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Research Article

The Effects of IWB Use on Mathematical Attainment: An Evidence Synthesis of the Literature

Dr. Hamad Al-Halaibi
Department of Curriculum and Instruction, Imam Abdulrahman Bin Faisal University, Saudi Arabia

Professor Allen Thurston
School of Social Science, Education & Social Work, Queen's University Belfast, United Kingdom
a.thurston@qub.ac.uk

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ABSTRACT

The manuscript addresses the gap in the existing knowledge regarding how interactive whiteboards (IWB) influence mathematical attainment within elementary, middle, and high schools. An evidence synthesis of the literature is presented, which examines the impact of IWB on the mathematical attainment of students aged 5-18. The search included twelve bibliographic databases: Best Evidence Encyclopaedia (BEE), Education Endowment Foundation (EEF), ERIC, JSTOR, Google Scholar, Web of Science, SCOPUS, PsycINFO, PsycArticles, PROQUEST Dissertation and Thesis, and WorldCat. Additionally, the Directory of Open Access Journals (DOAJ). Systematic analysis of reported studies indicated that IWBs improved student attainment in mathematics relative to other methods identified within the studies, with a mean reported effect size of d=+0.32, 95% CI [0.15, 0.50]. This effect size suggests a small to medium effect following Cohen's d benchmarks.

INTRODUCTION

Educational technology tools such as the IWB have been broadly used in the classroom (Hendawi & Nosair, 2020; Pour, 2013). Within the United Kingdom, 100% of primary schools and 98% of secondary schools have IWBs installed (Ghavifekr & Rosdy, 2015). However, there is limited evidential research on the extent of the use of IWBs or details of the correlation between improved mathematics attainment outcomes (i.e., the performance level of students in mathematics, as measured by the test) and IWB use in teaching practice.

Zevenbergen and Lerman (2007) examined the use of IWBs about measures of pedagogy using a productive pedagogical framework developed by Gore et al. (2004) to examine IWB use in middle school classrooms. Taking Engestrom's (1999) theory of Third Generation Activity as a starting point, the researchers examined tensions resulting from introducing the IWB to the mathematics classroom. Zevenbergen and Lerman (2007) studied ICTs in mathematics classrooms for four years in Australia. The IWB aspect of their study focused on two schools, one based in Queensland and one in Victoria. The focus was solely on using IWBs over Information and Communications Technology (ICT) in five classrooms to determine effects. Data were collected by video observations from which the observer rated the lesson against selected criteria. Data collected identified some 'worrisome' scores, which indicated that the effectiveness of IWBs is limited, showing very low levels of quality learning potential. Upon reviewing the observations, the au-

authors stated that 'despite the low scores, there were few behavioral difficulties with the students.' Still, nine of the 20 pedagogies researched within the study scored substantially lower when using IWBs over other ICT methods, indicating potentially low mathematical learning levels.

There is currently limited systematic evidence regarding the effects of using technology, including IWBs, on student achievement in mathematics. Cheung and Slavin (2011) conducted a meta-analysis of the impact of educational technology applications on mathematics achievement in grades K-12 (students aged 5-18). Seventy-five qualified studies, involving 56,886 K-12 students in 45 elementary school studies (n=31,555) and 30 secondary school studies (n=25,331), were included in the analysis. The selected studies were identified through a search of educational databases (e.g., JSTOR, EBSCO, Education Resources Information Centre (ERIC), Psych INFO, Dissertation Abstracts), web-based repositories (e.g., Google Scholar), and educational technology publishers' websites, using different combinations of keywords (e.g., educational technology, instructional technology, computer-assisted instruction, interactive whiteboards, multi-media mathematics interventions, etc.). All the studies selected lasted for a minimum of 12 weeks as the focus of the research was to determine if interventions with a duration of 12 or more weeks had lasting effects on student attainment. Effect sizes (ES) were computed as the difference between experimental and control groups. A comprehensive meta-analysis was conducted after calculating individual effect sizes for 75 studies. Results demonstrated that technology applications in education, including IWBs, commonly produce a positive, modest effect size (ES=0.15) compared to methods using only a blackboard and instruction. The study did not compute any specific effect sizes for IWB use.

A systematic review on the use of IWBs by Kyriakou and Higgins (2016) included 16 studies. Four of these studies (Campbell, 2010; Hall & Higgins, 2005; Rains, 2011; Somekh et al., 2007) included teacher training in IWB use. The four studies showed an advantage in the efficacy of IWB instruction over the remaining 12 studies, which did not include teacher training. Kyriakou and Higgins (2016) reported that the 16 studies included in the review covered several academic subjects. Twelve of the academic subjects included mathematics, while eight studies indicated improvement on the subject of mathematics (Hall & Higgins, 2005; Huang et al., 2009; López, 2010; Somekh et al., 2007; Swan et al., 2010; Thompson & Flecknoe, 2003; Watt, 2011; Winkler, 2011). Seven of the 12 studies examined student attainment in mathematics in terms of scoring (Hall & Higgins, 2005; Huang et al., 2009; Martin, 2007; Masera, 2010; Somekh et al., 2007; Swan et al., 2010; Thompson & Flecknoe, 2003). Only four of these provided evidence of improvement in attainment outcomes. Results from Higgins et al., (2005) study provided evidence that despite existing improvement in attainment during the second year of use (ES=0.09), such improvements were not maintained in the following year (ES= -0.10). The result suggests a Hawthorne effect that may undermine the results' integrity, particularly the relationships between variables.

Given the scope, range, and date of previous publications, and evidence syntheses looking at mathematics attainment and the use of interactive whiteboards, then this evidence synthesis aims to update existing knowledge in this important area of research.

MATERIALS AND METHODS

The methods used within this evidence synthesis are similar to those used by Slavin et al. (2009), who defined the procedures for conducting as best-evidence synthesis in his Best Evidence Encyclopaedia (Slavin, 1986). This evidence synthesis aims to address gaps in the existing literature and bring previous systematic reviews examining the impact of IWB usage in mathematical attainment up to date.

Research Question

The evidence synthesis aimed to answer the following research question:

'What does the previous research suggest about the impact of IWB use on mathematical attainment in students aged 5-18 over the last decade?'

Inclusion and Exclusion Criteria

To enhance the strategic search for this systematic literature review and ensure the accuracy of results, it is essential to include inclusion/exclusion criteria. The review applied the following inclusion criteria:

- The full text of studies must be accessible.
- Publications must be sufficiently recent to ensure the exclusion of outdated technologies and research. For this systematic literature review, only studies published after 1st January 2009 were considered both because IWB us age has increased since then and technological advances in software were evident from 2009 onwards.
- Studies must be written in English to eliminate the influence of language bias in this research and the researcher's ability to read and interpret findings.
- Only those studies that used randomized control trials (RCTs) or a quasi-experimental design with matched comparison groups (QEDs) were included.
- Mathematical attainment must be measured with a test to measure improvement from baseline to post-test or post-test comparing the experimental and control groups.
- Enough information must be reported to calculate effect sizes.
- Students must be from primary/junior/middle/elementary/senior high school/secondary school/grammar school, compulsory schooling.
- Six-hour minimum teaching using IWB to minimize the Hawthorne and Halo Effect.

Search Strategy

The following search strings were developed to search data bases:

(IWB OR "interactive white*board" OR "electronic *board" OR "digital *board" OR "smart white*board") AND (Math* OR Computation OR numeracy) AND (primary OR junior OR middle OR

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OR elementary OR high school OR *high school OR "secondary school" OR "grammar school" OR compulsory schooling) AND (assessment OR score* OR attainment OR evaluation OR achievement OR success OR test* OR outcome* OR performance).

Following the procedure advised by Kyriakou and Higgins (2016), the search included twelve bibliographic databases: Best Evidence Encyclopedia (BEE), Education Endowment Foundation (EEF), ERIC, JSTOR, Google Scholar, Web of Science, SCOPUS, PsycINFO, PsycArticles, PROQUEST Dissertation and Thesis, and WorldCat. Additionally, the Directory of Open Access Journals (DOAJ) was reviewed on 20 April 2019. A total of 33 journals published the full text in English and related to education and technology were found. Of these, one was not accessible, and any of the selected databases had not indexed four; therefore, a manual search was conducted on these journals. Another search was also performed on the EEF website, where a further 31 projects on mathematics were found; however, none of these used IWB technologies.

Calculating Effect Sizes

The following formulas were used to compute effect sizes.

$$d_{Cohen} = \frac{M_{E,Post} - M_{C,Post}}{SD_{C,Post}}$$

Cohen's d for pre-test and post-test:

$$d_{Cohen} = \frac{(M_{E,Post} - M_{E,Pre}) - (M_{C,Post} - M_{C,Pre})}{\frac{(SD_{C,Pre} + SD_{C,Post})}{2}}$$

Where $M_{E,Pre}$ is the mean for the experimental group at pre-test; $SD_{E,Pre}$ is the standard deviation for the experimental group at pre-test; $M_{C,Pre}$ is the mean for the control group at pre-test; $SD_{C,Pre}$ is the standard deviation for the control group at pre-test; $M_{E,Post}$ is the mean for the experimental group at post-test; $SD_{E,Post}$ is the standard deviation for the experimental group at post-test; $M_{C,Post}$ is the mean for the control group at post-test; and $SD_{C,Post}$ is the standard deviation for the control group at post-test.

The variance of Cohen's d (Cooper, 2017, p. 165) is as follow:

$$v_d = \frac{n_E + n_C}{n_E \times n_C} + \frac{d^2}{2 \times (n_E + n_C)}$$

Where n_E is the sample size of the experimental group and nC is the sample size of the control group.

The 95% confidence interval for Cohen's d (Cooper, 2017, p. 165) is:

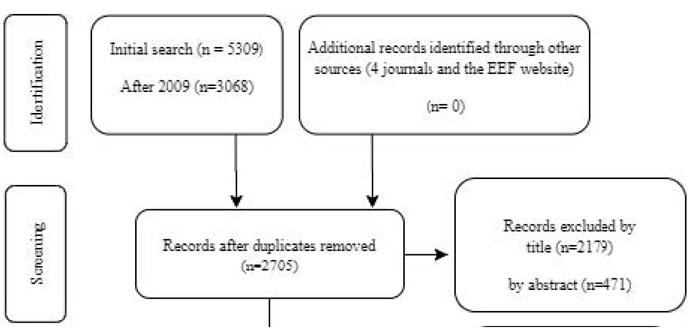
$$[d - 1.95 \times \sqrt{v_d}, d + 1.95 \times \sqrt{v_d}]$$

The Data Extraction Process

The data extraction process adhered to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards and is summarised in the PRISMA flow diagram in Fig. (1). As evidenced by Liberati et al. (2009), the PRISMA model is an evidence-based set of minimum items developed to improve systematic reviews and meta-analyses reporting.

Screening and selecting studies

Initial searches resulted in 5309 studies, out of which 3068 were published since 2009. These results were then imported into ProQuest RefWorks. However, after removing duplicates, 2705 studies remained. After screening these studies by title and abstract, 55 studies remained for full-text screening. Six papers were not full text, and three were not in English. Eight studies were not related to mathematical attainment. Eight papers were identified as neither randomized controlled trials (RCTs) nor quasi-experimental designs (QEDs) and therefore were eliminated from the search. Ten studies were deemed unreliable because they did not measure mathematical attainment. Four articles did not report mean or standard deviations for attainment results within the experimental and control groups. Four papers were not the right age group. This process produced a set of 12 studies for inclusion in the quantitative synthesis, as shown in Figure 1; brief descriptions of these studies are presented in Table 1. Finally, means and standard deviations for each study were used to calculate the effect size for each study based on formulas as evidenced above.



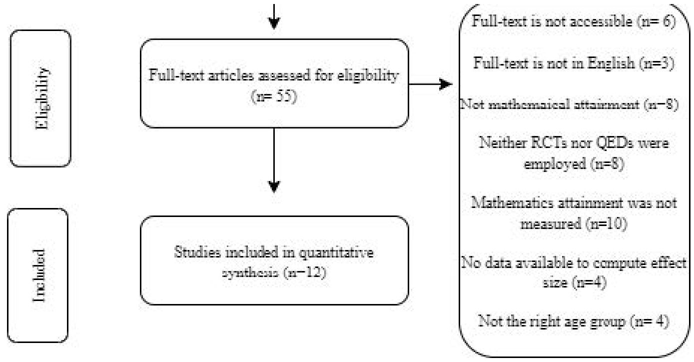


Figure 1: PRISMA flow diagram for systematic reviews.

RESULTS AND DISCUSSION

Description of Included Studies

As shown in Table 1, this review included 12 studies: four journal articles, six theses, one book chapter, and one conference paper. The sample size of the included studies ranged from 47 participants (Turan, 2014) to 4986 (Higgins, 2012). The included studies involved a total of 15542 participants. They were conducted in various countries, including the Taiwan (Huang et al., 2009), the UK (Higgins, 2012), the USA (Lutz, 2010; Riska, 2010; Watt, 2011; Winkler, 2011; Stout et al., 2013; Amaker, 2014), Turkey (Tunaboylu & Demir, 2016), Jordan (Nejem & Muhanna, 2014), Cyprus (Turan, 2014) and the Netherlands (Cabus et al., 2017).

Study	Publication Type and Location	Sample	Research Methods	Intervention	Outcome Measure
1. Turan (2014)	Journal article Cyprus	47 students split into two groups of 23 in experiment and 24 in control group	Quasi experimental study	Pre-test data collected via a maths test. Same test administered at post-test. Duration: 1 academic year	The study was designed to determine the efficacy of IWB use on mathematical attainment by using cartoon characters within IWB software to facilitate successful outcomes. Pre- and post-test scores were used to determine successful hypothesis data as was evaluated using SPSS 16. Results determined that the experimental group achieved higher, successful maths outcomes at post-test measuring a large effect size (Cohen's d=1.24).
2.Nejem & Muhanna (2014)	Journal article Jordan	103 seventh grade students from male governmental schools in the first Amman region in Amman city in the second semester of 2012/13 academic year	- Randomly chosen experimental 52 students and 51 in control group - Pre- and post-test	Experimental group using IWB vs control group using expository methods and board. Dosage: 1 semester	Pre-test applied to both the control and experimental group. All tests prepared by researchers. An achievement test was used to measure mathematics achievement and retention among students in the Geometry unit from the K-7 mathematics textbook. Tests were administered immediately after the study then followed up two days later and again at four weeks after the experiment to measure retention and achievement. Findings indicate a statistically significant difference between the means of the control and the experimental groups in the achievement post-test ($\alpha < 0.05$) in favour of the experimental group.
3. Amaker (2014)	Thesis United States of America (USA)	Participants included 95 fifth grade students (2007-08) and 48 5th grade students (2012-13) with learning disabilities. 58 elementary school teachers are also included. 2007/08 cohort	The the study is a qualitative, quasi-experimental.	Data was collated via teacher surveys and questionnaires. Duration: 1 academic year	The study was designed to investigate the impact of IWBs on the scores achieved by special education (Learning Disabilities Self-Contained) elementary students on the Palmetto Assessment of State Standards (PASS) test, a standardised test used by the state of South Carolina. The data was analysed using a statistical analysis software application (SAS 9.1). The results indicate that IWB use is beneficial in mathematical attainment with analysis of results demonstrating a highly significant difference in mean scores between the experimental and control group.

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		contained 66% African-American students and 32% Caucasian students. In the 2012/13 cohort, 48% were African-American and 32% described as Caucasian (dichotomous variable in study of Caucasian or non-Caucasian).			
4. Tunaboylu & Demir (2016)	Journal article Turkey	58 seventh grade students from one secondary school in the 2015/16 academic year in Ankara. No breakdown given of the participants' gender, racial group or economic status.	- A quasi-experimental design - Pre- and post-test	Experimental group using IWB vs control group using business as usual. Dosage: 12 hours over three weeks	Researchers developed a tool, the "Math Equation Equality and Achievement Test", for use as the pre-test and post-test to measure student achievement in the experimental and control groups. The ANCOVA model showed a significant effect size of post-test scores with group variables and pre-test scores of the achievement test [F(2, 55)=10.454, p<0.05]. It can therefore be said that teaching maths with an IWB is more effective in improving student attainment than the business as usual group..
5. Huang et al. (2009)	Conference paper Taiwan	Two sixth grade classrooms: 60 students aged 11-12 in the same school. No gender breakdown and no SEN difficulties reported.	- A quasi-experimental design - Pre- and post-test	Experimental group (classroom using IWB) vs control group (classroom using a projector). Dosage: approx. 20 hours	Researchers aimed to answer two questions about the impact of IWB on student learning, motivation and student attainment. Participants in the control and experiment groups were subdivided into six groups. Researchers used achievement tests created from questions from mathematics textbooks. The entire class in the experimental group increased their scores by more than ten marks while the control group rose by only two marks. The heterogeneous grouping was used based on pre-test scores. There were statistically significant differences (p=0.003) between instruction with the IWB and instruction with an overhead projector.
6. Watt (2011)	Thesis USA	72 Year 8 students in a middle school. Sample comprised of 25 boys and 47 girls 68 students were aged 13 Three students were aged 14 and one was aged 15. The sample was 51% Hispanic, 43% African-American and 6% others.	- A quasi-experimental design - All students were taught in both types of instructions; pre- and post-tests	Students were taught using two instructional methods: a PLS (Programmed Learning Sequence), an instructional resource that programmes content to suit many learning styles, and IWB (Geometer's Sketchpad and TI Smart view software). Learning styles: the clue to you (LS:CY) administered to identify participants learning style preferences. Learning Style Inventory (LSI) was used as a comparison. Dosage: 7 months	Participants administered the LS: CY! Test to determine learning style. Repeated administration of test ensured reliability. Scores compared with those of students administered the Learning Style Inventory (LSI) used as a comparison. Students were administered a test comprised of exam questions from previous years. Test-retest coefficients were computed. All tests were conducted 45 minutes after treatment where students were randomised into classes, enhancing the validity of data extrapolated. Students were also anonymised with an identification number. A 2x2 randomised block of variance ANOVA was used to analyse achievement. The results reveal that students gained significantly higher (p < .001) test scores in mathematics on the post-test compared to pre-test for both instruction with the IWB and the PLS. However, significant differences (p < .01) were not found between the mean IWB and PLS post-test scores. The two methods of instruction appeared to be equivalently effective.
7. Winkler (2011)	Thesis USA	18 teachers with an average of 19 years' teaching experience. 75% had a Bachelor of Science degree and 18% held a Master of Education while 11% had an education specialist degree. 311 elementary students from kindergarten, first, fourth and fifth grade at the same school. Experiment group consisted of 101 males and 83 females. Of these 4 students were Asian, 62 were African-American, 30 Hispanic and 88 students were Caucasian. 63 students in the treatment group are economically disadvantaged. In the control group, 53 students are male, 74 are female. Of these, 3 are Asian, 57 are African, 30 are Hispanic and 36 Caucasian. 99 students in the control group were economically disadvantaged. While the school does have SEN provision, no students described as SEN were reported.	- A quasi-experimental design - Pre- and post-testing using SAT; pre- and post (training)	Students' achievement and teachers' participation in specially designed training related to effective use of IWBs (experimental group) vs students' achievement on standard achievement tests (SATs) with no specialised teacher training other than the usual (control group) Dosage: 17 hours	The objective of this research was to determine how professional development in IWB use relates to the impact of IWB use on student attainment. Participants were divided into feature trained and non-feature trained. Feature-trained participants availed of professional development in IWB use before the experiment. Data gathered pertained to student achievement comprised the pre- and post-test scores of students on the Standardized Test for the Assessment of Mathematics (STAR Math) for first, fourth and fifth grades. The difference between pre-intervention and post-intervention mean scores was found to be statistically significant, indicating higher achievement outcome among feature-trained groups.
8. Stout et al. (2013)	Thesis USA	979 students over two fifth grade only campuses in Texas, 829 of whom were economically disadvantaged. 808 students (384 males and 424 females) participated in the study. Of these, 48 were African-American, 819 were Hispanic, 97 were White, 6 were American Indian, 5 were Asian and 3 were mixed race. No details were provided for students with specific learning difficulties.	A quasi-experimental design	The experimental group in Centre A taught using IWB vs the control group in Centre B taught without IWB. Dosage: 1 academic year	The study aimed to determine if Spring 2011 Texas Assessment of Knowledge and Skills (TAKS) scores were different for low SES students taught using IWBs relative to low SES students taught without IWBs. The mean maths score for Grade 5 Centre A was 36.4 of a possible 44 points. The mean maths score for Grade 5 Centre B was 34.22 of a possible 44 points. The results of this study indicate that Spring 2011 TAKS scores were significantly higher, suggesting 'Centre A' students achieved increased attainment when taught by teachers using IWBs. The results showed that the efficient use of the IWB significantly increased maths proficiency with 0.25. The Cohen's d for the difference between the Centres A and B on the TAKS Mathematics scores was medium at 0.309 (Cohen, 1988). The medium effect size suggested these results are significant.
9. Lutz (2010)	Thesis USA	3461 students from the third, fourth and fifth grades in 16 elementary schools and two intermediate schools in a rural county in North Carolina in academic years 2007/08-2008/09. No breakdown was given on participant gender, racial group or economic status. However, the study was made comparable based on three categories selected from the 'No Child Left Behind' programme. African American enrolment, reduced or free lunch and exceptional children enrolment.	A quasi-experimental design	Experimental group using IWB vs control group using expository methods. Dosage: 6 hours	The study was designed to examine the effect of IWB on End of Grade (EOG) scores and teacher instruction. The control group of 1251 students did not avail of IWB-assisted instruction, while the experimental group of 1636 students did. Data analyses were conducted sequentially examining the effect of IWB s on two outcomes. As EOG testing was already done and an ex post-facto design was employed, a limitation being lack of manipulation and control over the independent variable (IWB). Participants were not randomised in the study before the research began. Quantitative and qualitative data was collected and synthesised. Results indicate a statistical difference in outcomes for third and fifth grade improvement in achievement; however, no statistical difference was recorded for fourth grade results.
10. Cabus et al. (2017)	Journal publication The Netherlands	199 pre-vocational seventh grade students (99 girls, 100 boys) in the Netherlands. Students aged 12-13 years old. 15 students are described as being non-native. No information regarding SEN students was included.	Randomised control trail	Students participated in a maths intervention group in which the IWB was used to apply level differentiation. Dosage: 6 hours	The study was designed to determine the efficacy of specific training in IWB use on attainment scores. The teachers of experimental group classes using the IWB received specific training (Technological Pedagogical and Content Knowledge [TPACK]) in the use of the IWB in class. Control classes were taught by teachers without any formal training, who did not use the IWB in class. Results indicated a standardised effect size of 0.11, significant at the 6% level. It follows that IWB use is beneficial in inducing positive changes in mathematical attainment.
11. Riska (2010)	Thesis USA	173 fourth grade students (89 females, 84 males) from 6 elementary schools in a 7-mile radius in North Carolina. 80% Caucasian, 13% Asian, 4% multi-racial, 2% Hispanic, 1% African-American.	A quasi-experimental design Pre- and post-test	Experimental group classroom using IWB vs control group not using IWB. Dosage: 28 weeks	Participants were 51% female and 49% male. Outcomes used in the study to determine the impact of IWB use on the academic achievement of gifted students. Sample was not randomised as students were assessed by the state and deemed talented by state standards for gifted certification. Pre-test score was end of grade (EOG) result in third grade, post-test score was EOG result in fourth grade; the formula was devised by the state and used to determine the degree of growth for each student. EOG results were used as a means of testing, with results indicating no significant difference in the growth scores between the two groups of gifted students who participated in the research.
12. Higgins (2012)	Book chapter United Kingdom (UK)	2900 students in 67 schools in the first year, 2800 in the second year. No breakdown was given in relation to the gender, racial group or economic status of participants.	A quasi-experimental design	In the first year, initial impact of IWB after six months' use. In the second year, impact of IWB after 18 months' use. Dosage: 2 x 6-week blocks 12 months apart	Teacher instruction with IWB was 2 x 6-week blocks spaced 12 months apart involving two schools, one with IWB and one without. that the results showed higher mean scores for the school with IWB, demonstrating small effect sizes in IWB usage for mathematics. After 18 months of use, there was no significant difference between groups and effect sizes were negligible.

Figure 1: PRISMA flow diagram for systematic reviews.

Effect Sizes for the Included Studies

To analyze the results of the studies in this systematic review critically, the sample sizes (n), means (M), and standard deviations (SD) were used for the calculation of Cohen's d effect sizes. Cohen's d measures the standardized difference between the experimental and control groups means standard deviations. Accordingly, 20 effect sizes were extracted from 12 studies and sorted by size (Table 2). As shown in Table 2, student attainment measured between groups at post-intervention only and pre/ post-intervention ranged between d = 0.00 in Higgins's (2012) study of Year 2 and d = 1.24 in Turan's (2014) study. In this review, 8 of 20 dependent studies did not involve a pre-test. Overall, Table 2 and Figure 2 demonstrate that IWBs improved student attainment in mathematics relative to other methods identified within the studies with a mean reported effect size of d=+0.32, 95% CI

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[0.15, 0.50]. This effect size suggests a small to medium effect following Cohen's d benchmarks.

Author of Study / Focus of Study	Sample size		Pre-test		Post-test		Effect size 95% CI
	Exp	Con	Experimental M (SD)	Control M (SD)	Experimental M (SD)	Control M (SD)	
Turan (2014)/ Primary education	23	24	44.3 (14.61)	44.83 (19.34)	65.65 (18.24)	46.08 (13.18)	1.24 [0.617, 1.863]
Nejem & Muhanna (2014) Maths Achievement	52	51	4.92 (1.71)	5.18 (1.64)	22.78 (5.42)	18.59 (6.17)	1.14 [0.726, 1.554]
Amaker (2014)	48	47	Not available	Not available	579.04 (27.83)	550.05 (26.89)	1.08 [0.653, 1.507]
Nejem & Muhanna (2014) Maths Retention	52	51	Not available	Not available	19.84 (6.41)	16.03 (6.95)	1.10 [0.686, 1.514]
Tunaboylu & Demir (2016)	29	29	4.3448 (2.07)	4.6552 (1.82)	5.8621 (1.62)	4.7931 (1.54)	0.82 [0.286, 1.354]
Huang et al. (2009) Statistics and Pie Charts	30	30	80.97 (12.75)	82.17 (16.28)	92.58 (6.31)	84.53 (12.64)	0.64 [0.124, 1.156]
Huang et al. (2009) Solid Diagram	30	30	65.77 (18.69)	65.67 (18.75)	89.60 (8.40)	80.83 (13. 27)	0.54 [0.028, 1.052]
Watt (2011)	72	72	6.60 (2.30)	6.90 (3.22)	12.01 (4.42)	11.10 (4.51)	0.31 [-0.016, 0.636]
Winkler (2011) fifth grade	52	52	750.08 (85.32)	672.81 (114.48)	779.50 (89.60)	667.04 (111.44)	0.31 [-0.075, 0,695]
Stout et al. (2013)	441	284	Not available	Not available	36.40 (6.88)	34.22 (7.24)	0.30 [0.149, 0.451]
Lutz (2010) third grade	667	533	Not available	Not available	349.66 (8.22)	347.71 (8.29)	0.23 [0.123, 0.337]
Cabus et al. (2017)	80	119	7.95 (1.27)	8.16 (1.36)	7.71 (1.23)	7.65 (1.22)	0.21 [-0.073, 0.493]
Riska (2010) Paired Samples t-Test	107	107	Not available	Not available	6.85 (4.91)	5.98 (4.08)	0.21 [-0.098, 0.518]
Riska (2010)	107	107	359.18 (4.57)	360.04 (5.02)	366.03 (4.04)	366.03 (5.02)	0.17 [-0.138, 0.478]
Winkler (2011) first grade	34	33	369.00 (96.00)	354.58 (97.93)	407.24 (93.08)	379.55 (91.26)	0.14 [-0.338, 0.618]
Higgins (2012) Year 1	2892	2094	Not available	Not available	63.93 (21.00)	61.75 (21.06)	0.10 [0.038, 0.162]
Winkler (2011) fourth grade	48	20	621.21 (107.46)	689.35 (136.97)	649.04 (103.95)	709.30 (149.76)	0.05 [-0.47, 0.57]
Lutz (2010) 4th grade	439	674	Not available	Not available	348.64 (7.83)	348.42 (7.91)	0.03 [-0.093, 0.153]
Lutz (2010) 5th grade	530	618	Not available	Not available	352.68 (7.44)	352.44 (7.40)	0.03 [-0.093, 0.153]
Higgins (2012) Year 2	2824	1980	Not available	Not available	66.53 (21.41)	66.47 (21.20)	0.00 [-0.062, 0.062]
Combined effect size = 0.32 [0.15, 0.50]							

Table 2: Effect sizes for the included studies, in descending order

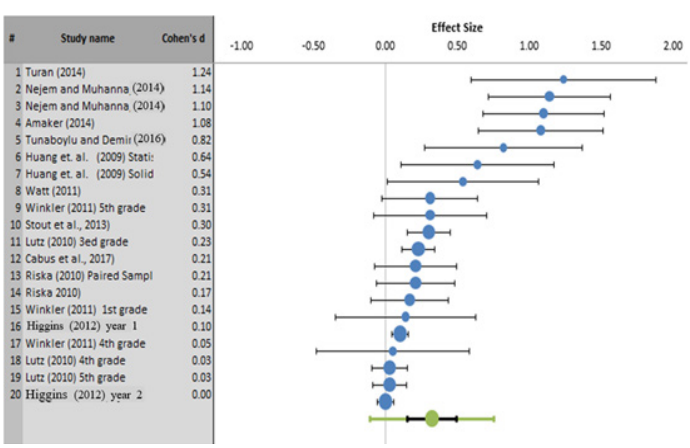

Figure 2: Forest plot of comparison between effect sizes of experimental group and control group

Studies	Pre/post testing	Control/ experimental group	Strengths	Weaknesses
1. Turan (2014)	**Yes**	**Yes**	- The aim of the study is explicitly stated, including two clearly defined research questions - Attainment tests validated and reviewed by experts - Data presented in tables	• Small sample size (n=47) • Only one school studied • Limited inclusion of relevant research; reduced rigour • While study is in English, numerous spelling, grammar and translation errors apparent • Poor explanation of methodology • Understanding of paper reduced due to poor translation • Limited discussion on findings • Results cannot be applied to local population • Difficulty in replicating study
2. Nejem & Muhanna (2014)	**Yes**	**Yes**	- Rationale for study is clearly defined - Two clearly defined research questions indicated and two hypotheses to be investigated - Clearly explained methodology - Results clearly explained - Hypothesis clearly explained - Retention was measured - Results are clearly presented and discussed	• Small sample size (n=103) • Lack of randomisation • Only one school studied • No breakdown of SES/SEN levels of students
3. Amaker (2014)	**No**	**Yes**	- The purpose of the study is clearly explained - Six hypotheses are included - Comprehensive critical review of relevant related literature included, enhancing rigour - Results clearly displayed in table format and discussed by author	• Study conducted at only one school • Study only focused on students with documented special needs. • Study was not limited to math, included other subjects • No randomisation took place for the study • Only fifth grade students included
4. Tunaboylu & Demir (2016)	**Yes**	**Yes**	- Aim of the study clearly defined - Authors included relevant studies - Study design enables replication - Clearly explained methodology - IWB use is emphasised - Results clearly displayed in table/graph format and discussed by author	• Small sample size 58 • Researcher states possibility of "Halo Effect" • SES/gender/SEN data not presented
5. Huang et al. (2009)	**Yes**	**Yes**	- Clear methodology presented - Appropriate study design - Data presented and explained clearly - Study can be replicated with a larger sample - Relevant studies included - Testing material verified by maths experts external to study - Pilot study conducted	• No clear research question identified • Only one school studied • Small sample size (n=60 students) • No breakdown of gender/SES/SEN students for comparison • No details of funding for the study identified
6. Watt (2011)	**Yes**	**Yes**	- Research rationale clearly explained - Three hypotheses clearly stated - Clear methodology presented - Comprehensive review of relevant related literature - Results clearly displayed in table format and explained by author	• Small sample size (n=72) • Disproportional gender difference in study, making it difficult to draw conclusions about attainment between genders • Generalisability of results limited as teachers created tests • If an alternative learning styles instrument had been used, the profiles of students could be different • If study was replicated with a larger sample size, study results could be different • Students exposed to varying degrees of IWB instruction prior to experiment
7.Winkler (2011)	**Yes**	**Yes**	- Study reviewed a clearly focussed question and included six hypotheses to investigate - Thorough literature search and discussion of research included - Relevant studies included - Clear methodology presented - Researchers reviewed studies to assess quality, enhancing rigour - Sample of 18 teachers and 311 students - Results can be applied to local population	• Participants drawn from only one school • Results may be different for other schools • Researcher conducted observation component of study, risking bias. • Blind observations would improve methodology • Volunteer teachers used, creating potential for teacher effect if different teachers are used • Reliability and validity of observation instruments would be beneficial. Teacher rubric and confidence survey were peer evaluated
8. Stout et al. (2013)	**No**	**Yes**	- Statement of research problem and significance of study clearly explained - Comprehensive critical review of relevant literature included, enhancing rigour - Research questions clearly defined - Important outcomes considered - Good sample size (n=979 students) - Study duration: one academic year, duration of study adds rigour to results. - Data and results tables clearly presented - Purpose of study clearly explained - Study can be replicated	• Two fifth grade schools chosen for study with Low SES with predominantly Hispanic Students where English was not their primary language • Sample sizes were unequal • Pre-test scores not given due to standardised assessment procedure • Internal validity of the study threatened
9. Lutz (2010)	**No**	**Yes**	- Rationale for the study clearly defined - Appropriate study design selected - Two research questions clearly stated - Comprehensive search for relevant literature, appraised by author, enhancing rigour - Large sample (13861 students drawn from two grades). - Study duration: two academic years duration of study adds rigour to results. - 18 schools participated, diversity of participants and sample size adds rigour to results. - Data and results tables clearly presented - Purpose of study clearly explained - Review of appropriate literature included	• Study conducted in a single rural school • No randomisation • No pre-test results, study used extant data • Researcher conducted focus groups; researcher bias assumed.
10. Cabus et al. (2017)	**Yes**	**Yes**	- Research question identified - Study reviewed a clearly focussed question - Appropriate design of intervention stated - Data presented in tables and discussion	• Research question not easily located • Results given but no effect sizes stated • Author could have explained results more clearly • Difficulty in interpreting results • Methodology not clearly stated, making study difficult to replicate • Structure of paper makes extrapolating information difficult
11. Riska (2010)	**Yes**	**Yes**	- The rationale for the study is clearly stated - Testing procedures explicitly stated and explained - 173 students over several grades studied, large sample size and diversity within sample with regards to age race and SES adds rigour to results focussing on gifted students. - Methodology clearly explained - Schools selected after comparative analysis with characteristics for each school defined in the study - Results clearly explained using graphs, charts and tables to aid interpretation. - Teachers required to use IWBs for 80% of teaching time - Study can be replicated with larger samples	• Only gifted students included in study • Lack of randomisation due to the nature of the study
12. Higgins (2012)	**No**	**Yes**	- Sample of 2900 students in first year and 2800 in second year of study - 67 schools participated, matched with a comparison group using previous years' attainment data - Methodology clearly explained - 2 x 12 weekly blocks of teaching with IWB instruction - Results clearly displayed in tables and discussed - Evaluation of interventions clearly displayed	• Absence of randomisation • No pre-test data given • No clear research question • Problematic design in terms of allocation bias (schools performing above national average were selected for study)

Table 3: Strengths and weaknesses of the included studies

Publication Bias

To assess the possibility of publication bias, the “trim and fill” procedure with random effects was shown for mathematical attainment to identify and correct funnel plot asymmetry. The Egger regression gives ‘the degree of funnel plot asymmetry as measured by the intercept from regression of standard normal deviates against precision (Egger et al., 1997, p. 629). As Figure 4.3 shows, the outcome of a t-test is significant (t=4.05; p=0.001), indicating there is a high risk of publication bias.

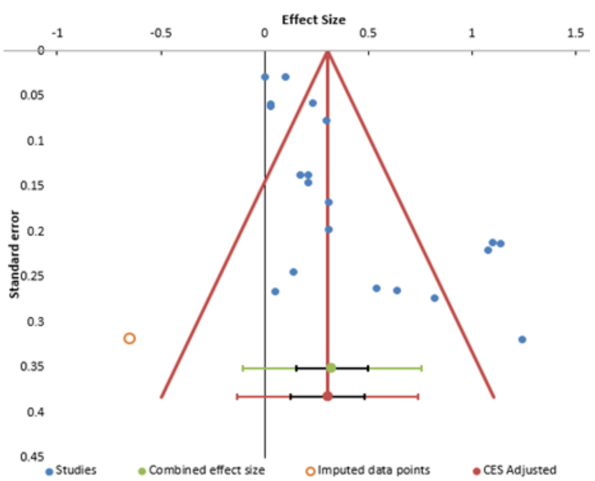

Figure 3: Funnel plot of standard errors Cohen’s d for experimental group and control group

Discussion

The review has concluded that IWB can assist with the teaching of children when learning numeracy. In comparison with the other teaching methods examined, such as lecture-based methods or PLS, IWB is a relatively new yet extensively used instructional teaching tool. Its effect on student achievement has been thoroughly explored and proven to be positive. Similar to other systematic evidence syntheses, there is a shortage of literature examining the effect on student learning achievement (e.g., Kiriakou and Higgins, 2016). Even fewer studies focus on a mathematics-specific environment using IWB technology. On the probability of evidence of the articles that we were able to identify and include in this evidence synthesis, the evidence suggests a positive impact of IWB use on students’ mathematical attainment. However, the merits of integrating IWB use into mathematics teaching seem to be conditional on the quality of the teacher professional development provided in the use of IWBs, e.g., Winkler (2011), who designed teacher professional development and reported positive effect sizes of +0.31, as well as the extent to which students make use of the IWB, e.g., Cabus et al., (2017) who reported positive effect sizes of +0.21. The efficacy of IWBs in facilitating attainment in different fields of mathematics seemed beneficial in traditional numerical mathematical fields (such as algebra and statistics) and the topological field of solid diagrams. It could be argued that its greatest benefit was seen in the field of Geometry, with the short- and medium-term outlook being positive, e.g., Watt (2011), Nejem & Muhanna (2014).

The Primary Schools Whiteboard Expansion Project (PSWE) report (Somekh et al., 2007) has provided evidence that the IWB is a very powerful tool in the hands of an experienced teacher or properly trained teaching assistant working with a small group. There is a need for basic training in pedagogies surrounding teaching literacy and numeracy and IWB use for teaching assistants (TAs). As observed in white and grey literature, it is often TAs rather than teachers who use the IWB for remedial work with small pupils.

Whole-class teaching, especially when conducted at the increased pace made possible with an IWB, does not address the specific needs of pupils who cannot grasp the relationships between symbols and words or concepts without help from the teacher.

For future research, it is essential to examine areas that have not been discussed to determine whether these areas would reduce the applicability of the results. Of the 12 studies, only Amaker (2014) included students with specific learning difficulties (SpLD), and the study demonstrated a large effect size (Cohen's d=+1.08). It would be pertinent for future research to ensure students with SpLD or special educational needs (SEN). Furthermore, the 12 studies neglected to determine the impact of IWB technology on the mathematical attainment of students with low SES. It would be beneficial to replicate studies employing problem-based learning and collaborative learning with problem-based learning on a larger scale to investigate the efficacy of these pedagogies further when employing IWB in mathematics.

Several limitations of this evidence synthesis have been identified. The small sample sizes and the few studies in this evidence synthesis have made it difficult to determine irrefutable effect sizes. The main problem with small studies is the interpretation of their results, in particular, confidence intervals and p-values. Faber and Fonseca (2014) state that samples should be neither too large nor too small since both have limitations that can compromise the conclusions drawn. As previously discussed, using smaller samples increases the chances of reporting false-positive results. A number of the studies included in this synthesis (Amaker, 2014 (n=95); Huang et al., 2009 (n=60); Nejem & Muhanna, 2014 (n=103); Riska, 2010 (n=173); Tunaboylu & Demir, 2016 (n=58); Turan, 2014 (n=47); Watt, 2011 (n=72)) came under scrutiny for their use of small sample sizes ,and have associated difficulty in extrapolating accurate and irrefutable effect sizes. This evidence synthesis of the literature allows interpretation of effectiveness from multiple similar studies, which is more valuable theoretically and statistically than an individual study. Despite this fundamental strength, this research should also be interpreted in the context of its limitations. The use of a small sample size affects the reliability of results as it leads to a higher variability, which may lead to bias. Hacksaw (2008) states that well-designed small studies can be valid, but it is important to interpret them carefully. While small studies can provide results quickly, they do not normally yield reliable or precise estimates. It is advisable not to draw definitive conclusions about an intervention, whether the results are positive or not. It should be considered that data extrapolated from small studies could be used to design larger confirmatory studies. Suppose the aim is to provide reliable evidence on the intervention of IWB use in mathematical attainment; the study should be large enough to provide the correct statistical power and take account of clustering effects within the data.

The search criteria for sources were limited to interventions reported in English. This exclusion of reports written in another language is a key review limitation, and it may decrease the accuracy of outcomes by excluding useful and relevant data (Moher et al., 1996). However, the limitation may be reduced since the papers included in this review drew information

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from various geographical locations, including the US, China, Turkey, and the United Kingdom.

This synthesis has helped clarify the literature's evidence regarding the positive impact that IWB use has on mathematical attainment. The data collected assisted in determining the advantages and drawbacks of using this technology for daily mathematics lessons amongst students in various class groups. Mostly, as several studies concluded (Cabus et al., 2017; Huang et al., 2009; Nejem & Muhanna, 2014; Stout, 2013; Tunaboylu & Demir, 2016; Turan, 2014), the IWB was seen as a useful tool for increasing attainment of mathematical skills. Generally, it was reported that teacher training in IWB had a positive impact on creating a more productive classroom environment.

CONCLUSION AND RECOMMENDATIONS

The study on evidence synthesis provides a useful baseline upon which further research can be predicated. However, given the few studies included in the review, after selective filtering of the sources based on the research literature, it is important to note the current shortage of robustly designed studies investigating the effects of IWB use on students' mathematical attainment. Therefore, further research to address this lack of robust evidence is needed, with a particular focus on increasing the evidence garnered from high-quality RCT experimental designs that utilize valid and reliable measures of students' mathematical attainment. In addition, further research involving systematic classroom observations, coupled with the teacher and/or student interviews, would help provide evidence regarding the particular teacher characteristics and classroom practices that are conducive to promoting high-quality mathematical learning using IWB technology.

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