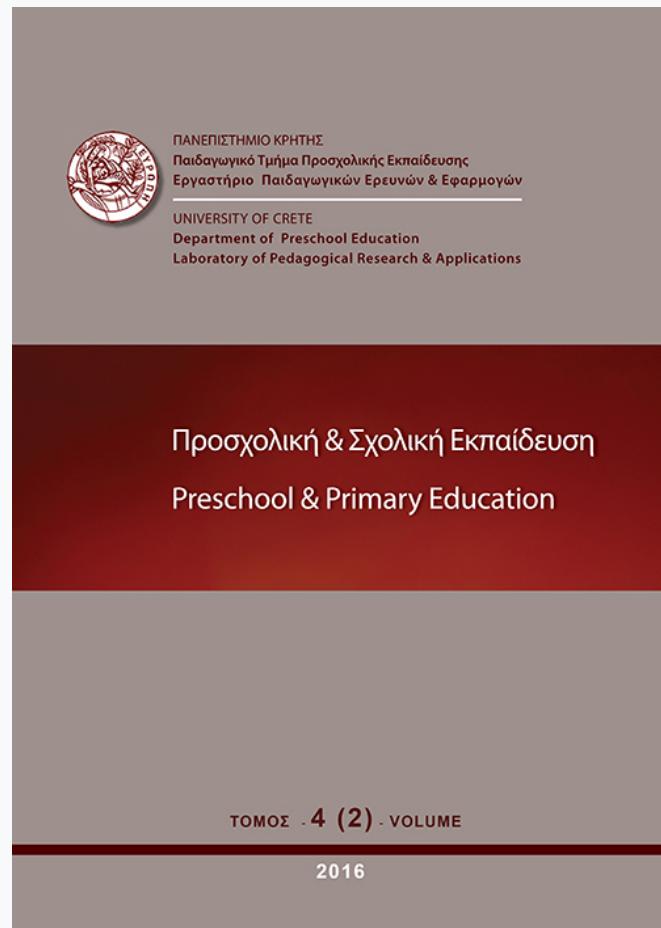


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Systematic review of the studies examining the impact of the interactive whiteboard on teaching and learning: What we do learn and what we do not

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Summary. This systematic review focuses on the impact of Interactive Whiteboards (IWBs) on teaching and learning. Learning is interpreted through a Vygotskian constructivist lens, emphasizing quality through dialogic interaction. Classroom interactions and achievement in standardized tests are considered formative and summative assessment tools, respectively. Thus, our aim was to investigate whether the IWB technology had any effect on teaching and learning, reflected in standardized forms of testing or in-classroom quality measures. An online search through Proquest and First Search resulted in sixteen studies of diverse methodologies. Qualitative synthesis of quantitative data indicated that IWBs have not raised the levels of pupils' achievement and do not necessarily impact the quality of classroom learning. More longitudinal studies should focus on particular subjects taught, the age of pupils and particular type(s) of use. Overall, quality teaching is an important condition for improved learning, which does not necessarily result from IWB use. However, there is a general consensus across all studies that learning can be facilitated and improved through the use of IWB. Synchronizing theory with technological applications seems to be key in answering such assumptions positively. More importantly, concerns are raised regarding the unfolded relation between achievement and classroom interaction.

Keywords: Achievement; classroom interaction; assessment; interactive whiteboards

Introduction

Considerable research on digital technologies has focused on the evaluation of different technological applications for education (Higgins, Xiao, & Katsipataki 2012; related to the introduction of both hardware and software into the classroom). Since the interactive whiteboard's (IWB hereafter) rapid introduction to schools in the UK and across the world, a considerable amount of research has been published related to the use of it. The vast majority of the studies are primarily based on teachers' and/or pupils' views, beliefs or perceptions about the technology (e.g. Hall & Higgins, 2005; John, 2005; Loveless, 2003; Slay, Siebörger, & Hodgkinson-Williams, 2008; Wall, Higgins, & Smith, 2005). Interestingly, almost all of these studies emphasize an overwhelming potential of IWBs to improve learning.

However, Holmes (2009) states that no change in classroom pedagogy will occur as long as research focuses only on teachers' knowledge, attitudes, and beliefs. Indeed, Smith,

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Higgins, Wall, and Miller (2005) support that there is "insufficient evidence to identify the actual impact of such technologies (IWB hereafter) upon learning either in terms of classroom interaction or upon attainment and achievement" (p.1). According to this last argument it is reasonable to assume that actual impact on learning remains unsubstantiated and learning is reflected in classroom interaction and attainment. The importance of classroom interaction becomes apparent in the theoretical stance adopted here, while connections between achievement and learning are presented as follows. In light of these, the authors aim to investigate the impact of IWB on classroom interaction and attainment by employing a systematic review.

Theoretical Perspective

It is important to provide the reader with our theoretical perspective since through this systematic review we look at IWB's actual impact on learning. We adopt a view of learning based on a Vygotskian constructivist perspective by endorsing the idea that interactivity during each lesson has the power to shape the type of learning that takes place, particularly in terms of the growth of a learner's participation over time (Mercer & Littleton, 2007). Drawing on Lambert et al. 's (1995) interpretation of constructivism:

"Individuals bring past experiences and beliefs...into the process of learning...As our personal perspectives are mediated with the world, we construct and attribute meaning to these encounters, building new knowledge in the process. This constructive, interpretative work is facilitated and deepened when it is undertaken with others and with reflection" (p. xi-xiii)

According to the constructivist view adopted, one might be inclined to adopt either an individual-centred learning view or a collaborative learning one (Luppincini, 2000). Piaget's and Vygotsky's work fit here and have shaped the two categories respectively. Following Vygotsky's (1978) views, cognitive development has a strong social dimension and higher or more complex mental functions can be developed through interactions, either with adults or more competent peers. Adult or more skilled peers are assumed to be at a higher level of cognitive and mental functioning in relation to a child or younger learner, and their role in the process of learning can be crucial.

Interactions within a classroom have the power to support and shape learning, while classroom talk shapes and is shaped by the types of interaction that take place. Indeed, Alexander (2008) argues that through language, especially spoken, teachers teach and children learn; language is a teacher's main pedagogic tool (Mercer & Littleton, 2007). Mercer (1995) takes this a step further, arguing that 'an analysis of the process of teaching, of constructing knowledge, must be an analysis of language in use' (p.6). Having said this, an in-depth analysis of the type and structure of language within a classroom is indicative of the types and levels of interaction. While this relationship to more formal learning outcomes is complex as discussed below, the development of richer interaction is hypothesised as educationally beneficial in itself. Overall, the quality of classroom interaction constitutes the cornerstone of effective teaching and is evident through the quality of classroom discourse.

Assessing Teaching and Learning

Having the above theoretical framework, classroom interaction shaped through discourse constitutes a means to assess students' learning. Achievement in diverse types of scoring tests constitutes another crucial assessment tool. We refer to the former as formative

assessment and to the later as summative assessment. In order to decide about the impact of a teaching method or instruction, both formative and summative assessment should be taken into account, as analysed below.

Formative assessment is related to quality measurements of pupils' progress during classes, identifying pupils' strengths and weaknesses while providing feedback to both pupils and teachers to guide learning and teaching strategies on a day-to-day basis (Callyingham, 2008; Peterson & Siadat, 2009; Tveit, 2014). Consequently, teachers' instructional strategy while shaping classroom interaction is clearly linked to formative assessment. Indeed, Clark (2012) points out that formative assessment is "a potentially powerful instructional process" since in a sharing community of assessing information towards learning, instruction is inevitably embedded in the process. In addition, with regards to the importance of talking, as previously stressed, prompting pupils to externalize their thinking constitutes a valuable mechanism for assessing learning.

Moreover, the importance of summative assessment should not be overlooked since there is an inextricable, though not explicit, link to formative assessment. Summative assessment is related to "factual knowledge and the final (learning) outcomes only" while "formative assessment should, in theory, prepare students to excel on summative tests" (Peterson & Siadat, 2009, p.93). Indeed, as Peterson and Siadat state, 'in theory' summative assessment mirrors pupils' acquired knowledge during formative assessment. In reality, this is far more complicated and is further discussed in the last section of the article. Moreover, summative assessment is literally any type of testing taking place at the end of an instructional period (Bloom, Hastings, & Madaus, 1971). The duration of the instructional period varies according the age of pupils and in turn, the type of test. For younger pupils, teachers prepare rather briefer and more frequent tests, while as they grow and develop, testing tends to be related to longer instructional periods. Callyingham (2008) says that summative testing measures the "size" of learning outcomes (Callyingham's quotation marks). Indeed, an accountability purpose is embedded in this form of assessment (Tveit, 2014). Many terms are used to refer to measurements of summative assessment through standardized forms of testing, such as scoring, attainment and achievement, whereas in view of the interpretations provided above, it is obvious that formative assessment influences somehow the achievement on summative testing.

The importance of scoring high on standardized achievement tests is explicit, perhaps undermining the vital process of formative assessment, as well as the connection between formative and summative assessment. Indeed, Dixon and Williams (2001) argue that while teachers realized the importance of formative assessment and its connection to instruction, they were unable to describe how they used the assessment information to enhance pupils' learning. Perhaps this is due to the direct impact of summative forms of testing on significant decisions and implications for both pupils and schools.

Summative assessment aims to inform pupils and their parents as well as school leaders, curriculum developers and national authorities about pupils' skills and monitor the quality of the educational system (Tveit, 2014). This process aims to indicate weaknesses and strengths of the diverse educational programmes and monitor changes over time (Callyingham, 2008). Also, McFarlane, Schroeder, Enriquez, and Dew (2011) claim that due to the economic crisis achievement has become more important today than actually acquiring skills, because schools receive financial rewards related to high test-scores, once again underestimating the preparation necessary to meet the required skills of most employers.

However, achievement in summative tests is the key tool for teachers to help pupils' learning and gain a picture of what has been learned (Harlen, 2007). The aim of education is to improve learning which is often measured by raising attainment, while expanding more complex thinking skills (Klopfer, Osterweil, Groff, & Haas, 2009). But improvement and effective learning should be mirrored in the improvement of scores and not necessarily in

high scoring itself. Raising each pupil's level of skills is the ultimate characteristic of effective learning and this should be related to raising each pupil's level of attainment. Designing assessment tools also constitutes a major factor in achieving this, although this part does not fall into the scope of this review.

With this in mind, testing does not constitute the only way for teachers to evaluate improvement in pupils' learning since, as it has already been stressed, synchronizing instruction to pupils' needs through formative assessment is essential. Evidently, testing is a single source of data and should be used in conjunction with other relevant information to evaluate progress (Campbell, 2010). For example, the ability of pupils to participate orally is considered crucial and is not measured through testing. However, as pupils move through schooling, standardized forms of testing hold the key to their subsequent learning opportunities and potential success. At the end of school life comparisons at national level are based on testing of one kind or another, and as long as this is the reality of educational systems, scoring well on assessments remains crucial. For example: in the United Kingdom students' scores in diverse subjects in the General Certificate of Secondary Education (GCSE) is pivotal to enter higher education institutions; in Greece and Cyprus national exams at the end of high-school determine if and to which university each student got entry.

Overall, the importance of classroom interaction (formative assessment) and scoring (summative assessment) to support teaching and learning has been made clear. Moreover, nowadays technological interventions, such as the IWB, are rapidly transforming the educational context. In turn, this impacts on classroom interaction and scoring; literally teaching and learning.

Teaching and Learning with an Interactive Whiteboard

Enormous amounts of money have been spent on schools, particularly in the UK, so that IWBs could be installed (Higgins, Beauchamp, & Miller, 2007) aiming to support more interactive teaching delivery (Smith, Higgins, Wall, & Miller, 2005) and raise attainment in core subjects (Beauchamp, 2004). It is critical though to refer to IWB's potential to enhance interactivity across two distinct levels: technologically oriented and pedagogically oriented change.

Technologically, there has never before been one single device in a classroom resulting in such a range of digital tools converging (Kent, 2006), characterised by such multimodal interaction (Hennessy, 2011). Numerous characteristics and functions of IWB can be found extensively and repeatedly in literature. These include facilities to save and re-use material, to drag and drop, to present in sharp colours, movement and animation, to get immediate feedback, to manipulate and annotate images. However, quality interactivity is not imposed or intrinsically enhanced when such claims are made.

Indeed, few teachers employ technological tools -hardware and software - in ways which improve teaching and learning, while teaching processes mirror patterns of previously applied teaching methods (Cuban, Kirkpatrick, & Peck, 2001). Even though IWB might encourage pupils' verbal and physical participation, the quality of such participation is not addressed nor implied as being enhanced (Smith et al. 2005), whereas broad participation might be considered as a surface, non-effective, feature of interactive teaching (Essarte-Sarries & Paterson, 2003).

Based on these assumptions and theoretical perspective, we set our target in finding studies for this review designed to examine the actual impact of IWB on teaching and learning. This will be explored by including studies that refer to tested attainment measured through numerical scoring and/or in-classroom quality measures through other designs and instruments.

Methodology

Research Questions

1. What does research on IWBs tell us about its actual impact on teaching and learning?
2. Are there any robust results that can inform teaching practice, scanning through the same body of research?
3. Are there particular points that need to be borne in mind for future research, scanning through the same body of research?

Systematic Review

Systematic reviews are “the underappreciated workhorses of academic publication” (Hallinger, 2013, p. 127). Yet good systematic reviews play a crucial role in evidence-based decision-making by policymakers, thus bridging the gap between research and practice (Gera, 2012; Murphy, Vriesenga, & Storey, 2007). More importantly, as a result of the expansion of digitally saved material, access to a massive amount of data is now a click away via innumerable databases on a global level. In fact, this enables researchers to systematically compare and target studies in the international scene.

A systematic review was conducted to locate, evaluate and synthesize the available evidence related to the research questions above in order to offer informative and evidence-based answers (Boland, Cherry, & Dickson, 2014). The transparency of the selection and review of studies differentiates a systematic review from other types of reviews (Hall, 2002) while enhancing its quality (Penn & Lloyd, 2006). Briefly put, “a systematic review is a review of research literature using systematic and explicit, accountable methods” in a range from quantitative to qualitative research (Gough, Oliver, & Thomas, 2012, p.5).

It is important to distinguish a systematic review from a meta-analysis. The terms are often used interchangeably, yet meta-analysis refers to the quantitative analysis of the results of multiple studies in a statistical manner, even if it is regularly based on a systematic review (Valentine, Pigott, & Rothstein, 2010).

The key features of a systematic review as presented by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre, 2012 as cited in Hallinger, 2013) are:

- Explicit and transparent methods
- It is a piece of research following a standard set of stages
- It is accountable, replicable and updateable
- There is a requirement of user involvement to ensure reports are relevant and useful.

The transparency of the systematic review in this study becomes evident by the ability of the reader to conduct the same review once again since each stage of the procedure is explicitly presented.

As suggested by Fink (2005), we followed seven steps to conduct the systematic review:

1. Finding research questions
2. Selecting the sources from which the sample will derive
3. Choosing search terms
4. Applying practical screening criteria
5. Applying methodological screening criteria
6. Conducting the review
7. Synthesizing the review

The first step of the procedure has been presented above while remaining steps were conducted in a manner that will become clear in the remaining part of the article.

Gathering data through online resources

A specific set of words was selected as the one that had the most effective searching results through First Search and Proquest: (interactive whiteboard OR electronic *board OR digital *board) AND (assessment OR scores OR attainment OR evaluation OR test*) AND (primary OR elementary). All searches were done by the first author, on the 29th of July in 2013, resulting in 14,735 studies, which were limited to 553 after scanning through the titles (Figure 1). Afterwards, abstract or full-text reading of each study led to a group of 57 studies. Many studies were excluded, mainly because they came from other disciplines, such as medicine or higher education. From this point onwards both authors worked collaboratively to decide and apply the exclusion criteria. Studies were excluded for the following reasons:

- Focus solely on teachers' or pupils' beliefs/views/perceptions or motivational aspect of the IWB (6 studies)
- Targeted population not applicable (minority pupils, difficult to teach, ELLs, etc) (2 studies)
- Meta-analysis of other reviews (1 study)
- Unofficial data (4 studies)
- Studies funded by IWB selling companies-possibility of biased results in favor of IWB (2 studies)
- Focus solely on teachers' experience and training (2 studies)
- Publication related to an already added paper (1 study).

This process lead to a final set of 16 papers included in the review for analysis (Table 1). One study could not be retrieved online but this was resolved by directly contacting the authors. The term "study" reflects diverse types of cases included in the review, such as journal publications, conference papers, PhD and EdD theses, etc., and all studies are presented in Table 1.

Initially, the aim was to identify studies in academic journals related to the use of IWB in primary school and its impact on pupils' maths achievement. However, at the time of this systematic review only limited data could be retrieved under the above scheme. A final search was done by having nursery up to elementary school pupils as the targeted population, without any limitation according to the teaching subject and type of publication: PhD or EdD thesis, dissertation, book chapter, conference paper, research report were considered legitimate for inclusion. Exclusive criteria are clearly listed above, while only Lopez's (2010) study might be confusing since it seems to fit in the excluded category, "Targeted population not applicable (minority pupils, difficult to teach, ELLs, etc)". However, ELLs of the specific study were taught in regular classes with native speakers, and data were gathered through the regular final exams, and so it was included.

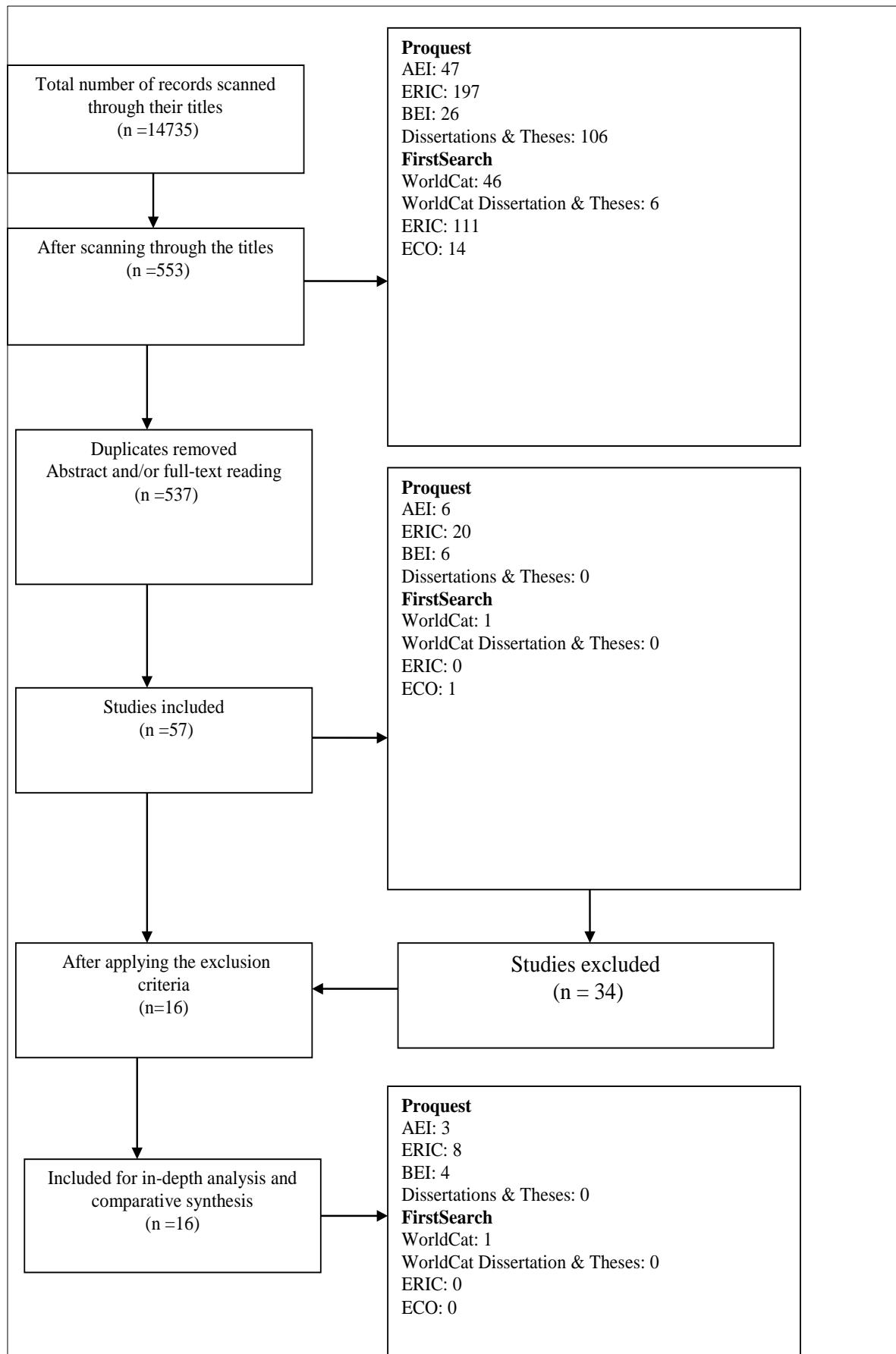


Figure 1 Numerical representation of the selection procedure

Analysis of data and discussion

The diversity of the methodologies in the final set of studies made the comparison among all of them impossible (Table 1). Content analysis was employed to bring the similar data together under certain themes (Ciltas, Guler, & Sozbilir, 2012). Categories were derived from the data and not predetermined, a procedure which Hsieh and Shannon (2005) name conventional content analysis. Six categories were shaped based on each study's focus (Table 2) so that comparisons could be made; for example, a paper could fit in more than one category.

Each study is related to a certain use of the IWB and/or a form of summative testing. The type of IWB use, if provided within each study, is presented in Table 1, in the column 'Type of IWB/ Research Methods'. The form of summative tests found across the studies can be divided into two categories. On the one hand, there are pre- and post- tests developed by the researcher for the particular study. On the other hand, there are standardized achievement tests (SATs hereafter) delivered and developed by formal bodies at national or state level. More details on the specific type of SAT met across the studies are provided below Table 1; the acronym is flagged using an asterisk throughout the table.

The quality of each study was evaluated since being "peer-reviewed" was not a requirement during search. Peer-review search suggests that a study has passed a minimum level of professional examination (Cooper, Hedges, & Valentine, 2009). If the "peer-reviewed" criterion were applied, only five studies would have been gathered. Instead, it was preferable to gather more studies and evaluate their methodologies. Quite remarkably, among the five "peer-reviewed" studies (studies 1, 6, 8, 9 and 14) only two were considered to have a strong methodological description (studies 1 and 6).

Pupils' scoring

Looking at the majority of the papers in the category – 5 out of 9 - there were no significant gains in quantitative scores related to the use of IWB (Table 3). However, a closer view of the methodology of each paper will substantially enhance the significance of each study's results.

More specifically, having a control group and pre-post testing is a crucial validity strengthener, at least in this case. Cheung and Slavin (2013) state that, "lacking a control group, of course, a pre-post design attributes any growth in achievement to the program, rather than to a normal, expected gain" (p. 92). Similarly, without pre-testing a study, it cannot provide valid data of effectiveness since improvement in scoring is an indicator of change. High scoring or performance is not sufficient. Only through comparing scores before and after any intervention can one make judgments about its effectiveness.

In this sense, the papers of Martin (2007), Swan, Schenker, and Kratcoski (2010), Thompson and Flecknoe (2003) and Lopez (2010) seem to have certain methodological weaknesses and are therefore not included in the overall conclusions.

Winkler (2011) concludes that IWB has a significant effect on maths only at nursery school ($p=0.001$) and 5th grade ($p<0.0005$). However, control and experimental groups at nursery school were unequal and in favor of the experimental, raising some issues of validity. There were 22 pupils in the control and 50 in the experimental group. Also, pupils of non-trained teachers in 5th grade did not improve their scores in maths, instead they did worse at the post-test. This outcome enhanced the positive results of the trained teachers in this age group. As a result, we do not think that in relation to the specific training described, it can be assumed that there is a specified advantage in maths when the IWB is applied.

Table 1 Description of studies included

Record of Studies included	Publication	Date/Location	Subject	Sample	Type of IWB use/ Research Methods	Results
1. Bahadur, G. K., & Oogarah, D. (2013). Interactive whiteboard for primary schools in Mauritius: An effective tool or just another trend? <i>International Journal of Education and Development using Information and Communication Technology (IJEDICT)</i> , 9, 19-35.	Journal publication	Africa (Mauritius)	Science (Solar System)	40 pupils (aged 9-10) -3 classes in 5th grade from 2 schools	An educational resource (ER) was developed and applied using the IWB via XERTE, an Open Source Authoring Tool; each class was divided into two groups; one group was taught via the ER and IWB (experimental) and the other via traditional methods without the IWB (control); Pre- and post- tests; observations	Both groups performed equally well, with and without the IWB. Observations indicated more enthusiasm and attention in the experimental group which didn't lead to any further improvement of scores
2. Campbell, T. L. (2010). <i>The effects of whiteboards on student achievement in fourth grade. Mathematics as measured on the Palmetto Achievement Test (PACT) at selected schools in North Central South Carolina</i> . Unpublished doctoral dissertation, , South Carolina State University, .	Thesis	2007-2008, South Carolina USA	Mathematics	356 4th grade students from 4 schools	141 students using IWB Vs 215 not using IWB, comparing SAT* (PACT and MAP)	No significant difference in scores (A significant difference in gender for the interaction of gender and IWB use)
3. Diaz, J. L. (2012). <i>A study of education today: Interactive classroom educational technology strategies (ICETS)</i> . Unpublished doctoral dissertation, Union Institute & University Cincinnati, U.S.A., Ohio.	Thesis	2010-2011, Florida USA	English	40 high-school students from a well-resourced school	18 students experimental group (9-week intervention using IWB and a voting system linked to IWB-Activote device) Vs 22 control group (same material without IWB), SAT* served as pre- and post-test (ACT)	No significant difference in scores (Females in experimental scored slightly better than males in experimental, though not statistically significant)
4. Higgins, S., Falzon, C., Hall, I., Moseley, D., Smith, H., Wall, K., & Smith, F. (2005). <i>Embedding ICT in the literacy and numeracy strategies</i> . Final report, University of Newcastle.	Report	Autumn 2002-Summer 2004, UK	English, Mathematics and Science	a) Year 5 and Year 6 pupils from 67 IWB schools (about 2800 pupils) and 55 non-IWB schools in 6 LEAs** (about 2000 pupils) b) 30 Year 5 and Year 6 teachers from same schools	a) Comparing Key Stage 2 national tests for three consecutive years (2002-2004) between the experimental (IWB) and control (non-IWB) group b) 184 structured observations with and without IWB by the same teachers in English and Mathematics, in early 2003 and 2004 (using a handheld computerized device)	a) The introduction of IWB is associated with some improvement in scores during the 2nd year of use, not maintained the following years. Also, it seems IWB improves performance of low-achievers in English b) IWB impacts effectively the type of classroom interaction, particularly when the use of it becomes embedded

<p>5. Huang, T. H., Liu, Y. C., Yan, W. T., & Chen, Y. C. (2009). Using the innovative cooperative Learning model with the interactive whiteboard to primary school students' mathematical class: Statistic vs pie chart and solid diagram. In L. Cameron & J. Dalziel (Eds.), <i>Proceedings of the 4th International LAMS Conference 2009: Opening Up Learning Design</i> (pp.84-94). Sydney: LAMS Foundation.</p> <p>6. Hwang, W., Chen, N., & Hsu, R. (2006). Development and evaluation of multimedia whiteboard system for improving mathematical problem solving. <i>Computers & Education</i>, 46, 105-121</p>	<p>Conference paper</p>	<p>Taiwan</p>	<p>Two 6th grade classrooms -60 pupils- same school</p>	<p>Experimental group-classroom using IWB Vs Control group-classroom using projector, pre- and post-test</p>	<p>The use of IWB is more effective than the overhead projector</p>
<p>7. Kennewell, S. (2007). The use of ICT to improve learning and attainment through interactive teaching (ESRC Full Research Report, RES-139-25-0167-A). Swindon: ESRC.</p>	<p>Journal publication</p>	<p>China (during one semester)</p>	<p>Thirty eight 6th grade students - same school</p>	<p>The IWB was used by pupils to write down mathematical problem solving solutions and also used a voice recording tool during their oral explanations. Methods employed were questionnaires, quantity and quality analysis of students' oral analyses</p>	<p>Female students and high achievers were better in oral communication (critiques, arguments and communication)</p>
<p>8. Lopez, O. (2010). The digital learning classroom: Improving English language learners' academic success in mathematics and reading using interactive whiteboard technology. <i>Computers & Education</i>, 54, 901-915.</p>	<p>ESRC Report-Funded study</p>	<p>UK</p>	<p>Mathematics, English and Science</p>	<p>41 teachers from 21 primary and secondary schools</p>	<p>Video-taped observations of IWB and non-IWB lessons, interviews with teachers and groups of pupils, pre- and post-tests</p>
<p>9. Martin S. (2007). Interactive whiteboards and talking books: a new approach to teaching children to write? <i>Literacy</i>, 41, 26-34.</p>	<p>Journal publication</p>	<p>US (2006-2007)</p>	<p>Mathematics and reading of ELL (English Language Learners)</p>	<p>213-3rd and 151-5th grade students in 3 elementary schools</p>	<p>Pre- and post- testing through SAT* (district's tests and TAKS) and comparisons among: ELL in IWB classrooms (experimental group), ELL in non-IWB classrooms and regular (non-ELL) students in non-IWB classrooms (control groups)</p>
<p>10. Masera, R. (2010). <i>Effects of traditional versus tactful/kinesthetic Interactive-Whiteboard Instruction on primary students' vocabulary achievement and attitude-test scores</i>. EdD Thesis, St.John's University, New York.</p>	<p>Journal publication</p>	<p>UK (6-week period)</p>	<p>Literacy (writing)</p>	<p>A 6th grade class-29 pupils</p>	<p>Using interactive Big Books on the IWB with graphics and sound, random selection of 10 pupils whose writings formed as pre- and post-tests, scheduled observations, questionnaires about pupils' beliefs about their learning</p>
	<p>Thesis</p>	<p>USA</p>	<p>Literacy (vocabulary)</p>	<p>87 children (45 in nursery school, 42 in 1st grade)</p>	<p>Children were taught and divided in 3 subgroups, 45 sight words were taught in 3 treatments using 3 different methods (traditional, tactful/kinesthetic and IWB), pre- and post-test of short and long term</p>

<p>11. Rains, C. (2011). <i>Effect of Interactive Whiteboard Instruction on 5th Grade Standardized Test Scores in the Area of Mathematics</i>. Unpublished doctoral dissertation, Walden University, USA</p>	Thesis	USA	Mathematics	<p>200 5th grade students in one elementary school</p>	<p>Students were divided in 3 groups: using IWB for 3 years (99 students), for 2 years (87) and for 1 year (14); Comparing SAT* between groups (CRCT)</p>	<p>Duration of IWB's instruction did not have a significant effect on scores in the areas of numbers and operations, measurement, data analysis, and total math score. However, the group which had been instructed by IWB for 3 years had significantly higher scores in geometry and algebra</p>
<p>12. Somekh, B. Haldane, M., Jones, K., Lewin, C., Steadman, S., Scrimshaw, P., et al. (2007). <i>Evaluation of the Primary Schools Whiteboard Expansion Project</i>. Manchester Metropolitan University, U.K..</p>	Research report	UK (2004-2006)	Mathematics, English, Science	<ul style="list-style-type: none"> • 3,156 pupils in Key Stage 1 • 4,116 pupils in Key stage 2 	<p>Multilevel analysis at pupils and class level: Comparison of pupils' scores (in national tests) taught with an IWB versus those taught without an IWB, comparison of scores and duration of instruction with an IWB. (Here noted only analyses related to scores)</p>	<p>The length of time taught with an IWB is a factor leading to attainment gains. In Mathematics, pupils of average and high attainment made greater progress if more IWB exposure was present during lessons</p>
<p>13. Swan, K., Schenker, A., & Kratcoski A. (2010). Interactive whiteboards and student achievement. In M. Thomas & E. C. Schmid (Eds.), <i>Interactive whiteboards for education : theory, research and practice</i>. USA: IGI Global.</p>	Book chapter	USA (2006-2007)	Mathematics, Reading/ language arts	<p>All 3rd to 8th grade students in a small urban area - 3152 in total (11 elementary schools, 3 junior high schools, and 1 alternative school)</p>	<p>Comparing SAT* (OAT) between 1466 students enrolled in classes with IWB and 1686 students who did not use it; Qualitative comparisons among teachers' use of IWB and students scores based on teachers' weekly online self-reports</p>	<p>Small achievement increase in the IWB group, statistically significant only in Mathematics. Significant differences in teachers of high performing students in the frequency and the way of IWB use; more frequent student-centered approach.</p>
<p>14. Thompson, J., & Flecknoe, M. (2003). Raising attainment with an interactive whiteboard in Key Stage 2. <i>Management in Education</i>, 17, 29-33.</p>	Journal publication	UK	Mathematics	<p>16 pupils in Year 5 (from a low-status school)</p>	<p>Pupils were taught in Maths while using "Easiteach" -teaching tool with Math resources; Comparison of children's scores in SAT* (RM Snapshot) at the end of spring term, autumn term and Year 4</p>	<p>Pupils' scores exceeded the expected progress of the year in just two terms. Attainment gains for all pupils and particularly for lower prior attainment pupils</p>
<p>15. Watt, K. (2009). <i>A comparison of the effects of programmed learning sequenced and Interactive Whiteboard instruction on the mathematics achievement and attitudes of the eighth-grade students</i>. Unpublished doctoral dissertation, St. John's University, New York USA</p>	Thesis	USA	Mathematics (Quadratic Functions and Trigonometric Ratios)	<p>72 Year 8 students in a Middle School</p>	<p>Students were taught with 2 instructional methods: a) PLS (Programmed Learning Sequenced-Instructional resource that programs content to suit many learning styles) b) IWB (Geometer's Sketchpad and TI Smartview software); All students were taught in both types of instructions; Pre- and post tests</p>	<p>Both methods appeared to be equally effective in raising Mathematics scores</p>

16. Winkler, R. L. (2011). <i>Investigating the impact of interactive whiteboard professional development on lesson planning and student achievement</i> . Unpublished doctoral dissertation, Liberty University, USA.	Thesis	USA	Mathematics	18 teachers with 311 elementary students from kindergarten, 1st, 4th and 5th grade at the same school.	Students' achievement and teachers participating in a specially designed training related to IWB's effective use (experimental group) versus students' achievement on SAT* with no special teacher training other than the usual (control group); pre- and post testing using SAT*; pre- and post (training) observations	Observations indicated significant instructional practices between featured trained and non-featured trained teachers after training with the trained group applying more interactive techniques group; differences in scores according to teachers' training were observed only in kindergarten and 5th grade, in favor of students whose teachers participated in training
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*SAT: Standardized Achievement Tests (Interpreted below)

** LAEs: Local Educational Authorities

TEST (SAT)	INTERPRETATION
PACT	Palmetto Achievement Challenge Tests in English, Mathematics, Science and Social Studies – once a year raw – raw score for each subtest
MAP	Measures of Academic Progress – minimum two times a year - sub score for each test given
ACT	American College Test – multiple questions on reading comprehension
TAKS	Texas Assessment of Knowledge and Skills
CRCT	Criterion Referenced Competency Test (at the State of Georgia)
OAT	Ohio Achievement Test
RM Snapshot	Software Assessment Package - pupils "log in" and work in a set of test questions

Table 2 Categories extracted through data

CATEGORIES	STUDIES INCLUDED
Pupils' Scoring	Diaz, 2012; Kennewell et al., 2007; Lopez, 2010; Martin, 2007; Masera, 2010; Bahadur & Oogarah, 2013; Thompson & Flecknoe, 2003; Swan et al., 2010; Winkler, 2011 (9 studies)
Length of time of IWB experience	Campbell, 2010; Higgins et al., 2005; Somekh et al., 2007; Rains, 2011. (4 studies)
Gender	Campbell, 2010; Diaz, 2012; Higgins et al., 2005; Hwang et al., 2006; Martin, 2007. (5 studies)
Pupils' abilities in terms of scoring	Hwang et al., 2006; Martin, 2007; Masera, 2010; Higgins et al., 2005; Somekh et al., 2007; Swan et al., 2010; Thompson & Flecknoe, 2003. (7 studies)
Comparing IWB with other sources and techniques	Huang et al., 2009; Masera, 2010; Watt 2009. (3 studies)
Classroom Interaction	Hwang et al., 2006; Winkler, 2011; Kennewell et al., 2007; Swan et al., 2010; Higgins et al., 2005. (5 studies)

The remaining four studies (Bahadur & Oogarah, 2013; Diaz, 2012; Kennewell et al., 2007; Masera, 2010) are consistent and support that no progress is found in test scores in relation to the IWB. Winkler's (2011) study raises more questions since it fails to show how the IWB impacts positively on scores when teachers are specially trained to use it. An optimistic view might be that the use of the IWB itself has a positive effect on outcomes, but this was not additionally enhanced when providing training to teachers. This interpretation seems unlikely however, given the findings of the other studies analyzed in the category.

Length of time of IWB use

When looking at Table 4 it is reasonable to exclude Rains' (2011) study when summing up in this category since there was an absence of pre/post tests and control-/experimental groups. At the same time, the complex and difficult to follow methodology of Somekh et al. (2007)

does not provide sufficient data to tackle questions regarding validity and reliability. The use of controls within models makes it difficult to ascertain whether the gains associated with the IWB in some classes were counterbalanced by poorer achievement in others. Higgins et al.'s (2005) study has a stronger methodological approach and did not find sustained improvement in scoring and this is in line with Campbell's (2010) results. In other words, overall evidence indicates that the length of time for IWB use has no impact on pupils' attainment, at least not during the period of these particular studies (2002-2006).

Table 3 Pupils' scoring

STUDIES	Pre-post testing	Control - experimental group	Other strengths	Other Weaknesses	Conclusions/Statistical details
Martin (2007)	X	X		Sample (10 pupils)	IWB has no significant effect on scores
Swan et al. (2010)	X	✓	Sampling (3000 pupils)	Unclear, rather blurred methodology	IWB has no significant effect on reading/language ($p=0.224$) but it has a significant effect on Maths ($p=0.018$)
Thompson & Flecknoe (2003)	✓			Additional strategies were applied to boost performance, Sample (16 pupils)	IWB has an effect on scores, "scoring exceeded the expected progress for the year in just two terms" p.31
Lopez (2010)	✓		Excellent statistical analysis, structured well-explained methodology, sampling (364 students)	Comparison between ELLs using the IWB and regular students not using the IWB doesn't seem useful (2 nd research question)	For ELLs: IWB has no clear effect on Maths and Reading. Statistical tests (t-test, chi-square and effect size) conflict in all cases comparing ELL students using and not using the IWB. (Also, not surprisingly, the disparity in scores between ELL and regular students not using the IWB is statistically proven to be significant)
Diaz (2012)	✓	✓	Nicely done; with a clearly explained methodology. Emphasizing a particular use of IWB.	Sample (40 pupils in total)	IWB has no significant effect on scores ($p=0.119$).
Bahadur & Oogarah (2013)	✓	✓	Nicely done; has a clear methodology. Emphasizing a particular use of IWB.	Sample (40 pupils in total)	IWB has no significant effect on scores [T-value (2.262) is greater than the T-calculated values (-0.137, 0.330 and 0.56)]
Masera (2010)	✓	✓	Nicely done; has a clearly explained methodology	—	IWB has no significant effect in scores. IWB group scored lower than the other groups ($p<0.001$ for short term word recall, $p<0.01$ for long term word recall)
Kennewell et al. (2007)	✓	✓	ESRC funded large-scale study has a strong methodological body, sampling (41 teachers from 21 schools)	—	IWB has no significant effect on pupils' scores. (Statistical details were not available in the particular publication)
Winkler (2011)	✓	✓	Nicely done; has a clearly explained methodology. Sample (18 teachers, 311 students)	—	IWB has a significant effect on the trained teachers' group in nursery school ($p=0.001$) and 5 th grade ($p<0.0005$)

Gender

The five studies included under this theme can be divided into two groups. On the one hand, Diaz (2012), Campbell (2010) and Higgins et al. (2005) compare scoring and, on the

other, Martin (2007) and Hwang, Chen, and Hsu (2006) observe pupils' behaviour in terms of participation and comments, while using the IWB.

The use of the IWB does not seem to impact differently on pupils' scoring according to their gender. However, in the second group/pair of studies there is indication that boys participate and comment much more than girls during IWB lessons. But the important question is whether girls or boys participate more, with or without the IWB; this could have been answered if a control group was added to the methodological design, in addition to comparisons of observable participation and scoring. Being able to comment and justify arguments during lessons constitutes a factor that indicates an improved understanding, quality learning and consequently, higher scores. Participation can take many forms and it should be observed more descriptively in terms of its content and connection to learning practices. As stated clearly in the beginning of this article, quality participation through reasoned arguments and justification constitutes an indicator of improved learning quality.

Pupils' abilities in terms of prior test scores

An interesting area to explore in terms of IWB effects on pupils' attainment is their actual levels of attainment, that is to investigate whether there are any differences in attainment among low and high scoring pupils, related to the use of IWB. Seven studies were included in this category but three of them were excluded (Somekh et al., 2007, Swan et al., 2010, Thompson & Flecknoe, 2003) since there are some clear methodological concerns which raise validity concerns.

The contrasting results stress the need for more longitudinal research in the field, while emphasizing the complexity of studying a technological resource, such as the IWB. Even within Higgins et al.'s (2005) study there are different outcomes from using IWBs, according to the subject taught, while Masera' s (2010) results on English contradict Higgins et al.'s (2005) in the same field. Higgins et al. (2005) conclude that the use of the IWB has a positive effect on low-achievers of English as a first language, as opposed to Masera who indicates that low-achievers did significantly worse while their teachers were using the IWB. The different ages of pupils in these particular studies might explain several differences in the overall outcome. But since both studies focus on primary schooling, the contrast is striking.

Overall, none of the above studies indicates that the use of IWBs is helpful to any group of pupils. Having said this, as presented in previous sections, effective teaching is reflected in raising each pupil's level of skills, knowledge and understanding. As long as a teacher's work is mainly related to whole-class teaching in a mixed ability class, one would expect the IWB to have a positive effect on both low and high achievers. Were some pupils to benefit more than others according to their capabilities, specific features and activities could be exploited to support either low or high achievers? This remains, unfortunately, an assumption.

Comparing the IWB with other sources and techniques

Being the most difficult category in extracting conclusions because of the diversity of the methodologies and the conclusions of each study separately, it becomes apparent that research has been somewhat varied in understanding the impact of IWBs. The indications are that younger pupils learn better when taught vocabulary actively, rather than through using the IWB, yet it seems to have a positive effect on Year 6 and 8 (high-school) pupils' mathematical performance. Results in favor of the IWB can be understood if one accepts that the instructional method compared to the use of IWB - the projector and Programmed Learning Sequenced (PLS) - seems to be more effective than the traditional method (no technological equipment). In each case, it is important to understand the nature of traditional instruction in any comparison.

Table 4 Length of time of IWB use

STUDIES	Pre-post testing	Control - experimental group	Other strengths	Other Weaknesses	Conclusions/Statistical details
Rains (2011)	X	X		Sampling groups based on the years of IWB use are unequal. (Using the IWB for: 1 year-99 pupils, 2 years-87 pupils, 3 years-14 pupils). Poor statistical analysis lacking significant levels.	IWB use has a significant effect only on Geometry and Algebra (ANOVA). This is related to a 3 year use of IWB by 14 pupils! Thus, there are no significant evidence to conclude otherwise, other than that IWB use has no significant effect on scores
Campbell (2010)	✓	✓	Nice and well-explained study	No statistical analysis regarding scoring among all pupils (only among certain groups based on gender, income and ethnicity)	By comparing the improvement from pre to post test mean scores among the two groups of pupils, it is obvious that IWB has no significant effect.
Higgins et al. (2005)	✓	✓	Sampling (5000 pupils Year 6 pupils), well-designed, strong methodological body with additional methods applied to enhance validity, excellent statistical analysis	---	IWB is associated with some improvement in scores during 2 nd year of use (effect size 0.09) which is not sustained the 3 rd year (effect size -0.10). Thus, we can conclude that IWB has no significant effect on scores.
Somekh et al. (2007)	✓	X	Sampling (7000 pupils), Detailed statistical analysis	Confusing and difficult to understand methodology: Scoring is presented as point scores equating to expected months of learning. Data presentation in the beginning does not correspond to the detailed analysis; non-IWB group is not included as presented in the beginning. Each pupil's progress was paradoxically compared to his/her own length of exposure to IWB use. Without a sustained and similar exposure, at least among classes of pupils, findings are controversial and complicated to analyse	IWB has a significant effect on scores. Validity and reliability of the statistical analysis are strongly questioned

Classroom Interaction

There are five studies in this category and they are presented descriptively, mirroring their qualitative dimension in the best possible way.

Higgins et al. (2005) investigated the type of discourse during IWB and non-IWB literacy and numeracy lessons in two consecutive years. Initially, it seemed that answers lasted longer during the IWB lessons compared to non-IWB lessons ($p<0.001$) and pauses were briefer ($p<0.001$). Teachers' explanations and uptake questions lasted longer in non-IWB lessons ($p<0.05$ and $p<0.001$ respectively). But when analyzing the data by each year, there was an increase of answers in the IWB lessons only in 2003, settling back down in 2004. Similarly, the decrease of pauses and teacher explanation in IWB lessons was temporary.

Such results indicate that the IWB has the potential to change a lesson's structure and enhance a classroom's discourse, keeping in mind the first year's results. But without sustainability this potential is minimised, while evolution in pedagogy constitutes the key to secure it.

Kennewell et al. (2007) gathered data in two phases like Higgins et al. (2005); in Phase I data came from both IWB and non-IWB classes while in Phase II only from the IWB. Overall, in Phase I "no significant difference" was found between IWB and non-IWB lessons, but there was a habit across the non-IWB using teachers to demonstrate a greater proportion of dialogic teaching. But the same teachers appeared to be less effective in Phase II. Kennewell et al. argue that this could be a short-term dip in effectiveness while gaining expertise in using new technology. In contrast, Higgins et al.'s (2005) study indicates that through the first year of IWB use there was an effective interactivity boost. More importantly, differences in attainment across the whole sample were found to be related to the level of interactivity in teaching rather than the use of IWB.

Swan et al. (2010), though excluded in the analysis of the first category, applied a different method to investigate the use of IWB in a qualitative way. They compared teachers' own reports through an online self-report system in which each teacher commented on the type and frequency of IWB use. Results indicated that teachers of high-achieving students were using the IWB more often than the others. The accuracy of this data can perhaps be questioned since teachers might not be precise or exaggerate about the frequency of IWB use for the sake of the study. Nevertheless, it is interesting that there is an association between performance and reported use.

Teachers of higher-achievers focused on things like visualization of concepts by having their students actively construct representations on the IWB (e.g. building fractions, designing PowerPoint presentations) while they also used it for brainstorming and interactive editing. The other group of teachers referred to activities that could be related to the use of a projector, such as PowerPoint presentations, the timer function, pupils correcting sentences, and less demanding activities. Teachers who are able to explain and comment on the IWB's effective features and use are more likely to use it more often. However, as shown above, no causal connection can be claimed between the IWB and high-scoring because scores were only measured once so it cannot be assumed that this intervention led to higher scoring.

Winkler (2011) conducted observations during IWB lessons with feature-trained and non-feature trained teachers. Two forms of data were gathered, and observation checklists. Feature-trained teachers had higher mean scores in both measures and this was statistically significant (observation rubrics: $p=0.027$, observation checklists: $p<0.0005$). However, the two groups of teachers should also have been observed before the intervention, since it is possible that this difference existed prior to training, and it cannot be assumed that training led to such differences. Also, the observed effectiveness and quality lessons of the feature-trained teachers is not triangulated with pupils' learning, indicating that even when more interactive lessons were observed with the use of IWB, there is still no clear link to learning outcomes.

Hwang et al. (2006) applied a voice recording system through the IWB to teach fraction division problems which enabled pupils to record their own oral explanations about the solutions, and to comment on others' solutions or reply to each other's arguments. The innovation was facilitated by IWB technology. Not surprisingly, comparisons made between pupils' achievement and performance in oral explanations indicated that higher achievers performed better in commenting during lessons. Additionally, after using this system in lessons, pupils completed questionnaires and presented their responses to a number of statements. It is notable that among the statements the pupils strongly agreed with the following:

"I can grasp various math solution methods through studying others' solving processes on the ...whiteboard system"

"It is helpful to math problem solving using voice playback to listen to others' oral explanation about their solving methods." (p.115)

Once more, such results are in line with our theoretical perspective. Pupils' learning is enhanced when they get opportunities to exchange their opinions verbally and to articulate and understand a specific mathematical problem, and, in this specific example, the IWB enables them to do this using a voice recording system. Of course, this is not to say that mathematical problem solving becomes easy through such technological innovations. Indeed, Hwang et al. (2006) state that it was hard for most pupils to truly understand and explain the difficult mathematical problems, and even when they solved them arithmetically it did not mean they always understood the solution.

It should also be noted that this kind of IWB application also offers teachers a view of pupils' level of skills and understanding that cannot be seen in any other way, at least not so quickly and openly.

Conclusion

Regarding the first research question, there is a general consensus across the studies of this review that IWBs have not raised pupils' achievement levels, at least as measured by tests of attainment. Similar results across a diversity of studies perhaps indicates the need for more longitudinal studies. Most studies do not take into account the novelty of the IWB's application, and longer-term studies could explore the development of specific features of the technology and of any further potential. It is crucial for future research on pupils' attainment to adopt designs where claims can be made based on progress or additional improvement made by learners.

Moreover, it does not seem that the IWB necessarily impacts on the lesson's quality as there were no consistent effects across the studies, particularly related to a control group. There appears to be considerable variation in the ways in which IWBs were used, with some studies indicating benefits in relation to lesson quality, and others not. This is partly related to the training and support provided to teachers. However, the potential of the IWB can be understood through research similar to that of Hwang et al. (2006), who designed a web-based multimedia system which enabled voice recording through the use of the IWB.

Thinking about the second question, the most interesting result, we find, which supports approaches based on dialogic teaching is identified by Kennewell et al. (2007). They conclude that differences in attainment were connected to the level of interactivity in teaching while improved learning and attainment was associated with more dialogic interactivity. This review's conclusions are in line with Kennewell et al.'s argument that the IWB was not found to have any necessary effect on either scoring or on classroom interactivity. If effects were found in one of the two areas of investigation, then the connection between quality interactivity and improved attainment would be questioned, assuming that scoring represents pupils' knowledge and thus can reflect progress in learning.

Finally, referring to the third research question, it becomes clear that the diversity of the use of the IWB lies across three major categories: 1) the subject taught, 2) ages of pupils, and 3) particular type(s) of use. Thus, while a particular application of the IWB can be effective (e.g. Huang, Liu, Yan, & Chen, 2009), another might not impact positively on pupils' learning (e.g. Masera, 2010). This reflects the IWB's complex potential and how a single technological device can be exploited in such diverse ways. The indications are that it

is not merely about the technology and its uses, but about aligning its use with more effective and dialogic approaches to teaching.

Dialogic teaching, of course, does not require technology. Indeed, Beauchamp and Kennewell (2010) argue that the wider literature supports the move towards more dialogic teaching, but that there is greater potential in ICT to support dialogic teaching than witnessed presently, underpinning the need to shift towards a more active role for learners in orchestrating resources to support their own learning.

Conclusions of this review may not constitute a fault line in the field of research on the IWB, but they are exceptional because they were generated by looking systematically at an international group of studies. However, it is strongly argued here that further inquiry driven by the conclusions of this review could determine such potential.

Further discussion

Interestingly, the impact of the IWB on classroom talk and summative assessment is consistent, thus it can be suggested that it enhances the theoretical framework adopted. Offering opportunities to pupils to elaborate and discuss, enhances their learning, and this learning will be mirrored in the improvement in scoring; as a result, no improvement in the quality of classroom talk leads to no increase in scoring. Having said this, it is also implied here that summative assessment offers substantial insight to students' learning. This issue, however, is very complex and needs to be addressed elsewhere since it had arisen after thinking about the results mentioned previously. More precisely, it has evolved around the concern that, perhaps, the pervasiveness of a traditional type of classroom talk is strongly related - and limited to - a reproduction of knowledge and processes that aim at succeeding in standardized forms of testing.

The content of summative assessment is the crucial factor in what kind of learning it addresses. Its significance and necessity have already been claimed. For example, in maths, problem solving in unfamiliar contexts is an increasing demand from employers and universities, but this factor is "neglected in most examinations of maths and, consequentially, in classroom teaching" (Jones, Swan, & Pollitt, 2015, p. 151). Jones et al. support that teaching on problem solving is shaped by, and for, the examination. Indeed, Greatorex and Malacova (2006) found that any coursework or examination is closely related to the teaching strategies. This said, research on interactive teaching practices and summative assessment should be synchronized in a realistic perspective to impact positively on educational systems.

Moreover, it seems that within the existing patterns of testing and examinations in secondary education, it is rather challenging to assess skills such as abstract thinking and reasoning. For example, the maths General Certificate of Secondary Education (GCSE) taken at the age of 16, in England Wales and Northern Ireland, mostly consists of short items testing memorization and duplication of routine procedures (Noyes, Drake, Wake, & Murphy, 2011 as cited in Jones et. al., 2015). Similarly, PISA is delivered as a multiple-choice test of short answers (Murphy, 2010). In other words, the education system demands from students the ability to respond effectively to prescribed types of testing. Besides, this formula more often than not will secure them a qualification or place in a university, as already elaborated above. Educators prepare students practically for such types of testing from early schooling to high-school, and consequently their teaching is shaped by, and for, them. In addition, the importance of developing and sustaining competence in maths education from early years is broadly recognised (Dorman, Adams, & Ferguson, 2003; Gifford, 2003).

Similar concerns are also evident by the addition of a new domain in the latest PISA, in 2015 (OECD, 2013), called "Collaborative Problem Solving":

Collaborative problem solving competency is the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution. (p. 6)

Thus, in order to truly transform an educational system, changes in teaching and testing should be reciprocal. Consequently, it is crucial to investigate the interplay between interactive teaching and different patterns of summative assessment, including the existing ones. Discovering the interplay between scoring and classroom interaction becomes critical, as it would be naïve to assume that this relationship is unambiguous or linear. To insist on this point of view would be to inhibit the consolidation of more interactive teaching practices by establishing connections with diverse forms of formative and summative assessment.

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