to the outcome variable (in this case progress in Maths, English and Science) and this affords the opportunity to identify classes which have performed somewhat differently from the cohort of classes overall.

Multi-level-modelling data analysis was undertaken in this project with a two level hierarchical structure of pupil and classroom. This facilitated the tracking of two groups of pupils, aged 11, who took national tests in 2005 and 2006 (Cohort 1 and Cohort 2), enabling combined and separate analyses, using national test data at age 7 as the baseline from which to assess progress. The analysis was based on the length of exposure to IWBs (in months) experienced by pupils. This increased the variance of the measure of exposure. A clear binary distinction of 'taught with IWB' versus 'not taught with IWB' was not possible due to the rapid uptake of the technology in schools that had not been included in the original pilot programme, and because of the variety of experiences that classes of pupils had as a result.

In Phase 1, ten schools were selected as case studies and visited for 2 days on two–three occasions between February 2005 and April 2006. The schools were demographically balanced; had an appropriate mix of ethnic and socio-economic groupings; and included nursery, infant and junior phases. Case study work involved classroom observations which were digitally video recorded, and interviews with learners, staff and managers. The use of video recording offered a powerful means of examining in great detail teaching practices with IWBs.

The analysis of data from the visits was undertaken collaboratively. Three key episodes were selected from each classroom observation and shared with the whole team. This proved to be a very powerful and insightful activity, both stimulating the original researcher's recall and enabling finer grained observations of things not noticed originally. It also enabled others to see important new things from the differing perspectives that researchers in the team could bring to bear from their individual backgrounds and prior experience. Through this process, the team developed a shared understanding of how to investigate the phenomena, which facilitated progressive focussing from Phase 1 to Phase 2 drawing on grounded theory principles (Strauss and Corbin 1990). The interviews were used to elicit

accounts which allowed much tacit knowledge to be inferred, and the data were used to triangulate interpretations. This enabled detailed accounts of pedagogic practice to be developed.

One of the aims of Phase 2 was to track change over an extended period of time. Another was to look for confirmation or disconfirmation of the tentative findings from the analysis of Phase 1 data. For example, the Phase 1 quantitative analysis suggested that pupils with low prior attainment were not benefiting from being taught with an IWBs; and in Phase 2 we were able to investigate why this might be so. Nine teachers from seven schools were selected as case studies, on the basis that in national tests in 2005 their classes had shown progress (identified through MLM) between the baseline and post-test outcomes that differed from the main trend. However, it was important that the researchers making these visits did not know beforehand whether the classes had fared better or worse than average, so a 'Chinese wall' arrangement operated to prevent foreknowledge.

This arrangement enabled the team to make unbiased observations in classrooms where the use of IWBs had become embedded in teaching and learning with more than 2 years use. It was then possible to develop explanatory theories as to why progress between the baseline and post-test outcomes had been different from the main trend in these classrooms. As in Phase 1, the teachers, groups of their pupils and their headteachers were also interviewed. The nine teachers who participated in the Phase 2 case studies were asked to consider the findings on the use of IWBs identified in Phase 1 and state whether they agreed or disagreed with them. The result of this exercise was a very positive overall agreement. In Phase 2 the researchers gained new insights and were also able to confirm Phase 1 findings through further observations.

Data were analysed through a socio-cultural lens, drawing on the role that tools play in 'mediating' human activity (Vygotsky 1978) whilst acknowledging that the ways in which tools are appropriated and not technologically deterministic (e.g. Fisher 2006). Rather, new tools provide opportunities to create new kinds of activity, but these new kinds of activity are created by the users as they develop skills in using the new tools, not by the tools themselves (Wertsch 1998). Thus we believe that "[t]he development of new social practices will therefore be transformative to varying degrees, depending on the affordances of the tool, the skill with which human agents learn to use them and their ability to imagine new possibilities" (Somekh 2007, p13). Initially, as with all new technologies, teachers explore ways of making the new tool fit their existing practice. Over time, however, where a professional community of practice develops, both formal and informal, within and beyond a school, teachers can learn from each other and help each other to find out new ways of using such technologies (Lewin et al. in press).

3 Findings and discussion

3.1 General findings

The take-up of IWBs in PSWE schools was rapid. There was an enthusiastic response from all teachers, leading to integration of ICT use across the curriculum as

the IWB was used—albeit to differing extents—in a variety of subject areas. This was unprecedented in our experience. As teachers had technology (IWB and a laptop or desktop computer) in the classroom, available to use whenever they wished to do so, there was a huge increase in teachers' ICT skills over a 2 year period. There was an observable process of continuing professional development through the development of Communities of Practice which generated mutual support (Lave and Wenger 1991), as the IWB was in many cases a whole school phenomenon, or at least installed in all classrooms in a year group, and thus a common experience for all staff or for those working closely together.

Along with ICT TestBed (Somekh et al. 2007a) which also equipped all classrooms in participating schools with technology, the PSWE initiative created a different atmosphere and different attitudes to ICT. For the first time, rather than early adopters struggling to implement technological innovation in isolation, there was a much greater sense of everybody being in it together, sharing ideas and practices over coffee in the staff room. Teachers had continuous access to the school servers and the internet, and so were able to immediately bring up lesson plans, pre-prepared resources or websites. Teachers either had laptops or memory sticks to use with their classroom workstations, which meant that they could more easily develop resources using IWB software at home if they chose to do so.

There were measurable gains in children's test score results (at age 11) in Mathematics, English and Science when they had been taught with an IWB for more than 2 years. The length of time pupils had been taught with an IWB proved to be a key factor. In Mathematics average and high attaining pupils (both cohorts combined) made greater progress with more exposure to IWBs. Although in Phase 1 there was little effect (but certainly not a detrimental effect) on progress for those pupils who were low attaining, analysis of the disaggregated data (each cohort separately) suggested that once the innovation becomes embedded positive gains are likely to be achieved by all attainment groups. In Science, Cohort 2 (once the IWBs had been embedded) showed benefits for all attainment groups except high attaining girls where there was a ceiling effect. In English there were indications of positive trends but the measures of attainment in this subject are less stable and therefore the results were inconclusive. In Cohort 2, once IWBs were embedded, low attaining boys showed a positive trend in greater progress in writing with more exposure to IWBs. Full results of the quantitative analysis are presented in the project final report (Somekh et al. 2007b).

3.2 Examples of pedagogical change with IWBs

In the case study schools we observed some teachers developing entirely new ways of working by using new skills that draw on possibilities offered by the board. Teaching and learning always involves interactivity between teachers and pupils and learning resources, but as they become skilful in its use the IWB teachers develop new kinds of interactivity with pupils, mediated through the IWB. Many teachers adjusted their style to be more inclusive and co-operative in supporting learning. Evidence that the IWB was embedded in teachers' pedagogy came from observing new patterns of teacher behaviour. These were either improvements on previous pedagogical practices made possible by the functionality of the board, or completely

new practices. Although these changes had, by the time of the second phase visits, all become routine, instinctive behaviours and part of what is often called 'tacit knowledge', in some cases, during questioning in interviews, teachers were able to give clear accounts of how these new practices helped them to teach more effectively.

Technical facility, that often rests upon confidence with ICT, is not enough by itself. A teacher also has to be able to appreciate what combination of modalities best aids a particular group of pupils to learn the subject matter in a particular area of the curriculum. Another component of the necessary expertise is being able to appreciate that sub-groups of pupils, e.g. the gifted, may need a fresh choice of modality, and a different sequence of experiences, if they are to learn as successfully as they can. The point is that, if teaching with IWBs is to work well, IWBs have to be used so that the full potential for them to act as a mediating artefact is realised. This entails the teacher adapting his/her approach so that IWB use fits the purposes of the teaching aims. To do this a teacher has to learn how to mediate the many learning interactions that IWBs can facilitate. If IWBs are used without this level of application, as glorified blackboards, or as occasionally animated passive white boards, then there will be little effect on pupils' learning.

An excellent example came in a Year 6 science lesson on the body's reactions to exercise. The teacher used a CD-Rom resource that allowed three 'characters,' who differed in levels of fitness, to walk, jog and run while their pulse and heart rates were monitored by the IWB/CD-Rom software to provide readings that could be graphed and compared by the class. The teacher introduced the situation, brought pupils up to the board to make choices and start the 'characters' exercising, and simultaneously had her teaching assistant keep a record of the resulting data in a grid on a nearby passive whiteboard. This latter arrangement was for the benefit of the less able pupils in the class. The levels of interaction during the lesson were thus many and varied, and the teacher showed high levels of expertise, not just technically, or even in her knowledge of the subject, but also in her classroom management skills that allowed her to run a well planned and conducted lesson that was centrally based on her enabling pupils' interactivity with the IWB.

Viewing the process of teaching with an IWB in this light, it is clear that, while teachers carry the onus of deciding appropriate modalities and content, they need to allow pupils to interact with the IWB in ways that permit it to function as the main mediating artefact. Both literally and metaphorically teachers have to learn to 'stand away' and allow pupils to fully engage in interaction with what the IWB presents, as the following extract from post-visit analytical notes illustrates.

> When the board was in use, the teacher tended to be at the board when he needed to bring up/change to a different screen, when he needed to write something on the board, and when he wanted to point something out. At other times, he seemed to stand 'away' from the board, sometimes moving into the classroom, but often standing just to the side of it at his desk (which was just to the left of the screen). In terms of where the children focused their attention—many of them often seemed to be looking at the screen rather than at the teacher. (Of course, this was not always true and sometimes dependent on what was being talked about/shown etc.). But, as I looked around the room a number

> of times, I noticed that the children did seem to be looking at the board and not the teacher—interestingly, this was confirmed by the children I spoke with in the interview. They told me that sometimes they found the board was useful for helping them to better understand what was being explained/discussed—or, if they lost track of where they were up to, they could look at the board for reference. Many of them said that sometimes hearing something out loud from the teacher did not explain it clearly to them, *but* looking at the same idea expressed in a different format, i.e. on the IWB, would often help to clarify this for them.

3.2.1 Improvement to an established pedagogic practice

One example of an improvement on an already established practice is the use of the IWB to facilitate a co-learner style of teaching, where teacher and pupils ('we') work together rather than adopting more formal roles as teacher and learner. The IWB as a mediating artefact facilitates this style of teaching very powerfully by allowing the teacher to 'stand off literally and/or metaphorically'. The notes from observation of a lesson in Phase 1 illustrate this:

> Leading into group work on scientific statements and the difference between conclusions and results type statements, the teacher started group work saying: 'I've given you a set of statements. I want you to decide as a group. But I want us all to come to a class decision.'
>
> When it was time for the first group to feed back, they had to move the statements into the correct box on the IWB, and the first group said they weren't sure where the statement went. So the teacher said, 'Right, where shall we put it then?'
>
> She didn't wield the power by saying something like, 'shall we put it in the middle?' Instead she said, 'Let's talk about it.' There was a class discussion, and she gradually got them all to agree that it went where she wanted it to go. The discussion ended with the pupils all agreeing the correct answer and the teacher smoothly took the power back as she showed them the results on the board.

While this mode of 'shared learning' existed in teachers' behaviour before IWBs were introduced, it takes on an added importance when IWBs are being used because the power of the IWB as a mediating artefact can be fully released when a teacher mediates the interactivity of learning in this way. However, observations also show that the 'teacher as co-learner' stance is adopted most frequently in the infant years, and is less frequent when teaching older children. There are several reasons for this. Older children are expected to take more responsibility for their own learning, and they also have more experience and contextual understandings to draw upon in doing this. They also become more adept at hiding their weaknesses, and have to be challenged more directly if teachers are to assess their levels of understanding accurately.

Another example of improvement on existing practice, arguably amounting to transformation, is the new style of lesson planning whereby resources for teaching

and presentations are stored electronically alongside lesson aims and objectives. The plan is thereby transformed from a paper sheet which lists actions to a dynamic 'script' for actions. These scripts are stored from year to year and 'tweaked' to suit different situations. They are often developed collaboratively by a year team and can be used by supply teachers and students on placement.

3.2.2 Emergence of a new pedagogic practice

The first of these comes about precisely because of the way in which the use of structured lesson plans, with associated choices of resources, can now be stored in computer memory, accessible at any time from the IWB, as described immediately above. This allows teachers to work to an invisible 'script' that is embedded in the lesson plans. By 'script' in this sense we imply a more complex idea than the way in which a lecturer or presenter has a script that resides in his or her presentation—or stack of overhead transparency slides. The 'script' that is embedded in the IWB/computer lesson plan, with its interlinking content, is a more complex manifestation because of the higher degree of flexibility in choice of affordance and action that is possible.

Being able to rely on the script of a lesson provides more than an aide-memoire to how the lesson should develop. Its existence enables teachers to multi-task in new ways. More of their mental capacity is released to make observational assessments for learning during whole class teaching. Assured of the shape of the lesson, this frees the teacher who is then able to direct full attention to observing how individual children in the class are responding. And by noting interactions with their TAs, teachers can also assess the progress being made by those children with special needs. Teachers gain time for assessing how individual children are progressing within the lesson. This increased attention to continuous monitoring aids formative assessment and the redirection of teaching as required. The impact this has on personalising learning is illustrated by the quotation below. During a Year 2 lesson on letter and sound combinations, the teacher was able to make direct observations of pupil response and supplement these for the pupils with special needs by noting the kind of interactions going on between these children and their assigned teaching assistant.

> I also knew quite quickly whether they had understood or not because their hands went up before (the SEN TA) had even said anything to them—and then you can see whether she needs to say something to them and re-word and re-phrase and just bring them back a step and help them—and then you can almost see the penny drop, or that she is still going. So you think, 'Right, I won't ask them that question', because they haven't quite got there yet. So sometimes you might pick up—she's still talking to them—and the rest of the class has got to the point where they've answered—(so you go on with the class) then (the SEN TA) will carry on teaching them to that point and then they'll pick up again (with the rest of the class).

The second example of these new pedagogical practices relates to the development of strategies to keep the rest of the class mentally engaged while one child is working at the IWB. In the first year we observed many occasions when the

pace of a lesson slowed appreciably when pupils came up to the board, and the rest of the class was left watching but inactive and often visibly bored. Now that IWBs are pedagogically embedded teachers have developed numerous strategies for managing pupil access to the IWB in ways that, at the same time, keep the rest of the class mentally engaged. Sometimes this involves the use of hand-held passive 'wipe' boards onto which pupils must write their answers ready to display them if their teacher asks them to. But it can also mean that teachers openly give the pupils new roles. Thus according to the circumstances, pupils may be expected to act as 'scrutineers', responsible for monitoring the work of whichever pupil is at the IWB, or 'commentators' on what the teacher is unfolding at the IWB. Some teachers actively enrol their pupils as 'helpers' when the unexpected happens. With our relatively small samples of classes we are unlikely to have tapped into the full range of practices of this kind that are emerging as parallel developments to changes in IWB teaching practices. But they all imply the creation of different social practices in the IWB classroom.

3.3 Pedagogical approaches for supporting pupils with low prior attainment

While IWBs can dramatically affect motivation for pupils who are not achieving their full potential, and the length of time pupils are taught with an IWB is the major factor that leads to attainment gains, this does not always appear to be the case for those with low prior attainment. However, in classrooms where there had been exceptional gains in attainment in the 2005 national tests (phase 1) for *all pupils* it seemed that a key factor was the use of the IWB for skilled teaching of numeracy and literacy to pairs or threesomes of children. The reason is: if the attainment of relatively small numbers of children at either extreme of the distribution of attainment in a group is lifted, this has a disproportionate effect to raise the average level of attainment within the group as a whole.

This kind of effective teaching of small groups who require additional support can be done by TAs provided they receive training in how to teach numeracy and literacy. Additionally, young children who have not yet acquired writing skills, and older lower attaining pupils, are highly motivated by being able to demonstrate their skills and knowledge with the tapping and dragging facilities of the IWB. These effects are greatest when they have the opportunity, individually or in small groups, for extended use of the IWB rather than as part of whole class teaching. We have seen only limited use of the IWB in this way but in case study schools teachers told us that such use is ideal as a means of assessing pupils' learning.

3.4 A model of pedagogical change

We were able to track the process of pedagogic change over 2 years and derive a three-stage model of its development. The process was one of IWBs becoming integrated with pedagogy as 'an extension of the [teacher's] self' (McLuhan 1964) and 'mediating' the interactivity between teacher/students and student/students (Wertsch 1998; Vygotsky 1978). When teachers have used an IWB for a considerable period of time—in this case at least 2 years—its use becomes embedded in their pedagogy as a mediating artefact in their interactions with their

pupils, and pupils' interactions with one another. The important process is not one of the IWB mediating teacher–pupil interactions. There is an important distinction here. Rather it is the teacher who, when teaching, mediates all the many kinds of interactivity that an IWB, as a mediating artefact, can facilitate to stimulate and support learning. Once teachers can operate at this level, then they inevitably change their pedagogic practices.

In summary, we identified a three stage model of pedagogic change with an IWB:

- Stage 1: teachers fitting new technologies into established pedagogies;
- Stage 2: teachers engaging in collaborative exploration of the new opportunities offered by these technologies;
- Stage 3: teachers using the IWB skilfully and intuitively in ways that extended or transformed their established pedagogic practices.

This model is grounded in the evidence collected in our research and analysed through a socio-cultural lens. Beauchamp (2004) and Haldane (2005) have developed similar models of teachers' development in their use of IWBs, each with five stages, both also drawing on observational data of classroom practices. Beauchamp presents a framework of transition (black/whiteboard substitute, apprentice, initiate, advanced, synergistic) through themes of system operation, technical skills, software use and pedagogical practices. Haldane's typology (foundation, formative, facility, fluency, flying) presents a similar set of stages arguably with a primary focus on technical development, although also referring to pedagogies. Glover et al. (2007) have also developed a three stage model (supported didactic, interactive, enhanced interactivity) with a particular focus on classroom interaction. As this is not as closely related this third model is not considered further here.

Haldane's (2005) typology proved a useful tool in the early stages of the IWB innovation, as the boards were being introduced and there was, understandably, a great emphasis on gaining the necessary technical ICT expertise to use them. However, in the first phase of the PSWE evaluation it was evident that teacher–pupil and pupil–pupil interactions were crucial. It is now apparent, from the analyses conducted during Phase 2, that once teachers demonstrate consistent facility when using an IWB, they have reached the minimum standard that allows them to mediate the interactivity of the IWB to support learning with great effectiveness. At this point the IWB becomes an integral part of teachers' own interactions with the children.

The argument that excellence in teaching with an IWB is made up from a compound of abilities, almost 'chemical' in their admixture, has been greatly strengthened by this experience of applying the typology in the case study schools. In the mixture that produces 'excellence', the level of a teacher's technical expertise with a board is important but, it is not possible to distinguish between excellent and less effective teachers on this basis alone. Whilst the models presented by Beauchamp (2004) and Haldane (2005) make a valuable contribution to the field, we agree with Jewitt et al. (2007) that the focus should be on the pedagogy rather than the technology. Therefore, we argue that our model provides a simpler (and less prescriptive) tool for understanding changes in pedagogical practice whilst allowing for the complexity of teaching and learning in classroom contexts with technology. Teachers do not necessarily need to develop high levels of technical expertise in order to transform their pedagogical practices.

The situation is still fluid. Manufacturers continue to improve IWBs and add to their modalities, and teachers continue to improve their usage as their experience as IWB users accrues. A sequence is now in train that can be described in almost Piagettian terms—where teachers themselves are the learners. Having had to adopt IWBs and adapt their teaching behaviours to accommodate them, teachers are now in the process of assimilating their knowledge and usage of IWBs. As the sequence proceeds all the various modalities of IWBs as mediating artefacts will become assimilated by teachers as extensions of their teaching capacity. In so doing, leading edge teachers will find ways of using the artefact's affordances that result in new social practices in classrooms.

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