OECD Education Working Papers No. 89

Learning from International Experiences with Interactive Whiteboards: The Role of Professional Development in Integrating the Technology

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https://dx.doi.org/10.1787/5k49chbsnmls-en

OECD

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

27-Mar-2013

English - Or. English

DIRECTORATE FOR EDUCATION

EDU/WKP(2013)4
Unclassified

LEARNING FROM INTERNATIONAL EXPERIENCES WITH INTERACTIVE WHITEBOARDS: THE ROLE OF PROFESSIONAL DEVELOPMENT IN INTEGRATING THE TECHNOLOGY

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This paper describes teacher strategies and experiences with interactive whiteboards (IWBs) and draws on the published research in this area to understand how a systemic approach to technology-based innovations in schools can contribute to quality education for all. It explores ways to support the cultural shift in teacher and learner roles that helps to integrate the technology effectively into classroom teaching. It begins by considering how the features of IWB technology might potentially be exploited in the primary or secondary school classroom to support subject teaching and learning. International experiences of implementing IWB programs are then described, mostly from the United Kingdom where integration efforts are the most prominent, and implications for future intervention efforts are examined. The review concludes by defining the organisational conditions for enhancing teacher commitment and thus the likelihood for successful change. In particular, the role of teacher professional development is foregrounded and characteristics of effective programmes are outlined. Some comments about the relative costs and benefits, and recommendations for policymakers, are made.

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JT03337172

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TABLE OF CONTENTS

Tables

Figures

Boxes

ABSTRACT

This paper describes teacher strategies and experiences with interactive whiteboards (IWBs) and draws on the published research in this area to understand how a systemic approach to technology-based innovations in schools can contribute to quality education for all. It explores ways to support the cultural shift in teacher and learner roles that helps to integrate the technology effectively into classroom teaching. It begins by considering how the features of IWB technology might potentially be exploited in the primary or secondary school classroom to support subject teaching and learning. International experiences of implementing IWB programs are then described, mostly from the United Kingdom where integration efforts are the most prominent, and implications for future intervention efforts are examined. The review concludes by defining the organisational conditions for enhancing teacher commitment and thus the likelihood for successful change. In particular, the role of teacher professional development is foregrounded and characteristics of effective programmes are outlined. Some comments about the relative costs and benefits, and recommendations for policymakers, are made.

RÉSUMÉ

Ce document décrit les stratégies et expériences des enseignants avec les tableaux numériques interactifs (TNI) et s'appuie sur la recherche publiée dans ce domaine pour comprendre comment une approche systémique de l'innovation fondée sur la technologie peut contribuer à une éducation de qualité pour tous. Il explore des manières de soutenir un changement culturel dans les rôles des enseignants et des élèves qui aide à intégrer la technologie de manière efficace dans l'enseignement au sein des classes. Il commence par examiner comment les spécificités de la technologie des tableaux numériques interactifs peuvent être exploitées dans les classes des écoles primaires et secondaires pour l'enseignement et l'apprentissage. Des expériences internationales de mise en œuvre de plans de TNI sont ensuite décrites, notamment au Royaume Uni où les efforts d'intégration sont les plus importants, et des implications pour des interventions similaires à venir sont examinées. L'étude conclut en définissant les conditions organisationnelles pour améliorer l'engagement des enseignants et donc la probabilité d'un changement réussi. En particulier, le rôle de la formation professionnelle est mis en avant et les caractéristiques de programmes efficaces sont soulignées. Il finit par quelques commentaires sur les coûts et bénéfices relatifs et esquisse des recommandations pour les hommes politiques.

LEARNING FROM INTERNATIONAL EXPERIENCES WITH INTERACTIVE WHITEBOARDS: THE ROLE OF PROFESSIONAL DEVELOPMENT IN INTEGRATING THE TECHNOLOGY

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Introduction

This paper describes teacher strategies and experiences with interactive whiteboards (IWBs) and draws on the published research in this area to understand how a systemic approach to technology-based innovations in schools can contribute to quality education for all. It explores ways to support the cultural shift in teacher and learner roles that helps to integrate the technology effectively into classroom teaching. It begins by considering how the features of IWB technology might potentially be exploited in the primary or secondary school classroom to support subject teaching and learning. International experiences of implementing IWB programs are then described, mostly from the United Kingdom where integration efforts are the most prominent, and implications for future intervention efforts are examined. The review concludes by defining the organisational conditions for enhancing teacher commitment and thus the likelihood for successful change. In particular, the role of teacher professional development is foregrounded and characteristics of effective programmes are outlined. Some comments about the relative costs and benefits, and recommendations for policymakers, are made.

Exploiting the interactive whiteboard to support teaching and learning

The interactive whiteboard (IWB) technology combines a large, touch-sensitive electronic board with a data projector, specialised software and a computer. The board displays the projected computer image and allows direct input via finger or stylus. Software provides a variety of functions, including those that replicate non-digital technologies such as flipcharts, dry-wipe boards, overhead projectors, slide projectors, and video players (Mercer *et al.*, 2010, p. 196). Tools provided as part of the IWB software package include those for annotating text, highlighting, drawing, hide-and-reveal, resizing and zooming.

Images from other technologies can easily be displayed on the IWB, and objects can be moved or transformed to produce enlarged and interactive images, animation and text (Northcote *et al.*, 2010). These objects can be directly manipulated by students and teachers to provide an interactive experience in lessons that is accessible to all. Transformed objects can also be stored and retrieved in future lessons to further spark discussions. These functions can help to draw attention to salient features of a representation or process, coupled with teachers or students publicly interpreting a display.

The term "interactive" has two meanings associated with the IWB: the tactile manipulation of objects and words on the board, and interactive contact with the content of the lesson, which creates a more fluid and discursive environment where students feel more comfortable and capable interacting with the lesson content (Gray, 2012). Likewise, Smith *et al.* (2005) distinguish "technical interactivity" (physical interaction with the device) from "pedagogical interactivity" (interaction between students and others in the context of classroom IWB use, that is designed to bring about learning).

IWB features perceived to support learning include immediate feedback (responding to user input contingently), dynamic representation of processes, and provisionality (the facility to change or eradicate content), access to a wide range of digital resources, visibility and multimodality. Multimodality refers to the multiple modes of representation and communication within a classroom (Kress *et al.,* 2001; Jewitt, 2006): image, gesture, gaze, interaction with objects, writing, and speech. The IWB in particular facilitates the interaction of teacher and students with a wide range of digital media resources: texts, drawings, diagrams, still photographs, multimedia presentations, animations, simulations and models of dynamic processes, interactive diagrams, maps, concept maps, databases, graphs, tables, hyperlinked web pages, audio and video files, mathematical representations, etc. Not all features are consistently supportive of learning, so care needs to be taken in managing activity at the board. Kennewell and Beauchamp (2007) point out that student inputs and real-time feedback help to reduce the fear of failure for learners, but students may also exploit these features to achieve their goals through trial and error. This avoids the cognitive effort that would be expected to result in learning. (In some contexts, trial and error is, of course, desirable.)

The IWB is considered particularly useful by teachers in supporting visualisation to assist in teaching difficult concepts or demonstrating skills – for example in using a ruler, thermometer or microscope at primary level (Somekh, Haldane *et al.,* 2007). Graphical and dynamic representations and audio or video help to make complex concepts and processes more explicit, concrete and transparent. This offers opportunities to check understanding and supply clarification. Teachers of course use traditional resources, as well as talk, gaze and gesture, alongside the IWB.

The IWB can also be effectively combined with other peripherals such as "visualisers" (also known as document cameras), where physical objects placed beneath the camera stand appear on the screen, or a standard digital camera. Such peripheral cameras can be used to display, critique or compare students' work or experimental results, or to project an image as a task stimulus. When visualisers are combined with IWBs, one can also freeze an image, then remove the object from the visualiser and manipulate it, and compare it with the original.

Table 1 provides a helpful summary of the teacher and learner actions that IWB features support or allow (these activities would not be possible with traditional blackboards). Examples of classroom activities are given alongside each action.

Many of the examples of classroom activities imply learners' rather than only teachers' use of the IWB. To fully exploit the possibilities of IWBs, Essig (2011) therefore argues that new and more creative classroom activities need to be designed so that the majority of children can have an opportunity within the same lesson. Adolescents may, however, be quite self-conscious and hence reluctant to come to the board. To overcome this reluctance, IWBs can be combined with handheld computers (tablets) or remote pointers (clickers, wireless mice): this reduces exposure of students, releases the teacher from the front of the room, and saves time spent on students moving to the front. Students' use of such remote input devices to interact with IWB content can extend the action around the classroom and add new strategies to engage everyone in learning activities. It can also create more space for learner involvement in the creation of lesson content.

We have presented an overview of some ways in which teachers and learners might exploit the interactive features of the IWB. Some of these uses can potentially be combined with a "dialogic" pedagogy that is known to promote learning in classroom contexts both with and without technology. Box 1 summarises the key principles of this promising approach and considers how the interactivity of the IWB might be more fully exploited.

Table 1. Possible actions with IWBs and examples of use in classroom activities

Action	Meaning	Example of classroom activity with IWB
Composing	Ideas can be recorded accurately as they arise.	Students brainstorm on IWB
Editing	Data or text stored and displayed can be changed easily with no trace of the original	Class collectively edit report of a science experiment after whole-class discussion of outcomes
Selecting	Choice of resource or procedure can be made from a list	Students select the appropriate words from a list of vocabulary in a language exercise
Comparing	Features of same object from different views or different items displayed can be compared	Teacher displays pictures of flower taken from different angles or different flowers looking for common features
Retrieving	Stored resources can easily be retrieved for use	Teacher retrieves examples of same work from different classes or students retrieve files to complete work or demonstrate to peers
Apprehending	The display (text, images, sound, diagrams) is easy for students to see or interpret	An image can be added to illustrate the meaning of an unfamiliar word
Focusing	Attention can be drawn to particular aspects of a process or representation	Teacher uses highlighter, or "reveal" tool to focus attention on component part before revealing its place in the whole object or uses zoom/magnify to look closer at a seed to identify how it becomes attached to an animal for dispersal
Transforming	The way that the data is displayed can be changed	Students and/or teacher enter data in a spreadsheet and view in different graph formats to discuss which is most appropriate for task
Role Playing	Activities can be carried out in a way which is similar to activity in the "real world"	Students use a simulation on the IWB to conduct a virtual scientific experiment
Collating	The facility to bring together a variety of items from different sources into a single resource	Students collect data around the school grounds and load into graphing or database project for whole class
Sharing	The facility to communicate and interchange resources and ideas easily with others	Teacher retrieves PowerPoint presentations compiled by colleagues from school network
Annotating	Notes can be added to a process or representation at the time of use	Teacher annotates a poem with student's interpretations or students predict the direction and shape of a graph and draw on the IWB for class discussion
Repeating	An automated or stored process can be repeated at will	Students can replay an animation of the flow of blood through a heart when writing an explanation of it
Simulating	A process can be simulated by representing relationships between variables	Students enter different food quantities into spreadsheet and watch effect on graphs representing high energy foods, food for growth and so on
Cumulating	Building up a representation of knowledge in a progressive manner	Students compile a group presentation (using a variety of media) over the course of a term/topic before presenting to peers
Revisiting	Repeating an activity or returning with a different focus	A list of ideas generated by the class at the start of the lesson is reviewed following an Internet search and discussion
Undoing	Reversing an action	A tentative idea or solution to a problem is removed without trace
Questioning	Piece of dialogue requiring a response	"Can you find two numbers which add up to 7?"
Prompting	Action or piece of dialogue which suggests what someone should do	"Try to find another word which means the same thing there"
Responding	Action which is contingent on a previous question/prompt	Change "big" to "enormous" when prompted

Source: Adapted from Kennewell and Beauchamp (2007, p. 232-233)

Box 1. A dialogic pedagogy for using the IWB more effectively

Recent case studies by Hennessy and her colleagues show how the interactive whiteboard can be used to support classroom dialogue (Hennessy, 2011; Mercer *et al.*, 2010; *http://dialogueiwb.educ.cam.ac.uk/).*

Dialogue is more than just "talk", it is shared enquiry that bridges the gap between two or more perspectives (Bakhtin 1986; Wegerif 2007). Dialogic classroom interaction is an evolving and increasingly recognised pedagogical approach in which teachers and learners actively comment and build on each other's ideas, pose open-ended questions, and jointly construct new knowledge (Mortimer and Scott, 2003; Mercer and Littleton, 2007). Importantly, dialogue is cumulative and responsive to the previous person's contribution. It involves chained sequences of questioning and responding and chained lines of thinking and enquiry (Bakhtin, 1986; Alexander, 2008). Dialogic pedagogies have benefits for individuals' subject learning and for the development of language, reasoning and collaborative inquiry skills (Knight, in press; Mercer *et al.,* 2004; Mercer and Sams, 2006; Wegerif *et al.*, 1999; Rojas-Drummond *et al.*, 2010; Wegerif *et al.*, 2004).

The IWB is particularly well-suited for supporting a dialogic pedagogy because it expands the possible modes of classroom dialogue beyond talk and gesture. New dialogues can evolve around digital artefacts: images, texts, and other digital objects that teachers and learners iteratively manipulate and develop through collective scrutiny and collaborative activity.

In a dialogic classroom, learners reflect on their own explanations and others' critical perspectives. The IWB facilitates this process because it helps learners to create and share concrete representations of ideas and to receive feedback. Different ideas can more easily be juxtaposed, explored, connected and compared, highlighting strengths and weaknesses. Digital artefacts make words and ideas available for manipulation – as 'improvable objects' (Wells, 1999). Interacting with these provisional knowledge objects helps both to highlight differences between perspectives and to continue dialogues over time. By making both learning histories and trajectories more visible, including tracking them over time, digital artefacts can help dialogue to progress cumulatively.

While most of the research on IWB use focuses on whole class teaching, work by Warwick *et al.* (2010) has shown that the IWB has certain features and perceived benefits of those features that make it a suitable tool for use in group work activities where the teacher is not physically present, but s/he prepares the task structure beforehand. This can provide a highly productive environment for dialogic group activity and interaction.

The IWB also has the potential to assist with specialist teaching of children who are dyslexic or have severe difficulties with basic number work. A small, yet significant body of work by Somekh, Haldane *et al.* (2007) provides evidence that the IWB is a very useful tool in the hands of an experienced teacher or properly trained teaching assistant working with a small group. Moreover, the tools can potentially be used to improve the functional capabilities of children with disabilities (Basilicato, 2005).

The potential of the IWB as a powerful learning tool is beginning to become apparent. We now turn to examining the nature and extent of its integration in classroom teaching around the world.

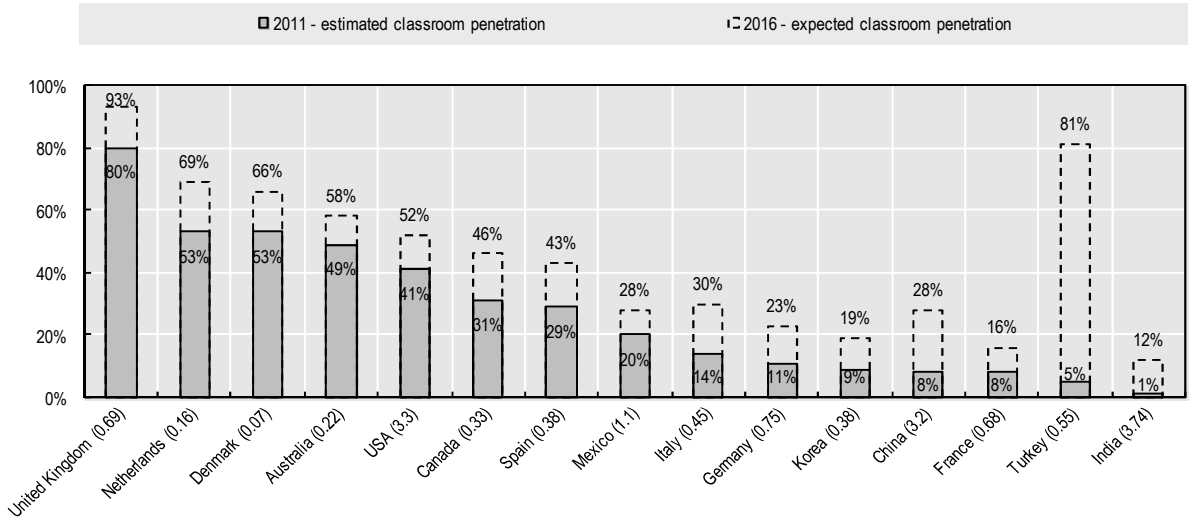
Policy initiatives in the United Kingdom and the spread of IWBs worldwide

The decision to introduce interactive whiteboards (IWBs) in the United Kingdom, the country with the highest penetration of IWBs worldwide, was based on an intention to improve student literacy and numeracy, targeting mainly primary schools, through interactive whole class teaching (Higgins *et al.* 2005). Policy required what the technology seemed to offer – a visual tool for supporting well-paced "interactive whole class teaching", and one that was cheaper than a class set of computers. Initial government-sponsored programmes involved parallel large-scale rollouts during 2003-04 in London secondary schools (Schools Whiteboard Expansion or SWE), and in 2004-05 in primary schools across the country (Schools Whiteboard Expansion Evaluation Project or SWEEP).

A further parallel programme, "ICT Test Bed", invested a total of GBP 34 million (EUR 50.6 million) over 4 years (2002-06) in 28 British schools and three further education colleges across three geographical regions. This initiative provided access to very high levels of hardware and appropriate software, and offered a model that other countries may want to consider. Test Bed schools procured laptops for every teacher and appropriate presentation technology such as interactive whiteboards and projectors in all teaching areas. The funding covered staffing release and training support. The schools were supported in developing a bespoke continuous professional development plan including strategic leadership in ICT use and integration of ICT resources into curriculum delivery. This plan derived from an analysis of existing staff skills. The project provided dedicated support to assist with change management, plus advice to Test Bed Schools on how they could ensure the long-term sustainability of the benefits derived from the project once direct project funding had ceased. Significant changes in performance on national tests were measured against matched comparator schools and national averages. (The independent evaluation of Test Bed by Somekh, Underwood *et al.,* 2007, offers more detail.)

Mexico initiated an IWB expansion scheme in 2004, shortly after the first initiatives in the United Kingdom. IWBs were installed in fifth and sixth grade classrooms and in initial and continuing teacher education institutes, as part of a MXN 20 billion (Mexican pesos; EUR 1.43 billion) Ministry of Education IT infrastructure scheme, *Enciclomedia*. The scheme included teacher training and educational support, equipment, evaluation and monitoring. The associated software comprises a database with digital resources (video, text, virtual visits, audio and images) corresponding to the curricular contents of the official textbooks used in primary schools.

Figure 1. Classroom penetration of IWBs across the world



Source: Futuresource consulting (2012). The total number of classrooms (teaching spaces) in each country is given in parentheses.

Today, The IWB is an increasingly popular educational technology globally; according to the market research company Futuresource Consulting (2012), one in eight classrooms (34 million teaching spaces) across the world now have an IWB and by 2015, one in five will have one. It is found in 80% of British classrooms. Figure 1 indicates that its prevalence is rapidly increasing in a number of other countries too, notably Netherlands, Denmark, Australia and the United States. The graph also highlights where further rapid growth is expected in the next few years. Turkey is expected to have the most rapid growth: the 5-year FATİH project, launched in 2012, will equip 620 000 classrooms in Turkey with IWBs and will provide tablet PCs to all teachers and students (*http://fatihprojesi.meb.gov.tr*).

Unlike many preceding forms of educational technology sponsored by the government (some of which still remains in boxes in school cupboards), uptake of IWBs by classroom teachers in England at least has actually been very high.

Several reasons can explain its rapid adoption by English teachers. First, in many contexts the old dry-wipe whiteboards were ripped out to force teachers to use the new ones. Teachers consequently were forced to learn basic skills in how to use the boards exceptionally quickly, often pooling knowledge and providing mutual self-help. Somekh, Haldane *et al.* (2007) point out that learning together when there is a pressing "need to know" is a powerful strategy for creating a sense of urgency and encouraging teachers to learn together. Second, teachers perceive the IWB as a tool in line with popular views of effective whole class teaching practice. Third, the IWB is billed as a tool that allows different types of learners ("visual" and "kinaesthetic" in particular) to access lesson content; despite lack of evidence for its validity, this perspective had a major impact on IWB popularity and uptake (Franklin, 2006). Lastly, IWBs can accommodate many different teaching styles and activities, including non-interactive pedagogies. Compared to other technologies, it is not disruptive and can replicate all the features of the traditional, dry-wipe board; it can be placed in an otherwise traditional classroom. Indeed, a key reason for the astonishingly rapid uptake in the United Kingdom was rather cynically expressed by Gray (2010, p. 80): "It is no coincidence that the most popular technological application so far in schools is one which meets many teachers' desire for control over content, learning and behavior rather than one which promotes independent learning."

While the evidence on the impact of IWB programmes is now accumulating, as we shall see in subsequent sections, it is extraordinary, but not uncommon in the context of technology, that the demand for such evidence has followed rather than driven the scale-up phase – in the United Kingdom as well as in many other countries. Governments often do not seem to learn the lessons of their predecessors and global neighbours where technology is concerned. There is a common but unfounded assumption that educational "innovation" (whether technology-based or not) is a positive step forward, but not all new ideas work well in practice of course. Summarising the lessons learned from a 2009 OECD meeting in Brazil that considered a range of recent technology innovations, Johannessen and Pedró (OECD 2010, p. 147) concluded: "Technology-based school innovations are rarely the result of an embodied set of knowledge or empirical evidence accumulated over the years, knowledge or evidence from which stakeholders nourish their decisions and to which they contribute with their feedback."

The IWB rollout is one more such innovation. The authors suggest that in reality "the availability and, in some cases, even the fascination for technology is the main driver behind innovations in this area. The link between technology and pedagogy is too weak or in the worst case non-existent" (*ibid.,* p. 144). Indeed, as new IWB features, new technologies, and richer forms of interaction emerge, these attract attention from researchers and educators and the education technology sector. For example, smart tables – horizontal multi-touch boards – and other technologies are now more affordable and available to support collaborative learning within and between groups (Higgins, Mercier, Burd & Hatch, 2011). Group members are able to work simultaneously on such a table device and the focus of attention can be shifted away from the front of the classroom. Teachers can also centrally manage student tables and project them onto the vertical IWB. As always, however, educators must harness these new tools mindfully and purposefully as they can also be used mundanely.

Lessons learned from implementing large-scale IWB programmes

The research into integration of IWBs was carried out predominantly in England, and other countries then endeavoured to learn from the English experiences.

In this section, we first review the results of past IWB expansion plans and show that the debate is still open about the effect of IWBs on teaching and learning. Reaching a consensus about the "impact" of many new educational technologies has proved notoriously difficult and is actually considered unrealistic by many researchers in the field. The impact of educational technology depends on teachers' uses of the technology, which depend in turn on their understanding of the pedagogic purpose. Research has consistently shown that the IWB, like the myriad of preceding forms of educational technology, itself has no agency or transformative power over pedagogy: therefore, understanding the benefits within particular contexts and for particular educational purposes is essential to focus any evaluation.

We argue nevertheless that the rapid adoption of IWBs fundamentally changed stakeholders' perceptions of the place of technology in schools. Indeed, the thrust of interest that this diffusion created helped catapult it to the top of the pile of educational technologies (Gray, 2012). We assert that this in turn helped to bring far more technology into the classroom where it could be used flexibly and at any time in conjunction with other classroom resources, and thus away from confinement to centrally located computer labs.

We then present the recommendations for school organisation and for the design of teachers' professional development that emerge from these evaluations, as well as more generally from research on the effective integration of IWB in teaching and learning.

Impact of IWBs on pupil outcomes and classroom pedagogies

English schools began using IWBs without being able to rely on established and detailed professional knowledge about what the technology's role in enhancing pedagogy might really be. There was little available research evidence to define what might constitute effective practices. The Department for Education and Skills therefore commissioned two evaluations of the initial government-sponsored plans for IWB expansion: SWE, for London secondary schools, was evaluated by Moss *et al*. (2007); SWEEP, involving primary school nationwide, by Somekh, Haldane *et al.* (2007).

The main interest of policymakers in England and elsewhere has been in tracking whether or not the IWB expansion plans had a positive effect on standards of student achievement through their impact on teachers' pedagogy and use of ICT. Although there have been a number of studies evaluating the rollout of IWB use in teaching and learning and its systemic impact internationally, to date the investment in this research and evaluation remains small in comparison to the enormous investments made in the equipment itself.

Some key conclusions emerge from these evaluation efforts.

First, IWBs as such have no transformative power on pedagogy. Teachers' diverse beliefs about pedagogy and student learning, their preferred uses of conventional boards, their goals and their prior experiences, shape the way in which they use all educational tools, including the IWB. New approaches can be developed if supported by adequate investments in professional development, but not imposed.

Second, professional learning about IWBs and their effective use takes time. Pedagogical change only comes with significant investment in professional development and is generally only observed after at least one year of full-time use by teachers.

Third, because their impact on pupils is mediated by their use by teachers, there are no robust, clear-cut positive effects on pupil learning associated with IWBs as such: the context and the nature of use of IWBs are all-important. Nevertheless, effects on learner achievement attributed to IWBs are generally more positive than for all other forms of technology.

Lastly, IWBs have been a major factor in accelerating teachers' use of technology and web resources.

The impact of IWB introduction on classroom pedagogies

Interactive whiteboards have generally been introduced with an explicit aim of encouraging more "interactive" classroom teaching. What are the ascertained impacts of interactive whiteboards on teachers' pedagogies?

Research in general has disputed the claim that IWBs fundamentally change teachers' pedagogies. Higgins *et al.* (2005) carried out a longitudinal study of the use of the IWBs in the early programme in the United Kingdom. 184 lessons were observed in primary schools in 6 geographical regions over 2 years, comparing teaching with and without an IWB. The outcomes were mixed. Lessons which used IWBs had faster pace and less time was spent on group work, reflecting the intended increased focus on whole class teaching (Smith, Hardman and Higgins, 2006). Worryingly, fewer uptake questions (feedback which goes beyond evaluation of a student's answer and makes connections with other contributions during the lesson topic) and extended answers were observed; answers during IWB lessons were frequent, but brief. However, in those lessons that used an IWB there were significantly more open questions, repeat questions, probes, evaluation, answers from students, and general talk. The research team concluded that "while our findings support some of the claims being made for IWBs, they do not suggest a fundamental change in teachers' underlying pedagogy" (*ibid.,* p. 254). Likewise, according to Gray (2010), teachers (foreign language teachers, at least) have resisted the discourse of "transformation towards constructivist practices" and appropriated the IWB to serve their own needs.

In practice, the impact on teaching varies depending on their pre-existing beliefs, goals, and experiences of teachers. Indeed, in contrast to the constructivist discourse that usually motivates their introduction, the technology can also reinforce a transmission style of whole class teaching in which the contents of the board multiply and go faster, whilst students are increasingly reduced to a largely spectator role. The evaluation of SWE (the IWB expansion plan in London secondary schools) similarly concluded that successful exploitation of IWBs in secondary schools depended on a clear understanding of the pedagogic purpose of their introduction. A focus on technical interactivity led to some mundane activities being over-valued, especially in classes with lower ability students, where it could actually slow the pace of whole class learning as individual students took turns at the board (Moss *et al.* 2007).

Research on implementations in other countries confirms that in practice, teacher responses to the arrival of an IWB vary; no simplistic messages emerge. Cutrim-Schmid and Whyte (2010) examined the integration of IWB technology by non-native speaking teachers of English as a foreign language in state secondary and vocational schools in France and Germany. (Teacher uptake and technology training are low in France and Germany compared with other countries, such as the United States, the United Kingdom, Australia and Mexico). Findings from their 3-year longitudinal study suggested that in spite of communicatively oriented, socio-constructivist training, teachers used IWB technology to implement a variety of different pedagogical approaches. These were shaped by multiple factors, such as teachers' teaching and learning experience, pedagogical beliefs, institutional demands, and alignment with their curricular and personal goals. The research suggested that with appropriate training, feedback and time for development, teachers can acquire the knowledge, skills and resources to respond positively to the socio-constructivist computer-assisted language learning approach, which the authors identify as the current best model for language teaching with technology. But it was clear that changes in pedagogical practice cannot be imposed from above, via isolated training sessions and in the absence of ongoing support in the classroom.

Fernández-Cárdenas and Silveyra-De La Garza (2010) examined Mexico's implementation of IWBs in more than 170 000 primary classrooms. The researchers videoed and compared practice with IWBs and traditional boards and solicited teacher perspectives. Their findings show that the way a teacher uses conventional dry-wipe whiteboards has a direct impact on the way s/he uses the IWB; for instance, similarities were observed in proportions of time on individual, small group and whole class activity, in pedagogic beliefs, and in the perceived importance of learners interacting directly with the board (Fernández-Cárdenas and Silveyra-De La Garza, 2010, p. 177). Pedagogic ideologies remained static between IWB and non-IWB contexts despite the change of artefacts, although those ideologies themselves varied between individuals.

Slow-burner development of IWB proficiency

Professional learning about IWBs requires time. Teachers must become confident users of the technology and must adapt their practice to integrate its use.

In the already mentioned study by Higgins *et al.* (2005), most of the differences in the frequency of various classroom activities were only observed after the IWBs had been in use for over a year – an embedding effect. Somekh, Haldane *et al.* (2007) observed during SWEEP that it took about two years before teachers felt truly comfortable and proficient enough to use the IWB interactively and for its use to become embedded in their pedagogy as a means of supporting their interactions with learners, and learners' interactions with one another.

The more powerful and functionally complex a technological tool, the longer it will take teachers to learn how to use it effectively and how to develop and refine their pedagogic approaches in relation to the tool (Wright, 2010). IWBs are deceptively complex and to fully utilise the interactive aspects of the technology, teachers must invest time to build confidence, design resources, adapt practices and learn to harness their power. For example, Gillen *et al.* (2007, p. 254) concluded that the effective use of IWBs involves striking a balance between providing a clear structure for a well-resourced lesson and retaining the capacity for more spontaneous adaptation of the lesson as it proceeds. Teachers need time to develop the knowledge to exploit technology in ways that effectively enhance student learning in their specific contexts (*e.g.* Cutrim-Schmid and Whyte, 2010).

Some research has characterised a number of "stages" that teachers progress through in accommodating the IWB in their classrooms, with increasing pedagogical interactivity (*e.g.* Haldane, 2010). Moss *et al.* (2007) suggest that there is "a continuum in which new technologies initially support, then extend and finally transform pedagogy as teachers gradually find out what the technology can do" (p. 6).

Teachers need time to become confident users of new tools; teachers in addition need targeted support to adapt their pedagogy to integrate the potential of new technology. Recent research by Hennessy and Warwick (2010, p. 127) indicates that teachers take the initiative to develop their ICT proficiency to support and enhance their established interactive pedagogies; in contrast, it is unrealistic to expect the technology to drive teachers to new forms of pedagogy. The reason for this asymmetry is that IWB tools are designed to make it simple for teachers to create interactive multimedia teaching materials. Ease of achieving "technical interactivity" using the IWB encourages dialogically oriented teachers to extend opportunities for dialogue.

Fancy use is not a prerequisite, however, and can even be a distraction. "We all know how easy it is to get swept along by new technology, but as professionals we need to remember that we are simply using it to assist in providing quality teaching. We must stay focused." (Betcher and Lee, 2009, p. 135).

The effect of IWBs on student outcomes

In the years preceding the major IWB expansion plans, government-funded research in England led to the assertion that school standards are positively associated with the quantity and quality of school ICT resources and the quality of their use in teaching and learning, regardless of socioeconomic characteristics (Pittard *et al.*, 2003). However, effects are notoriously inconsistent across technologies, subjects and phases, with greater impact often documented at primary level in England where ICT is more regularly used for teaching purposes (Machin, McNally and Silva, 2007).

In interpreting these results about educational technology in general, caution is needed since most of the available data demonstrate statistical association, but cannot prove causality, and generalisations are often unfounded. Moreover, much of the evidence base derives from small-scale studies and is limited, fragmented and unsystematic according to the landmark review of the literature by Condie *et al.* (2007).

What impacts on student learning outcomes, then, can be attributed to the introduction of IWBs in particular?

Given the stark differences in the uses of IWBs across teachers, any effect on pupils' learning outcomes is likely to be highly contingent on the wider pedagogical and socio-cultural setting. Moreover, the time it takes for teachers to develop IWB proficiency reduces the ability to draw general conclusions from pilot phases. Accordingly, Thomas and Cutrim-Schmid (2010, pp. 20-23) introduce their edited collection of work on IWBs by asserting that "impact" depends crucially on how the technology is used and not on its mere absence or presence in the classroom. We need to understand the benefits within particular modes of teaching, for particular student groups, within particular social, cultural and political contexts, and for particular educational purposes.

Nevertheless, the few studies looking at IWBs in particular almost unanimously report increased student motivation (Somekh, Haldane *et al.,* 2007). Regarding achievement, in the literature review by Condie *et al.* (2007), effects attributed to IWBs are reportedly greater than those for all other forms of technology: "The outcomes are almost universally positive, particularly where [IWBs] are used in conjunction with other technologies and there are clear pedagogical reasons for their use. Display and presentational software, including animations and simulations, combined with IWBs, help pupils to develop an understanding of abstract concepts through concrete examples and graphical images of, for example, microscopic processes." (Condie *et al*., 2007, p. 5). Somekh, Haldane *et al.* (2007) observed during SWEEP that a positive impact on attainment emerged when students were taught with an IWB for at least two years, particularly for those with average or high prior achievement. This time lag most likely reflects the learning curve of teachers in using the IWBs effectively.

The impact of IWBs on teachers' use of technology and web resources

Although their direct effects on teaching and on learning remain open to debate, we argue that IWB expansion plans changed teachers' and other stakeholders' dispositions towards technology more than any other ICT initiative before.

The key difference between the IWB and a set of desktop computers is that the IWB allows technology to be used flexibly, and it brings technology firmly into the classroom and away from confinement to now-outdated computer labs. Lee (in press) observed from experiences in Australia that while the IWB does not change the nature of teachers' pedagogy, it draws the vast majority of teachers into the digital world in a way that desktop computers never could. Lee (in press) argues therefore that the real impact of IWB use is that it moves teachers from their traditional paper-based *modus operandi* with its constancy and continuity to teaching that is primarily digitally based and characterised by constant

evolution. Somekh, Haldane *et al*. (2007) corroborated this assertion through their observation of greatly increased "live" use of the Internet during SWEEP.

Such impacts on teachers' dispositions towards technology need not be limited to the classrooms equipped with IWBs and may only appear with a lag; as such, they are more difficult to attribute with certainty to IWBs. Nevertheless, a positive disposition among teachers towards the use of technology and of web resources to support their professionalism could lead in the long run to significant benefits for the quality of teaching.

In sum, the impacts of IWBs on classroom activities and on students' learning depend strongly on the pedagogical culture in which they are deployed and on a set of complementary investments that facilitate their integration in existing contexts. While IWBs can be used to support a variety of teaching styles, they have been found to trigger little resistance from teachers and, on the contrary, to draw them over time to increase the use of technology and of web resources in and out of class. This in turn helps teachers document, share, and easily locate best practices, thus brokering decentralised collaboration and catalysing continuous improvement.

Organisational conditions for successful integration of IWBs in schools

The research summarised above has shown that IWB expansion plans have not always had the expected result of promoting the use of interactive pedagogies. What can be learned from the success and challenges of past plans?

The conditions that enable the successful adoption of IWBs span a wide range, from the simple availability of equipment and connectivity, to technical and pedagogical support for teachers, as well as the production and distribution of digital learning materials. In this section we summarise the organisational conditions that support teachers in developing both technical and pedagogical proficiency in using IWBs and are therefore associated with higher impacts of IWB introduction.

Teachers' proficient use of IWBs positively depends on the informal opportunities for practice and exchange that the school offers: this requires regular and uniform access to technology for all teachers in a school. Teachers' effective use of IWBs also depends on the availability of digital resources that support the school curriculum. Finally, teachers' ability to involve all students in classroom dialogue may be limited by the traditional organisation of subject lessons in short units: more flexible time arrangements provide greater room for interactive teaching.

Regular and uniform access to technology

Personal access to PCs or laptops has a major impact on teachers' roles and those of support staff, giving flexibility and choice with regard to the location of work and increasing confidence with technology, according to Somekh, Underwood *et al.* (2007). This is corroborated by Betcher and Lee (2009) who argue that every teacher needs a laptop of their choosing. This need was never considered in the Australian programme, but it needs to be met if teachers are to use digital tools in their classrooms.

Moreover, priority should be given to installing IWBs in *all* classrooms in a school as this ensures continuity for students as they move through the school, and enables teachers to learn together (Somekh, Underwood *et al.,* 2007). A culture of sharing and mutual support develops as the whole staff faces the task of embedding the technology into their pedagogy. Collective need leads to collective solutions being found and shared, and thus to change embedded in practice.

Access to quality digital resources

Availability of digital resources can be a supportive or constraining factor in using the technology interactively in lessons. In Ireland, where prevalence of IWBs is relatively low, a study by Hallinan (2009) found that teachers given an IWB did integrate ICT use, but the lack of training and digital resources available proved a significant drawback. The report concluded that there were not enough interactive resources that support the curriculum, and a transmission approach to learning resulted.

Schools need to build sustainability – of both resources and pedagogic change – into their change management strategies from the start. For example, shared server areas and virtual learning environments make it easier for teachers to find, store, share, create and reuse resources and lesson plans. This ensures long-term value from the initial high investment by the workforce and makes it easier to induct new teachers into the school ethos. It also provides greater consistency for the learners, though it brings with it new tasks for organising and maintaining resources. Schools can even join with others locally to create resources.

Flexible school timetables

Timetabling is an issue, especially at secondary school level where in many countries subject lessons are constrained by a rigid structure of 50-minute chunks. Thus work that really requires continuous engagement over several hours has to be fragmented (Pearson and Somekh, 2006). In the Test Bed programme, impact of ICT use on attainment levels was greater for primary schools than secondary schools (Somekh, Underwood *et al.*, 2007): one possible explanation lies in the greater flexibility offered by a single teacher in a class to incorporate the use of ICT into extended sequences.

The benefits of introducing more flexible timetables are illustrated by one of our case study schools in Cambridge. Recently, this school doubled the length of its lessons; with a significant effect on teachers' ability to support learning through extended classroom dialogue. According to the Deputy Head, Lloyd Brown, "With many lessons now 100 minutes not 50 and no bells half way through, there are opportunities for teachers to develop more in-depth, investigative student-centred work [across all subjects]. This [work] seems to be emerging more quickly than the leadership team envisaged."

Characteristics of successful approaches to professional development

Conducive organisational conditions are a necessary but insufficient prerequisite for teacher adoption of IWBs. Of paramount importance is a programme of well-structured, well-coordinated and sustained professional development to support the process of integrating IWBs into the classroom; a consideration of the developing proficiencies, confidence and views of teachers is central in embedding the use of IWBs (Hennessy and Warwick, 2010, p. 128).

Yet, the experience of many contries shows that the adoption of IWBs in many schools has outpaced the delivery of professional development of adequate quality and length. As a consequence of patchy professional development provision, IWBs remain a poorly or under-utilised resource in many classrooms today, in England and elsewhere (DeSantis, 2012).

There is often lack of both clarity about responsibilities and planning for training. In the case of the SWE programme, for instance, an ongoing and pedagogically-oriented programme was not included in the design. The funding stream did not include money for training: Moss *et al.* (2007, p. 55) report that operational training was assumed to be available from suppliers, whilst pedagogical training was initially expected to be provided either by ICT coordinators or by software suppliers (Becta, 2004). Education authority consultants were intended to contribute to pedagogical support, but no monies were committed to this end. It was anticipated that funding to pay for the necessary support would be available at school level

as part of existing budgets for in-service training. It was apparently always clear that the introduction of IWBs would generate training needs, but there was uncertainty about exactly how the costs would be met, within what timescale, and who was best placed to offer what kind of support. The lesson is that clarity is needed about who should take the lead on which aspects of policy development and meet its associated costs, and that action needs to be aligned across stakeholders.

The importance of well-designed professional development in supporting pedagogical change is developed further in this section and forms the key thrust of this paper. After reviewing the effectiveness of professional development components in past IWB expansion plans, we examine the extensive literature on teachers' professional learning in technology-enhanced and other contexts to propose an optimal approach to support IWB integration.

The effectiveness of professional development in the English IWB expansion plans

Although the ultimate objective of investing in teachers' professional development is to benefit students' learning outcomes, it is always difficult to measure improvements in learning outcomes and to attribute them to a single cause. To assess the effectiveness of professional development, it is therefore equally important to gather information on all the intermediate levels of impact through which effects work. A useful framework for assessing the effect of teacher professional development distinguishes five critical levels of impact (Guskey, 2002): (1) participants' reactions, (2) participants' learning, (3) organisational support and change, (4) participants' use of new knowledge and skills, and (5) students' learning outcomes. Guskey (2002) cautioned that "[w]ith each succeeding level, the process of gathering evaluation information gets a bit more complex. And because each level builds on those that come before, success at one level is usually necessary for success at higher levels" (p. 46).

The nature of professional development activities matters more than the amount of time and money invested in it. Research on professional development consistently indicates that the effectiveness of professional development efforts is strongly dependent on its nature and format: a synthesis across the literature on professional development concluded that much investment in teacher professional development has no effect on valued student outcomes and some actually has negative effects (Timperley and Alton-Lee, 2008).

Although there is no systematic analysis of the effectiveness of professional development to support IWB integration, the literature on IWB integration initiatives identifies some pitfalls and promising approaches among the professional development components of past IWB expansion plans. Most of the time, the evidence refers to teacher-level outcomes only, because pupil-level outcomes were affected simultaneously by many concurring changes.

A first message from the literature is that pedagogical change requires pedagogically oriented professional development – of a kind that prepares teachers to exploit the IWB in ways that are consistent with current models of teaching for each subject (Cutrim-Schmid, 2010, p. 170). A major shortcoming identified in the longitudinal study by Higgins *et al.* (2005) was that many of the schools involved failed to focus the teacher training on improving literacy and numeracy; instead, the focus was on how to use the IWB technology. The typical introduction that teachers receive – in all countries – is a short one delivered by the company supplying the IWB. It often focuses purely on the technical features of the equipment. Research indicates that this type of training is woefully inadequate to help teachers make the best use of IWBs. Haldane (2010) examined how teachers acquire proficiency in the use of IWBs for the enhancement of whole-class teaching and concluded that they are unlikely to make optimal use of the affordances of the technology through preparatory training alone; such an expectation could adversely affect the chances of successful implementation. In contrast, the evaluation of the secondary whiteboard expansion (SWE) in London (Moss *et al.* 2007) showed that three-quarters of all teachers found subject departmental training in

IWBs to be useful. This has the advantage of being directed to very specific areas of the curriculum, with a body of teachers agreeing where an IWB resource should be integrated into existing working patterns, and thus effectively doing so.

The format of professional development also makes a difference. A clear message deriving from the key IWB initiatives in the United Kingdom is that in-school professional development sessions led by colleagues are more effective than other approaches, and teachers prefer them.

The evaluation of SWE (Moss *et al.* 2007) found that the preferred source of learning for most teachers (83%) was informal day-to-day assistance in using IWBs. Moss *et al.* (2007, p. 139-140) concluded that teachers' preference is for training on a "need to know" basis that can accommodate to their existing working patterns.

The evaluation of the Test Bed initiative (Somekh, Underwood *et al.*, 2007) identified the most effective forms of professional development not only in terms of teachers' preferences, but also in terms of their impact on teachers' ICT skills and on the use of ICT during teaching activities. In Test Bed schools, external trainers were used for specific events, but as teachers became more proficient, they supported and sustained activity undertaken by their colleagues. In primary schools, ICT coordinators used their increased non-teaching time to work with colleagues; in secondary schools, specialist ICT teachers, advanced skills teachers[1] or other teachers, technicians and content developers designed and delivered specific training for colleagues. The evaluation of the Test Bed initiative found that the most effective forms of professional development were often informal, involving teamwork and mutual support. Training became more effective when staff could see what colleagues were doing, take part in more informal team learning, pick up tips and new techniques, and practice with the equipment on their own. In primary schools, action research supported professional development and pedagogical change. The development of "champions" with expertise in using particular equipment was valuable – both in primary schools and within secondary departments – in providing support at the point of need. This was particularly effective when the role of "champion" was spread among colleagues and not focused on a single school/department expert.

The indications that emerge from IWB initiatives on this point are in line with the richer conclusions from a rigorous evaluation of the national initiative to train all school teachers in England to use ICT in teaching carried out in 2004 (Davis *et al.,* 2009a; 2009b). Among the approaches proposed by the various providers, centralised skills-focused approaches, especially those with online access to trainers, were found largely ineffective. In contrast, the most successful professional development model against Guskey's criteria proved to be an "organic" approach that provided school-based training designed to support evolution of each teacher's classroom, school and region. In addition to face-to-face training and case studies of good practice, groups worked on classroom assignments that made specific links to participants' professional practice. Teachers set personal objectives and there was also a collective needs analysis for each training group.

Trainers themselves need to be part of a wider community of practice in order for professional development to be effective: The simple strategy of sequentially "training the trainers" centrally so they may cascade workshops to others in their locality was not recommended by Davis *et al.* (2009a, 2009b).

A proposed approach to professional development in support of pedagogical change

A school-based, active learning model, combining formal and informal learning opportunities, emerges as the most effective approach from the limited literature on the professional development components of large-scale initiatives for ICT integration. These indications can be developed into recommendations by considering the larger practical and theoretical literature about professional development for pedagogical change.

In this section, we expose the central tenets of the professional development approach developed by Hennessy and colleagues through collaboration with practitioners in a series of research studies over the last decade. The approach involves sustained, planned and purposeful opportunities for teacher learning and reflective practice sits at the core. This collaborative inquiry approach has inspired in particular the development of resources for supporting IWB use (as described in Box 2).

The six principles can be summarised as follows:

1. Professional development is school-based, and includes action research led by practitioners.

2. The focus and course of action is initiated and driven by teachers' needs and beliefs.

3. Professional development is a team inquiry process proceeding in cycles of reflection and trialling.

4. The inquiry is focused on supporting student learning.

5. Professional development activities are embedded in the teachers' normal work organisation.

6. School leaders and administrators actively support the process.

Each principle is explained below, and illustrated with suggestions relating to programmes supporting ICT integration.

First, professional development is school-based, and includes action research led by practitioners.

School-based professional development implies that the professional development activity is situated within an established and supportive community of practice. The issues that its members choose to explore and the actions and theories-in-use that they implement are contextualised through their situation within a localised school and/or departmental learning community (Retallick, 1999).

In the proposed approach for ICT integration, teachers receive support or mentoring mainly from more expert colleagues ("champions"). The teachers collaborate as equals, act as peer mentors, work in small groups and observe each other in order to develop and evaluate new ideas. Thus, teachers themselves lead professional development and share responsibility for embedding improved practices in their schools (Frost 2012).

The professional development may also include support – at least initially – from an external facilitator who can expose teachers to new pedagogical approaches and can familiarise them with the full range of IWB features (Moss *et al.* 2007). New practices however should never be prescribed or imposed on a passive audience, as in the traditional meaning of "training", but negotiated and developed with the active engagement of teachers, who bring their own experiences, outlooks, expertise and contexts to bear in that process of professional learning.

Although we emphasise the importance of the school as a community of practice, wider communities of practice may play a role too, particularly for internal and external trainers, champions, and mentors (as the Test Bed 'cluster' approach linking local schools showed). Their network extends beyond the single school, brokered through online exchanges. Personal Learning Networks (PLNs) are reshaping the way that many educators view professional development (Betcher and Lee, 2009). Instead of waiting for their school to "deliver" professional development, these PLNs are creating a global learning environment for many lead educators that operates all year round, working across schools, educational sectors, countries, and time zones.

Second, the focus and course of action is initiated and driven by teachers' needs and beliefs.

Teacher learning requires that teachers take ownership of the material, interpreting and adapting it for themselves, and building on what they already know, believe and do. This is most likely to happen when the professional development activities are localised, adaptive and available on-demand.

In the proposed approach for ICT integration, professional development programmes are tailored to subject discipline and individual teachers' pedagogy and practice (Davis *et al.,* 2009a). Too often the specific needs of teachers are poorly targeted. If professional development cannot be structured in an ongoing, relevant and on-demand way, experience suggests that much of it will be wasted. Professional development for embedding the use of IWBs in pedagogy should start from where the teachers currently are and encourage them to question their existing practices and beliefs. In an already pedagogically interactive context, teachers need to learn how to exploit the potential of a powerful tool to support that pedagogy; the professional development activities will be very different from what is useful in a transmission-based context where the need is to develop both a new pedagogical approach and the ICT skills required. Research shows that teachers otherwise respond to ICT integration initiatives by simply adapting new ideas and technology resources to their existing practices and beliefs (Kennewell and Beauchamp, 2007). Effective interventions secure commitment by building teachers' confidence in their own abilities to use new technology (Zhao and Cziko, 2001).

Every school will also be at a different point in its evolution and will be situated in a different context, requiring its own tailored and responsive professional development programme. A critical factor in the effective use of ICT generally is the existence of a well-defined school-level e-strategy that addresses future development and sustainability and includes some means of monitoring progress against identified milestones (Condie *et al.,* 2007).

Third, professional development is a team inquiry process proceeding in cycles of reflection and trialling.

In the proposed approach, video exemplars of other teachers' (or their own) lessons, and multimedia resources and texts highlighting the underpinning approaches, stimulate reflection and dialogue between colleagues, for change and innovation. The videoed lessons are not intended to be models of "best practice" but illustrate a mixture of different approaches for consideration. The materials include specific built-in prompts for reflection on teachers' own current practice, reflection upon the approaches and practices illustrated, and discussion with peers. The guidance can be more or less structured, depending on how experienced the teachers are with the technology and the pedagogical techniques.

New ideas that emerge from this reflection process are then related to classroom practice through a cycle of trialling and refinement. This helps to test the practical applicability and boundaries of the new approaches in a given context, resulting in re-contextualised techniques and practices. Considering teaching as inquiry is a central success factor in professional development programmes generally (Alton-Lee, 2011).

Fourth, the inquiry is focused on supporting student learning.

In the proposed approach, both the prompts and the classroom inquiry activities focus on the impacts of the new practices for learners' engagement and learning outcomes; on which pedagogical strategies are applicable, assistive and appropriate for the context; on the added value of the technology and the extent of its exploitation.

Fifth, professional development activities are part of a sustained, long-term process, supported by the organisation; opportunities for dialogue, planning and team teaching, are embedded in the teachers' normal work organisation.

In the proposed approach, training is coordinated with the introduction of the equipment so that teachers are immediately able to practice their newly learned skills. Importantly, professional development programmes supporting ICT use need to continue after the initial phase in order to ensure that new learning can take place and so that "bad habits" can be addressed (Somekh, Underwood *et al.* 2007). Yet ongoing or pedagogically-oriented support is rare. The general literature on professional development concludes that it needs to be part of a sustained process (1-2 years) of reassessing pedagogy and reflecting upon practice, rather than a one-off intervention or one-day course (Cordingley *et al.*, 2004; Hoban, 1999). The intended changes must be understood and embraced at all levels, creating a collaborative and collegial learning environment that supports opportunities to change teachers' practices, knowledge and effectiveness (*e.g.* Hord, 1997). The process involved enables teachers to embed new ICT practices in their own classroom settings, in particular through dedicated non-contact time, collaborative lesson planning within workshops and team teaching (Bowker *et al.*, 2009; Cordingley *et al.*, 2004).

Opportunities for professional dialogue between colleagues are central here. British teachers, for example, have regular discussions about teaching with their line manager but performance management meetings typically focus on their own classroom teaching. The discussions stimulated by critiquing video clips of other teachers' practice can be more wide-ranging, allowing teachers to process new learning with others and to examine the effects of different types of activities without needing to account externally for their own actions and decisions.

Sixth, active support from school leaders and administrators is crucial.

Although it can be a huge challenge, experience from Australia indicates that shifting the focus towards a whole-school approach to ongoing professional development can make a major difference to progress in integrating IWB technology (Betcher and Lee, 2009, p. 137). The research emphasises the importance of the school principal in visioning, leading and funding interventions. It shows that strong support from the school leadership team and winning over a majority of the staff to the educational value of the boards are a critical combination to starting out on the path to successful school-wide implementation (*ibid.,* pp. 116-117). This reinforces the suggestion made earlier that IWBs should be introduced into all classrooms simultaneously (Somekh, Underwood *et al.,* 2007). Betcher and Lee (2009) argue that sufficient resources and induction should be provided to enable all staff to work collaboratively to embrace the powerful possibilities of the IWB and learn the necessary new skills to effectively embed IWBs into daily practices. A successful whole-school approach additionally depends on giving teachers "recognised responsibilities, authority, time to collaborate and [active] support from school administrators to assume leadership roles" (Teacher Leadership Exploratory Consortium 2011, p. 12).

School leaders play an often unrecognised role; along with teaching assistants they are often shortsightedly left out of IWB training initiatives (Moss *et al.,* 2007). Yet, rigorous syntheses of research evidence on professional development across the world clearly show that by far the largest effect of school leadership on student learning outcomes is when leaders promote and themselves participate in teacher learning (Alton-Lee, 2011).

Box 2. Existing resources for a collaborative inquiry approach to professional development for IWB integration

Previous research by Hennessy and colleagues carried out both in the United Kingdom and Zambia (Haßler, Hennessy, and Lubasi, 2011) in close collaboration with practitioners using new forms of technology confirms the value of the above approach in terms of teachers gradually changing their practices and thinking over time.

The T-MEDIA project documented case studies of IWB use in science, history and English, and projected graphware in mathematics. It produced thematically organised multimedia representations of them, with built-in professional development activities (freely available at *http://t-media.educ.cam.ac.uk/*). A follow-up study found lasting tangible impacts of engagement with theory, reflection and trialling new approaches and tools on the professional thinking and practice of participating teachers (Hennessy and Deaney, 2009). There was also evidence of their spread and independent adaptation by colleagues.

In the Dialogue and IWBs project, we collaborated with three (primary, middle and secondary school) teachers to analyse and develop dialogic practice in different subjects (Hennessy, Warwick and Mercer 2011). Teachers then designed and taught lessons employing new dialogic approaches supported by IWB use. Spontaneous whole-school initiatives took place, evaluating new uses of IWBs. This collaborative work led to the development of a further multimedia resource for using the IWB to support dialogue. The resource, co-authored with the three practitioners involved in the research, includes:

- A guided programme of collaborative action research containing discussion and practical activities
- A resource bank of video clips (freely available online at *http://sms.cam.ac.uk/collection/1085164*) and screenshots, each with a description of potential classroom application
- IWB flipchart templates for lesson activities
- Photocopiable resources for teachers and school leaders
- A series of accessible background readings, including the teachers' own detailed case stories of authentic classroom practice with accompanying lesson materials.

Source: Hennessy, Warwick, Brown, Rawlins and Neale (in press)

An independent evaluation of a series of workshops based on the resource was carried out in two English schools by an IWB-expert teacher. The (unpublished) report highlighted the value of the materials as a powerful stimulus for critique, discussion, reflection and testing out of new ideas, rather than a model to copy. The resource bank in particular was considered an excellent stimulus for discussion and development of ideas about how to link dialogic teaching with the IWB. The resource is adaptable to other subject and country contexts (see further information about the resource and the original research project at *http://dialogueiwb.educ.cam.ac.uk*).

The lessons we can learn from previous professional development programmes and associated research are clearly pointing towards a peer collaboration model for integration of IWB technology into classrooms in new contexts. The benefits of collaborative professional development (in general) can also extend beyond the areas targeted by the professional development (Cordingley *et al.*, 2003), and can in fact be very wide-ranging. Teacher benefits include enthusiasm about professional learning; increases in confidence and self efficacy; a greater commitment to changing practice and willingness to try new things; activities to generate more effective and targeted dialogue between students; and a conscious effort by teachers to use computers more for both instruction and to increase the range of teaching and learning strategies targeted at specific student needs. Student benefits include: a demonstrable enhancement of student motivation; improvements in performance on tests; more positive responses to specific subjects; an increased sophistication in response to questions; the development of a wider range of learning activities in class and strategies for students.

A cost-benefit analysis of IWB programmes

IWBs are expensive to install and maintain. Funding to meet the costs of sustaining laptops, data projectors and bulbs over time needs to be built into school budgets. Debate continues to rage about whether the costs are proportionate to the benefits, and about the "added value" of IWBs over other forms of projection technology such as a simple data projector and computer or laptop combination. One local authority region in the Test Bed project, for instance, chose to invest in the latter combination along with visualisers in order to equip far more classrooms, and was very satisfied with the outcomes (although of course they had no direct means of comparison); this combination is also frequently found in Singapore.

Cost savings can be expected as new, cheaper hardware options are becoming available – a cheaper, LCD IWB, and data projectors with in-built interactivity. A simple data projector coupled with a tablet computer or laptop plus slate can act as an alternative input device that retains access to the technology and – even the specialised IWB software – in the learners' hands and costs less than half the price of an IWB. Free screencasting programs can be used to capture/record lessons for subsequent playback. However, many argue that the IWB and its specialised software tools continue to offer significant pedagogical advantages. The technical issues arising from the various options are not within the scope of this review.

The benefits of introducing IWBs to support interactive pedagogies and to more generally embed ICT across the curriculum are evident from some of the research and evaluation studies discussed above. These benefits however are to a large extent conditioned by a larger set of conducive conditions.

Creating conducive conditions for integrating technology into classroom teaching inevitably costs more than the price of the equipment infrastructure, but it is difficult for policymakers and educators to gauge. In particular, the costs of professional development within large-scale IWB programmes are very elusive; they are not referred to in published reports and anecdotal evidence derived from personal communication with those who led the programme evaluations in the United Kingdom confirms that they were not examined. We have seen that confusion was evident in some cases about how professional development costs would be met and by whom. Betcher and Lee (2009, pp. 133-135) suggest that to set more realistic expectations, educators should discuss progress with similar schools using IWBs, including how much time and money has been set aside each year. Some further tentative suggestions can be made, as follows.

If teachers are to have the time they need to develop professionally, then money must be allocated for the vital ongoing development and support. Teachers ideally need to be released from formal teaching duties on a regular basis in order to participate in any form of professional development, and this incurs teaching cover costs. However, for school-based professional development this can if necessary be minimised through using staff meetings already scheduled outside of teaching time (although it is not ideal to undertake this kind of professional development after a full day's teaching). Informal support from knowledgeable colleagues is clearly a low-cost as well as a popular option. Action research is likewise a successful, sustainable and low-cost approach to reflective practice.

A cascade approach involving working with a small number of teacher mentors (and "champions") who then work with their colleagues teaching the same (primary) ages or (secondary) subjects would be cheaper than inducting all teachers initially, and it allows the recommended peer collaboration model to flourish. Where specialist external help or workshops are desired, there are various options. Teachers attending centralised workshops within a university or national/local education authority setting are usually more expensive in terms of travel and cover time than a regional hub model in which teachers from neighbouring schools congregate at one of their institutions. Location might be rotated, potentially offering an additional valuable opportunity to observe and learn from practice in another context. Secondary schools in England at least already do effective outreach work with feeder primary schools and such

clusters offer a fruitful model for building ICT expertise and sustaining it throughout a child's schooling (Somekh, Haldane *et al*., 2007). Similar schools may also work together to share practices, ideas and digital resources. As mentioned earlier, trainers or mentors themselves need to be part of a wider and ongoing community of practice in order for professional development to be effective (Davis *et al.,* 2009a).

Finally, it must be acknowledged that positive outcomes of the impact of collaborative professional development sometimes may emerge only after periods of relative discomfort in trying out new approaches. Cordingley *et al.* (2003, p .4) observed that practices often worsened before they improved and collaboration was critical in sustaining change. This finding resonates with early experience of IWB initiatives; in Test Bed schools, there was a dip in performance until the ICT became embedded and staff developed the requisite skills (Somekh, Underwood *et al.*, 2007). A long-term investment is needed to secure and sustain long-term gains, however the costs can be kept to a reasonable level through relying largely on peer rather than "expert" support, at least after initial induction by pedagogical experts. Structured support materials are important in helping to guide teachers' progress within this model; initial costs of developing or procuring these materials are mitigated through their replication and re-use over time *(ibid.)*.

Conclusion

This paper outlined the lessons learned from international experiences with IWBs. It considered ways to support the shifting roles of teachers and learners, in particular to foster more interactive and dialogic pedagogical approaches. The relevant organisational conditions for successful integration of IWB technology were described.

Research confirms that the skills and professional knowledge of the teacher in mediating interactions with learners is the most crucial factor in determining how much value is gained from IWBs (Higgins *et al.*, 2007). The roles of appropriate professional development and institutional capacity building here are utterly essential to support the continuous learning through innovation that underpins technology integration. Based on these considerations, and the fact that technology by itself has no transformative power, the research literature on effective forms of professional development was drawn upon in introducing a suggested, school-based professional learning approach. This model is primarily teacher-led, sustained over time, school-wide and actively supported by school leaders; it is based on peer collaboration, reflection, inquiry, direct classroom application and trialling, plus some external input. Overall it is also relatively low cost and may offer educational policy makers in other contexts a way forward that avoids the mistakes of some past technology integration initiatives.

NOTES

[1] Advanced Skills status (and a significant salary increase) is awarded upon application to recognise expert United Kingdom teachers and release them from 20% of their teaching in order to share their subject practice through outreach with other schools. They are not necessarily present in every school; in 2012 there are 4500 nationwide.

REFERENCES

Alexander, R. (2005), "Culture, Dialogue and Learning: Notes on an Emerging Pedagogy", conference presentation at *Education, Culture and Cognition: intervening for growth*, International Association for Cognitive Education and Psychology (IACEP),10th International Conference, University of Durham, United Kingdom, 10-14 July 2005, Keynote: 12 July 2005.

Alton-Lee, A. (2011), "(Using) Evidence for Educational Improvement", *Cambridge Journal of Education,* Vol. 41, No. 3, pp. 303-330.

Bakhtin, M.N. (1986), "The Problem of Speech Genres" in C. Emerson and M. Holquist (eds.), *Speech Genres and Other Late Essays,* University of Texas Press, Austin, TX, pp. 60-102.

Basilicato, A.N. (2005, March/April), "Interactive Whiteboards: Assistive Technology for Every Classroom", *Today's School*, Vol. 5, No. 5, pp. 44-45, *www.interactivewhiteboards.com/www/files/articles/Article_2005todaysschool.pdf*, accessed 19 December 2011.

Becta (2004), *Getting the Most from Your Interactive Whiteboard: A Guide for Secondary Schools*, Becta, Coventry.

Betcher, C. and M. Lee (2009), *The Interactive Whiteboard Revolution: Teaching With IWBs*, ACER Press, Australia.

Bowker, A., S. Hennessy, M. Dawes and R. Deaney (2009), "Supporting Professional Development for ICT Use in Mathematics Using the T-MEDIA Multimedia Resource" in M. Joubert (ed.), *Proceedings of the British Society for Research into Learning Mathematics,* Vol. 29, Routledge, Cambridge, pp. 19-24.

Condie, R., B. Munro, L. Seagraves and S. Kenesson (2007), *Impact of ICT in Schools: A Landscape Review*, Becta.

Cordingley P, M. Bell, B. Rundell and D. Evans (2003), "The Impact of Collaborative Continuing Professional Development on Classroom Teaching and Learning", *Research Evidence in Education Library*, Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre), Social Science Research Unit, Institute of Education, University of London, London.

Cordingley, P., B. Rundell, J. Temperey and J. McGregor (2004), "From Transmission to Collaborative Learning: Best Evidence in Continuing Professional Development (CPD)", paper presented at the International Congress for School Effectiveness and Improvement (ICSEI), Rotterdam.

Cutrim-Schmid, E. (2010), "Developing Competencies for Using the Interactive Whiteboard to Implement Communicative Language Teaching in the English as a Foreign Language Classroom", themed issue of *Technology, Pedagogy and Education* on Interactive Whole Class Technologies (guest edited by Hennessy and Warwick), Vol. 19, No. 2, pp. 159-172.

Cutrim-Schmid, E. and S. Whyte (2012), "Interactive Whiteboards in State School Settings: Teacher Responses to Socio-Constructivist Hegemonies", *Language Learning & Technology,* Vol. 16, No. 2, pp. 65-86.

Davis, N., C. Preston and I. Sahin (2009a), "Training Teachers to Use New Technologies Impacts Multiple Ecologies: Evidence From a National Initiative", *British Journal of Educational Technology*, Vol. 40, No. 5, pp. 867-878, *www3.interscience.wiley.com/cgi-bin/fulltext/120848254/HTMLSTART*.

Davis, N., C. Preston and I. Sahin (2009b), "ICT Teacher Training: Evidence for Multilevel Evaluation From a National Initiative", *British Journal of Educational Technology,* Vol. 40, No. 1, pp. 135-148.

DeSantis, J. (2012), "Getting the Most From Your Interactive Whiteboard Investment: Three Guiding Principles for Designing Effective Professional Development", *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, Vol. 85, No. 2, pp. 51-55. *http://dx.doi.org/10.1080/00098655.2011.607867.*

Essig, D. (2010), "A Case Study of Interactive Whiteboard Professional Development for Elementary Mathematics Teachers", Ed. Doctoral Dissertation, ProQuest LLC, Walden University.

Fernández-Cárdenas, J.M. and M.L. Silveyra-De La Garza (2010), "Disciplinary Knowledge and Gesturing in Communicative Events: A Comparative Study Between Lessons Using Interactive Whiteboards and Traditional Whiteboards in Mexican Schools", *Technology, Pedagogy and Education,* Vol. 19, No. 2, pp. 173-193.

Franklin, S. (2006), "VAKing Out Learning Styles—Why the Notion of 'Learning Styles' is Unhelpful to Teachers", *International Journal of Primary, Elementary and Early Years Education*, Vol. 34, No. 1, pp. 81-87.

Frost, D. (2012), "From Professional Development to System Change: Teacher Leadership and Innovation", *Teacher Leadership and Professional Development: Perspectives, Connections and Prospects,* Vol. 38, No. 2, pp. 205-227.

Futuresource Consulting (2012). *Interactive displays quarterly insight: State of the market report*, *Quarter 2*, Futuresource Consulting.

Gillen, J., J. Kleine Staarman, K. Littleton, N. Mercer and A. Twiner (2007), "A 'Learning Revolution'? Investigating Pedagogic Practice Around Interactive Whiteboards in British Primary Schools", *Learning, Media and Technology,* Vol. 32, No. 3, pp. 243-256.

Gray, C. (2010), "Meeting Teachers' Real Needs: New Tools in the Secondary Modern Foreign Languages Classroom", in M. Thomas and E. Cutrim-Schmid (eds.), *Interactive Whiteboards for Education: Theory, Research and Practice,* Hershey, New York, pp. 69-85.

Gray, D. (2012), "Evaluating the Key Issues of Interactive Whiteboards and Their Effectiveness in the Classroom: A Literature Review", unpublished Masters Essay, Faculty of Education, University of Cambridge.

Guskey, T.R. (2002), "Does It Make a Difference? Evaluating Professional Development", *Educational Leadership,* Vol. 59, No. 6, pp. 45-51.

Haldane, M. (2010), "A New Interactive Whiteboard Pedagogy Through Transformative Personal Development" in Thomas and Cutrim Schmid (eds.), *Interactive Whiteboards for Education: Theory, Research and Practice,* IGI Global, pp. 179-186.

Haßler, B., S. Hennessy and B. Lubasi (2011), "Changing Classroom Practice Using a School-Based Professional Development Approach to Introducing Digital Resources in Zambia", *Itupale Online Journal of African Studies,* Vol. 3, *www.cambridgetoafrica.org/resources/Hassler__et_al__2011.pdf*.

Hennessy, S. (2011), "The Role of Digital Artefacts on the Interactive Whiteboard in Mediating Dialogic Teaching and Learning", *Journal of Computer Assisted Learning,* Vol. 27, No. 6, pp. 463-586.

Hennessy, S. and R. Deaney (2009), "The Impact of Collaborative Video Analysis by Practitioners and Researchers Upon Pedagogical Thinking and Practice: A Follow-Up Study", *Teachers and Teaching: Theory and Practice,* Vol. 15, No. 5, pp. 617-638.

Hennessy, S. and P. Warwick (2010), "Editorial: Research Into Teaching with Whole-Class Interactive Technologies", themed issue of *Technology, Pedagogy and Education* on Interactive Whole Class Technologies (guest edited by Hennessy and Warwick), Vol. 19, Vol. 2, pp. 127-131, *http://dx.doi.org/10.1080/1475939X.2010.491211*.

Hennessy, S., P. Warwick and N. Mercer (2011), "A Dialogic Inquiry Approach to Working with Teachers in Developing Classroom Dialogue", *Teachers College Record,* Vol. 113, No. 9, *www.tcrecord.org/content.asp?contentid=16178*.

Hennessy, S., P. Warwick, L. Brown, D. Rawlins and C. Neale (eds.), (in press), *Developing Interactive Teaching and Learning Using the IWB: Teacher Resource,* Milton Keynes, Open University Press.

Higgins, S., C. Falzon, I. Hall, D. Moseley, F. Smith, H. Smith and K. Wall (2005), *Embedding ICT in the Literacy and Numeracy Strategies (Final Report),* University of Newcastle.

Higgins, S.E., M. Mercier, E. Burd and A. Hatch (2011), "Multi-Touch Tables and the Relationship with Collaborative Classroom Pedagogies: A Synthetic Review", *Computer-Supported Collaborative Learning,* Vol. 6, No. 4, pp. 515-538, *http://dx.doi.org/10.1007/s11412-011-9131-y*.

Hoban, G. (1999), "The Role of Community in Action Learning: A Deweyan Perspective" in J. Retallick, B. Cocklin and K. Coombe (eds.), *Learning Communities in Education*, Routledge, London.

Hord, S. (1997), "Professional Learning Communities: What Are They and Why Are They Important?", *Issues about Change,* Vol. 6, No. 1, *www.sedl.org/change/issues/issues61.html*.

Jewitt, C. (2006), "Technology, Literacy and Learning: A Multimodal Approach", Routledge, London.

Kennewell, S. and G. Beauchamp (2007), "The Features of Interactive Whiteboards and Their Influence on Learning", *Learning, Media and Technology*, Vol. 32, No. 3, pp. 227-241.

Knight, S. (in press), "Creating a Supportive Environment for Classroom Dialogue" in S. Hennessy, P. Warwick, N. Mercer, L. Brown, D. Rawlins and C. Neale (eds.), *Developing Interactive Teaching and Learning Using the IWB: Teacher Resource*, Open University Press, Maidenhead.

Kress, G. R., C. Jewitt, J. Ogborn and C. Tsatsarelis (2001), *Multimodal Teaching and Learning: the Rhetorics of the Science Classroom*, Continuum London and New York.

Lee, M. (in press), "Where to After the Digital Education Revolution?", *Education Technology Solutions*, January-February 2013.

Lee, M. and A. Wizenried (2006), "Interactive Whiteboards: Achieving Total Teacher Usage", *Australian Educational Leader,* Vol. 28, No. 3, pp. 22-25.

Lee, M. and A.Wizenried (2009), *The Use of Instructional Technology in Schools,* ACER Press Melbourne.

Lee, M. (2010), "Interactive Whiteboards and Schooling: The Context", *Technology, Pedagogy and Education*, Vol. 19, No. 2, pp. 133-141.

London, L. (2012), "Educational 'Transformation' Through Technology Integration? An Exploration of Perspectives and Expectations in Tanzania", MPhil Thesis, University of Cambridge.

Machin, S., S. McNally and O. Silva (2007), "New Technology in Schools: Is There a Payoff?", *The Economic Journal,* Vol. 117, No. 522, pp. 1145-1167.

Mercer, N., L. Dawes, R. Wegerif and C. Sams (2004), "Reasoning As a Scientist: Ways of Helping Children to Use Language to Learn Science", *British Educational Research Journa*l, Vol. 30, No. 3, pp. 367-385.

Mercer, N., S. Hennessy and P. Warwick (2010), "Using Interactive Whiteboards to Orchestrate Classroom Dialogue", *Technology, Pedagogy and Education,* Vol. 19, No. 2, pp. 195-209.

Mercer, N. and K. Littleton (2007), *Dialogue and the Development of Children's Thinking*, Routledge, London.

Mercer, N. and C. Sams (2006), "Teaching Children How to Use Language to Solve Maths Problems", *Language and Education,* Vol. 20, No. 6, pp. 507-527.

Mortimer, E.F. and P.H. Scott (2003), *Meaning Making in Secondary Science Classrooms,* Open University Press, Milton Keynes.

Moss, G., *et al.* (2007), *The Interactive Whiteboards, Pedagogy and Pupil Performance Evaluation: An Evaluation of the Schools Whiteboard Expansion (SWE) Project*: *London Challenge*, DfES Publications, London.

Northcote, M., *et al.* (2010), "Interactive Whiteboards: Interactive or Just Whiteboards?", in M. Thomas and A. Jones (eds), "Interactive Whiteboards: An Australasian Perspective", *Australasian Journal of Educational Technology*, Vol 26, No. 4), pp. 494-510, retrieved 19 December 2011 from *www.ascilite.org.au/ajet/ajet26/northcote.html*.

OECD (2010) *Inspired by Technology, Driven by Pedagogy. A Systemic Approach to Technology-Based School Innovations*, Educational Research and Innovation, OECD publishing, Paris.

Pearson, M. and B. Somekh (2006), "Learning Transformation with Technology: A Question of Sociocultural Contexts?", *International Journal of Qualitative Studies in Education,* Vol. 19, No. 5, pp. 519-539.

Pittard, V., P. Bannister, and J. Dunn (2003), *The Big pICTure: The Impact of ICT on Attainment, Motivation and Learning*, DfES Publications, London, *www.dfes.gov.uk/research/data/uploadfiles/ThebigpICTure.pdf*.

Retallick, J. (1999), "Transforming Schools into Learning Communities: Beginning the Journey" in J. Retallick, B. Cocklin and K. Coombe (eds.), *Learning Communities in Education*, Routledge, London.

Rojas-Drummond, S., K. Littleton, F. Hernández and M. Zúñiga (2010), "Dialogical Interactions Among Peers in Collaborative Writing Contexts. Chapter 7", in K. Littleton and C. Howe (eds.), *Educational Dialogues: Understanding and Promoting Productive interaction,* Routledge, Abingdon, Oxon, pp. 128-148.

Smith, F., F. Hardman and S. Higgins (2006), "The Impact of Interactive Whiteboards on Teacher-Pupil Interaction in the National Literacy and Numeracy Strategies", *British Educational Research Journal,* Vol. 32, No. 3, pp. 443-457.

Smith, H. J., S. Higgins, K. Wall and J. Miller (2005), "Interactive Whiteboards: Boon or Bandwagon? A Critical Review of the Literature", *Journal of Computer Assisted Learning,* Vol. 21, No. 2, pp. 91-101.

Somekh, B., M. Haldane *et al.* (2007), *Evaluation of the Primary Schools Whiteboard Expansion Project (SWEEP), Report to the Department for Education and Skills*, Becta, London.

Somekh, B., J. Underwood *et al.* (2007), *Evaluation of the ICT Test Bed Project*, Becta.

Teacher Leadership Exploratory Consortium (2011), "Teacher Leader Model Standards", *www.teacherleaderstandards.org/.*

Thomas, S. and E. Cutrim-Schmid (2010), *Interactive Whiteboards: Theory, Research and Practice*, IGI-Global, Hershey, PA.

Timperley, H. and A. Alton-Lee (2008), "Reframing Teacher Professional Learning: An Alternative Policy Approach to Strengthening Valued Outcomes for Diverse Learners", *Review of Research in Education,* Vol. 32, No. 1, pp. 328-369.

Warwick, P., N. Mercer, R. Kershner and J. Kleine Staarman (2010), "In the Mind and in the Technology: The Vicarious Presence of the Teacher in Pupils' Learning of Science in Collaborative Group Activity at the Interactive Whiteboard", *Computers and Education,* Vol. 55, No. 1, pp. 350-362.

Wegerif, R. (2007), *Dialogic, Education and Technology: Expanding the Space of Learning*, Springer, New York.

Wegerif, R., K. Littleton, L. Dawes, N. Mercer and D. Rowe (2004), "Widening Access to Educational Opportunities through Teaching Children How to Reason Together", *Westminster Studies in Education*, Vol. 27, No. 2, p. 143, *http://dx.doi.org/10.1080/0140672040270205*.

Wegerif, R., N. Mercer and L. Dawes (1999), "From Social Interaction to Individual Reasoning: An Empirical Investigation of a Possible Socio-Cultural Model of Cognitive Development", *Learning and Instruction*, Vol. 9, No. 5, pp. 493-516.

Wells, G. (1999), *Dialogic Inquiry, Toward a Sociocultural Practice and Theory of Education*, Cambridge University Press, Cambridge.

Wright, D. (2010), "Orchestrating the Instruments: Integrating ICT in the Secondary Mathematics Classroom through Handheld Technology Networks", themed issue of *Technology, Pedagogy and Education* on Interactive Whole Class Technologies (guest edited by Hennessy and Warwick), Vol. 19, No. 2, pp. 195-209.

Zhao, Y. and G.A. Cziko (2001), "Teacher Adoption of Technology: A Perceptual Control Theory Perspective", *Technology and Teacher Education,* Vol. 9, No. 1, pp. 5-30.

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