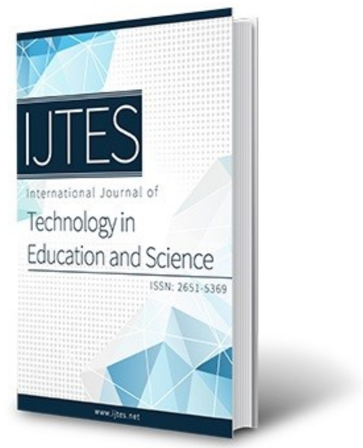

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To cite this article:

Aspiranti, K. B. & Larwin, K. H. (2021). Investigating the effects of tablet-based math interventions: A meta-analysis. *International Journal of Technology in Education and Science (IJTES), 5*(4), 629-647. https://doi.org/10.46328/ijtes.266

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International Society for Technology, Education, and Science (ISTES): www.istes.org

International Journal of Technology in Education and Science

2021, Vol. 5, No. 4, 629-647 https://doi.org/10.46328/ijtes.266

Investigating the Effects of Tablet-Based Math Interventions: A Meta-Analysis

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Article Info

Article History

Received:
01 April 2021
Accepted:
30August 2021

Keywords

Apps
Intervention
Tablet
Math
Meta-analysis

Abstract

There is debate over the effectiveness of using touch-screen tablet technology on overall student learning gains. This article provides a meta-analysis of studies that used tablets for the delivery of math interventions, programs, or apps to increase student math achievement. A total of 20 group design studies with 2,805 participants were included in the meta-analysis. Overall, tablet-based math interventions provided moderate positive effects for student math gains. Significant moderator variables included participant ethnicity, and socio-economic status, selecting a specific app for use, minutes in intervention, dependent variable, and type of control group. Discussion focuses on the need for more rigorous methodology and reporting of participant and design variables in future studies and the implications for researchers and practitioners when using tablets as a delivery method for math interventions.

Introduction

The prioritization of technology integration in the classroom has transformed the field of education and has become a standard in classrooms across the United States. With technology-driven initiatives such as 21st-century learning, a program that emphasizes creativity, collaboration, and digital literacy, teachers are preparing students to become members of a technological society and help them learn the skills needed to become a digital citizen (Lapek, 2017). The use of technology within the schools in the United States has also been embraced through the Common Core State Standards, which require students to develop skills such as accessing the internet, typing, and using digital devices (National Governors Association Center for Best Practices, 2010). One of the ways that teachers have incorporated technology into classrooms is by providing touch screen devices such as tablets, smartphones, or laptops for student use during instruction.

There are many benefits to incorporating tablet devices, or portable PCs with a primarily touch-screen interface occupying the full length/width of the device, within the classroom. Examples of tablets are the iPad, Samsung Galaxy Tab, and Microsoft Surface Pro; all which have applications that can be added onto the device from an accompanying app store. Tablets are relatively small, lightweight, and can be easily transported to different locations around the classroom. Features such as video and camera capabilities, internet access, accessibility features, and parental/teacher controls provide customizable experiences for each student. The touchscreen element also allows students with poor fine motor skills to better engage in learning activities as compared to the traditional mouse and keyboard that is needed with a desktop computer (Cooper, 2005). Given the appeal and popularity of tablet technology, it is not surprising that some school districts are disseminating tablets to entire populations of students (Lapowsky, 2015). Even though incorporating hand-held touch screen technology within classroom settings has generated consumer interest and attention, a lasting concern exists as to the effectiveness of whether tablet technology is an effective delivery system for academic instruction and intervention (Kucirkova, 2014; Petersen-Brown et al., 2019).

The incorporation of tablet devices into the classroom has gained increased interest in the area of educational technology research. Studies investigating the impact of using tablet technology in the classroom show interventions delivered via mobile devices (including tablets) led to improved learning outcomes for students with disabilities (Ok & Kim, 2017). Tablets have also been found to support teachers in teaching multiple subjects (Ferrer et al., 2011) as well decreasing teacher workload and increasing lesson variety (Heinrich, 2012). However, researchers in the field remain divided on the level of effectiveness of tablets as a delivery system for math interventions or programs. Multiple studies have found that tablet delivery of a math intervention has led to increases in math achievement, but there is substantial variation in just how much impact has been found (e.g., Haydon et al., 2012; Riconscente, 2013; Schacter et al., 2016). These studies varied in the makeup of their participants (i.e. grade level, demographic information), the math concept taught (i.e. fractions, addition), and the overall measure (i.e. math fluency, accuracy, or ability). With the multitude of research available on tablet technology in math classrooms, a consensus on the effectiveness of a tablet-based intervention in improving math skills continues to be elusive.

Evidence for Tablet Devices

Studies conducted on the use of tablets as a delivery system for math interventions provide promising results. Tablets can facilitate student learning through the incorporation of multi-sensory activities (Carr, 2012) and provide instantaneous student feedback (Kaur et al., 2017). There have been several published reviews on the use of touch screen devices within the school setting. Ok and Kim (2016) conducted a literature review investigating the use of iPads and iPods to increase academic engagement of students with disabilities. They included 20 studies with effects ranging from small to large. However, their study only examined single-case design (SCD) studies and neglected to examine tablet use for general education students. A meta-analysis by Aspiranti and colleagues (2018) investigated the use of a specific type of tablet, iPads, for the delivery of academic interventions to students with autism. Results showed that overall, students increased their academic abilities after completing an intervention presented on an iPad.

Petersen-Brown and colleagues (2019) conducted a meta-analysis of 65 studies using touch screen devices within the educational setting. They included separate analyses of group design studies and single case design studies and suggest that the use of touch screen devices is moderately effective in enhancing academic achievement skills. However, this study did not exclusively examine which variables are most effective for math interventions. It also did not separate the analysis to differentiate the effects of tablet technology from other touch-screen modalities. Another limitation of this study was the lack of investigation as to the specific applications used on the device.

Math Applications for Tablets

Tablet use has the potential to improve student math achievement, however, improvements in math achievement is conditional on the math intervention, practice, or application provided and how it is used. One of the most common ways to use a tablet is to download an app from a universal app store. Educators should be aware of the purpose and function of an app before purchasing, but information on an app is typically limited to the description provided by the app store, which includes user reviews, star ratings, and a general overview of the app (Larkin, 2013). However, reviews of apps located in the app store can be heavily influenced by publishers or large district purchases (Powell, 2014). Teachers are required to use limited information to make decisions as to whether or not they implement a specific app in their teaching practice. O'Malley and colleagues (2014) noted that there is a lack of teacher professional development focusing on effective methods of mobile technology integration in the classroom and the skills needed to assess the quality of an app selected for potential use.

Classroom teachers have incorporated the use of apps into lessons to support the academic performance of students with and without academic difficulties (Hutchison et al., 2012). However, research on the empirical evidence of the effectiveness of specific apps on student academic performance in math is severely limited (Zhang et al., 2015). There is no centralized database that provides a list of evidence-based apps, nor is there a way to access non-biased information on the quality of apps. Sites such as Intervention Central and What Works Clearinghouse provide lists of evidence-based academic practices and interventions that can be implemented in the classroom, but these sites are not focused on app programs. Supporting empirical evidence on the effectiveness of individual apps to improve targeted math skills is lacking and has not developed in a manner that would allow the use of specific apps to gain support (Powell, 2014). While the process of aligning apps to standards and norm-referenced tests is extensive, it provides educators with the assurance that the students are working on curriculum-based skills. With the relative dearth of app-specific research, school professionals are left to select and troubleshoot the use of apps on their own.

Purpose and Research Questions

Although there are several studies reviewing the use of mobile devices to increase student achievement, these studies often either focus only on SCD studies, focus only on students with disabilities, examine the use of all touch screen devices and not just tablets, or examine all academic and/or behavioral areas of concern and not just math achievement (Aspiranti et al., 2018; Larkin, 2013; Ok & Kim, 2017; Petersen-Brown et al., 2019). The purpose of the present study is to assess the impact of math interventions, programs, or apps delivered through tablets on K-12 student achievement. The following research questions were posed for the present study:

1) What participant characteristics, study characteristics, and design elements are included in the research investigating the use of tablets for math interventions/programs/apps?

2) What is the impact of using tablets to deliver math interventions/programs/apps?

3) What study characteristics lead to greater effects when using a math intervention/program/app provided on a tablet?

Method

Literature Search

A systematic literature search was conducted in November of 2018 to identify research studies that included the use of tablets to deliver a math intervention. Researchers searched the electronic databases PsycINFO, ERIC, Education Full Text, and Education Research Complete using the terms "iPad" OR "tablet" AND "math*". The search was limited to articles in peer-reviewed journals published in or after 2002. Results of the initial search yielded 715 articles. After duplicate records were removed, 488 articles remained.

Titles and abstracts of the 488 articles were reviewed using the following additional inclusionary criteria: (a) implemented a math intervention aimed at increasing student outcomes in math; (b) used a tablet (not a laptop, iPod, or phone) to deliver the intervention; (c) used participants in grades prekindergarten through secondary school (approximately aged 3 through 19) within a school-based setting; and (d) used group design methodology containing quantitative data. After applying these criteria to the article titles and abstracts, 27 articles remained. Next, the reference lists of these 27 articles were hand-searched in order to discover any additional articles not represented in the identified online databases. Five additional articles were found for potential inclusion when searching reference lists. Two of the authors independently reviewed the full text of the 32 identified articles with 100% agreement that the articles met criteria. Seventeen articles fit the full inclusionary criteria, with one article containing four separate studies. Six studies did not include a math intervention, three studies did not employ group design methodologies, two studies did not include quantitative data, one study used mobile devices in addition to tablets, two studies combined academic areas, one study did not take place within a school setting, and did not focus on math interventions, and one study used a math intervention but did not use technology. Therefore, 20 studies were included in the final analysis.

Coding Procedures

Each study was coded for 18 variables related to publication characteristics, participant demographics, study characteristics, and design elements. For publication characteristics, the year of the publication and nationality of the publishing journal were coded. For participant characteristics, the number of participants, ethnicity (Caucasian/European, African, Asian, or multiple ethnicities), and socioeconomic status (SES; low, middle, or high) were coded. Mean participant age and participant grades were also coded and combined into four levels (ages 3-5 corresponded to Pre-Primary grade levels, ages 6-9 corresponded to Lower Primary grade levels, ages 10-13 corresponded to Upper Primary grade levels, and ages 14-19 corresponded to Secondary grade levels), Variables were only coded if they were mentioned in the article. For instance, not every study identified the SES, ethnicity, or ages of their population. For study characteristics, the study was coded for classroom (general education or special education), iPad or other tablet use, the specific math app used, math skills addressed, dependent variable, frequency of intervention, and total minutes in intervention. For design elements, coded items were methodological quality, control group intervention (no intervention or “business as usual”, other tablet apps, or no control group), experimental design (pre-post test or repeated measures), and the dependent variable measurement (accuracy, efficiency, or standardized score).

Methodological quality was evaluated using the *What Works Clearinghouse Procedures and Standards Handbook* (WWC; Institute of Education Sciences, 2017). WWC presents specific methodological criteria for group design studies that examine the strength of the overall design, which in turn impacts the strength of the findings. Studies can earn a rating of Meets Standards, Meets Standards with Reservations, or Does Not Meet Standards, depending on the methodological rigor. Studies are evaluated through three criteria: randomization of group membership, sample attrition, and baseline equivalence in groups. Studies who meet the criteria of randomization and sample attrition are assigned the rating of Meets Standards. Studies who fail to meet sample attrition standards but meet both baseline equivalence and group randomization earn the criteria of Meets Standards with Reservations.

In order to evaluate inter-rater reliability a second researcher independently coded six randomly chosen studies (30% of all studies). Both raters were trained on coding procedures and how to rate studies using WWC standards. Inter-rater reliability was computed using the following formula: number of agreements/number of agreements plus disagreements times 100. The overall inter-rater reliability was 92.2%. Any disagreements were discussed, and the raters came to a final agreement.

Data Analysis

The meta-analysis for the current investigation was conducted in Comprehensive Meta-Analysis, a dedicated meta-analytic software program. The analysis of the extracted data began by computing an overall effect size estimate of all studies deemed appropriate for inclusion. The resulting estimate provides an indication of whether the result across all studies is homogenous or heterogeneous. If heterogeneity is found across the studies, then analysis continues to examine all available moderators to establish where the effect size estimates differ. Effect size measures for this investigation are calculated by computing mean differences and dividing those mean differences by pooled standard deviations in order to establish an estimated effect measure (*d*). If the resulting value is less than zero, the intervention is considered to have a negative effect, whereas if the resulting value is greater than zero, the effect is of the intervention is considered to be positive.

Results

Table 1 displays the characteristics of each study included in the meta-analysis. The 20 studies were published in 17 articles (one article included four separate studies). There were a total of 2,805 participants aged 3-13 across all studies. All studies took place in a general education setting. Eleven studies took place in the United States and nine studies were located in other countries. Several studies did not specify the app or program that was used, and several studies did not provide information regarding the amount of time spent within the intervention. Of the 20 studies, seven met the WWC Standards, five met the Standards with reservations, and eight did not meet the Standards.

Several different math apps and programs were named within the studies, but few were used more than once. No specific app was named in five studies, and four studies (Outhwaite et al., 2017) simply mentioned using a math app through onebillion, although the app was not named. Of the remaining 11 studies, three used Math Shelf (one that compared it to other iPad math apps) and two others included several different apps within the study, including Masamu 1, Masamu 2, Count to 10, Count to 20, Motion Math Zoom, Splash Math, and Long Division. The final six studies investigated the use of a single app or tablet-based program. These included Bedtime Math, Zorbit Math, Chasing Planets, VoiceThread, Motion Math, and Math Creations. Because the majority of apps and programs were only used in one study and several studies did not even provide the name of the specific app or program used, this was not included as a moderator variable. However, analyses were conducted comparing those studies that named a specific math app or program and those that did not.

Table 1. Characteristics of Studies

Study	**N**	**Grade**	**Setting and Country**	**Design, Control Group, Device**	**App Used and Independent Variable**	**Dependent Variable(s)**	**Duration of Intervention**	**Total Intervention Time**	**WWC**
Al-Mashaqbeh (2016)	84	LP	General Education; Jordan	QE Control iPad	No specific app; independent math practice instead of teaching	Math problems correct on researcher made test	1 semester	ns	MWR
Berkowitz et al. (2015)	587	LP	General Education; USA	RCT Control iPad	Bedtime Math; math word problems completed at home with parent	Rasch-scaled score on the WJ-III applied problems subtest	0 to 4.3 times per week over 9 months	ns	NM
Carr (2012)	104	UP	General Education; USA	QE Control iPad	No specific app; independent math practice after direct instruction	Scores on 5th grade math assessment	daily math activity for one quarter	ns	NM
Hassler Hallstedt et al. (2016)	283	LP	General Education; Sweden	RCT Control Tablet	Chasing Planets; math games played after direct instruction	Scores on the Grade 3 Math Battery, HRT, and Diamant AG1	20 min daily	ns	M

Study	N	Grade	Setting and Country	Design, Control Group, Device	App Used and Independent Variable	Dependent Variable(s)	Duration of Intervention	Total Intervention Time	WWC
Kosko & Ferding (2016)	73	PP	General Education: USA	QE Control Tablet	Zorbit Math; math games completed at home with parent	Math problems correct on researcher made test	3 week exposure	ns	M
Outhwaite et al. (2017) Study 1	83	PP	General Education; England	QE Control Tablet	Math app through onebillion; math games after direct instruction	Math problems correct on researcher made test	30 min daily for 6 weeks	900 min	NM
Outhwaite et al.(2017) Study 2	18	PP	General Education; England	QE No Control Tablet	Math app through onebillion; math games after direct instruction	Math problems correct on researcher made test	30 min daily for 13 weeks	1,950 min	NM
Outhwaite et al. (2017) Study 3	27	PP	General Education; England	QE No Control Tablet	Math app through onebillion; math games after direct instruction	Math problems correct on researcher made test	30 min daily for 13 weeks	1,950 min	NM
Outhwaite et al. (2017) Study 4	27	PP	General Education; England	QE Control Tablet	Math app through onebillion; math games after direct instruction	Math problems correct on researcher made test	30 min every other day for 16 weeks	1,200 min	NM
Park et al. (2016)	103	PP	General Education; USA	RCT No Control Tablet	No specific app; tablet game on arithmetic versus tablet game on picture memory	Scores on Test of Early Mathematical Achievement (TEMA) and a short term memory task (STM)	12 min daily sessions over 2-3 weeks	120-180 min	M
Pitchford (2015)	283	LP	General Education; Malawi	RCT Control iPad	Masamu 1; Masamu 2; Count to 10; Count to 20; compare math	Math problems correct on researcher made test	30 to 60 min daily sessions for 8 weeks	1,200-2,400 min	M

Study	N	Grade	Setting and Country	Design, Control Group, Device	App Used and Independent Variable	Dependent Variable(s)	Duration of Intervention	Total Intervention Time	WWC
					tablet intervention to non-math tablet to control group				
Reeves et al. (2017)	28	PP	General Education; USA	QE Control iPad	Various unnamed math apps	Math problems correct on researcher made test	15 min daily sessions for 7 months	approx. 2,700 min	NM
Riconscente (2013)	122	UP	General Education; USA	RCT Control iPad	Motion Math; fraction game played during school	Student knowledge of and attitude towards fractions	20 min sessions for 5 days	100 min	MWR
Schacter et al. (2016)	100	PP	General Education; USA	QE Control Tablet	Math Shelf; Team Umizoomi; Numbers with Nemo; Monkey Math; Elmo Loves Math; Park Math HD; Compare Math Shelf to other iPad apps	Math problems correct on researcher made test	3 days a week for 10 min, over 6 weeks	180 min	M
Schacter & Jo (2017)	433	PP	General Education; USA	RCT No Control Tablet	Math Shelf; iPad math intervention game versus teacher math intervention	Math problems correct on researcher made test	2 days a week for 10 min, over 22 weeks	440 min	M
Schacter & Jo (2016)	227	PP	General Education; USA	QE Control iPad	Math Shelf	Math problems correct on researcher made test	10 min daily sessions for 15 weeks	750 min	MWR
van der Ven et al. (2017)	103	LP	General Education; Netherlands	RCT Control Tablet	No specific app; playing tablet arithmetic game versus	Math problems correct on researcher made test	15 min sessions, 4 days a week for 5 weeks	300 min	M

Study	N	Grade	Setting and Country	Design, Control Group, Device	App Used and Independent Variable	Dependent Variable(s)	Duration of Intervention	Total Intervention Time	WWC
					no tablet game				
Working (2018)	52	LP	General Education; USA	RCT Control Tablet	VoiceThread; used app to collaborate to solve word problems	Math problems correct on researcher made test	Ten 30 min sessions, 2-3 days a week for 4 weeks	300 min	MWR
Yang et al. (2016)	51	LP	General Education; Taiwan	RCT Control Tablet	Math Creations; iPad reciprocal peer tutoring versus teacher instruction	Math communic ation skills on researcher made test	Thirteen 80 min sessions over one semester	1,040 min	MWR
Zhang et al. (2015)	17	LP	General Education Inclusive; USA	QE No Control iPad	Splash Math; Motion Math Zoom; Long Multiplication; three sessions using a different app with pretest-posttest of specific app skills	Math problems correct on researcher made test;	40 min Splash Math session; 50 min Motion Math Zoom session; 60 min Long Multiplicati on Session	150 min	NM

Note: PP—Pre-Primary; LP—Lower Primary; UP—Upper Primary; WWC—What Works Clearinghouse; RCT—Randomized Control Trial; QE—Quasi-Experimental; M—Met; MWR—Met with Reservations; NM—Not Met

Overall Effects

The global effect size estimate for the studies meeting the inclusion criteria is d = .486, p <.001, based on a random effects model. This indicates that there is significant heterogeneity across the 20 studies and 28 effect size measures. Therefore, additional analysis is needed to understand where the heterogeneity exists across the studies. Figure 1 provides a graphical representation of the effect size measure extracted from each study included in this investigation. There were three effect size measures that were negative (less than zero), one that revealed no effect, and twenty-four that revealed positive effects (greater than zero), however with differences in magnitude. As indicated in Figure 1, those studies plotted below the vertical “0” line have negative effect size estimates. Likewise, those above the “0” line were found to have a positive effect size estimate. Some studies provided more than one effect size estimate when multiple measures were reported.

Study name	Statistics for each study						
	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Al-Mashaqbeh	-0.284	0.112	0.012	-0.503	-0.066	-2.547	0.011
Berkowitz et al.	0.366	0.092	0.008	0.186	0.547	3.983	0.000
Carr	0.004	0.195	0.038	-0.379	0.386	0.019	0.985
Hassler Hallstedt et al.1	0.463	0.121	0.015	0.227	0.700	3.843	0.000
Hassler Hallstedt et al.2	0.315	0.120	0.014	0.081	0.550	2.635	0.008
Kosko & Ferdig	0.224	0.163	0.027	-0.096	0.543	1.372	0.170
Outhwaite, Gulliford, & Pitchford1	0.126	0.110	0.012	-0.089	0.341	1.145	0.252
Outhwaite, Gulliford, & Pitchford2	0.126	0.110	0.012	-0.089	0.341	1.145	0.252
Outhwaite et al.2	1.479	0.334	0.111	0.825	2.134	4.430	0.000
Outhwaite et al.3	1.396	0.266	0.071	0.874	1.918	5.239	0.000
Outhwaite et al.4	1.396	0.266	0.071	0.874	1.918	5.239	0.000
Park et al.	0.206	0.099	0.010	0.012	0.401	2.078	0.038
Pitchford 1	0.319	0.140	0.020	0.043	0.594	2.270	0.023
Pitchford 2	-0.189	0.149	0.022	-0.480	0.103	-1.266	0.206
Reeves et al.	1.346	0.425	0.180	0.514	2.179	3.170	0.002
Riconscente	0.475	0.141	0.020	0.198	0.752	3.358	0.001
Schacter & Jo1	0.938	0.103	0.011	0.736	1.140	9.110	0.000
Schacter & Jo 2	1.000	0.159	0.025	0.688	1.312	6.283	0.000
Schacter et al.	0.573	0.203	0.041	0.176	0.970	2.830	0.005
van der Ven et al.1	0.163	0.196	0.038	-0.221	0.547	0.830	0.406
van der Ven et al.2	0.189	0.196	0.038	-0.195	0.573	0.965	0.335
van der Ven et al.3	0.119	0.196	0.038	-0.265	0.502	0.605	0.545
van der Ven et al.4	0.623	0.200	0.040	0.230	1.016	3.110	0.002
Working1	-0.103	0.137	0.019	-0.372	0.165	-0.753	0.452
Working2	0.689	0.152	0.023	0.390	0.987	4.518	0.000
Yang et al.	1.786	0.328	0.107	1.144	2.429	5.452	0.000
Zhang et al.1	1.210	0.356	0.127	0.513	1.907	3.401	0.001
Zhang et al.2	0.507	0.341	0.116	-0.160	1.175	1.490	0.136
	0.486	0.082	0.007	0.324	0.647	5.893	0.000

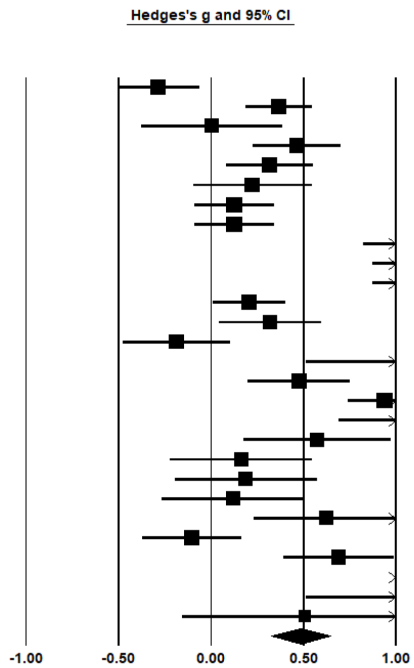

Figure 1. Graphical Representation of the Computed Effect Size Estimates for each Study

Moderator Variables

Additional analysis of the potential moderators was conducted to identify the potential sources of heterogeneity. The result of this analysis is presented in Table 2. Year of study was collapsed into two categories: 2012-2015 and 2016-2018 to allow for comparisons to be made; differences between the earlier published studies and later published studies were not significant. Results indicate that for grade level, the greatest effect is found within the Pre-primary grades (*d* = .75), although these differences were not significant. While only represented by one effect size measure, SES, the middle-class students revealed a significantly larger impact (*d* = 1.44) relative to those identified as low income (*d* = .58). Some caution should be exercised in interpreting the SES results since not all studies provided this information for each participant.

Table 3 provides effect size measures associated with the study designs. As indicated in Table 3, those in the tablet group revealed a greater effect (*d* =.62) relative to the iPad group (*d* = .38), although this was not significant. Those using a specific application had a significantly higher impact (*d* = .60) relative to those that did not (*d* = .20). Further moderator analyses were not conducted for specific apps because most apps were only used in one study. Math skills were collapsed into two categories: Early math skills (e.g., addition, subtraction, basic numeracy) and later math skills (e.g., fractions, math communication, multiplication). The math skill levels were not significantly different, and neither was the type of classroom. The dependent variable type, as a single study (math communication skills) revealed a significantly higher effect (*d* = 1.81); the other two levels (standardized assessment and items correct) both revealed a moderate level effect. The minutes used revealed significant differences with the “over 1000 minutes” showing the greatest effect (*d* = .87), followed by the “300-1000” minutes (*d* = .54).

Table 2. Primary Effect Size Moderators: Demographics and Year

Demographics/Year	Number Studies	Point estimate	Lower limit	Upper limit	p-value	Q-value	df	p-value
Year								
2012-2015	7	0.31	0.07	0.55	0.01	2.21	1	0.14
2016-2018	21	0.55	0.35	0.76	0.00			
Grade								
Pre-Primary	11	0.75	0.45	1.04	0.00	5.38	2	0.07
Lower Primary	15	0.35	0.15	0.55	0.00			
Upper Primary	2	0.26	-0.20	0.72	0.27			
Country								
United States	13	0.52	0.30	0.74	0.00	0.11	1	0.74
International	15	0.47	0.23	0.71	0.00			
SES								
Low	13	0.58	0.33	0.82	0.00	13.12	2	0.00
Middle	1	1.44	0.90	1.98	0.00			

Note: Not all studies reported the race/ethnicity or SES of the participants

Table 3. Primary Effect Size Moderators: Study Characteristics

Study Characteristics	Number Studies	Point estimate	Lower limit	Upper limit	p-value	Q-value	df	p-value
Classroom								
General Education	26	0.47	0.30	0.64	0.00	1.17	1	0.28
Gen Ed Inclusive	2	0.87	0.17	1.57	0.00			
iPad or Tablet								
iPad	14	0.38	0.15	0.60	0.00	1.95	1	0.16
Tablet	14	0.62	0.37	0.87	0.00			
Independent Variable								
No Specific App	8	0.20	-0.04	0.45	0.11	5.97	1	0.02
Specific App	20	0.60	0.40	0.79	0.00			
Math Skill								
Early Math Skills	22	0.44	0.27	0.62	0.00	1.13	1	0.29
Later Math Skills	6	0.72	0.25	1.18	0.00			
Dependent Variable								
Items Correct	21	0.49	0.28	0.70	0.00	18.91	2	0.00
Standardized Assmt	6	0.33	0.17	0.50	0.00			
Math Communication	1	1.81	1.16	2.47	0.00			
Minutes								
Under 300	11	0.37	0.19	0.56	0.00	9.09	3	0.03
300-1000	4	0.54	0.07	1.02	0.03			
Over 1000	9	0.87	0.47	1.26	0.00			

Table 4 includes the design elements that were examined as potential effect size moderators. Only type of control group revealed significant differences across the various levels the design elements with significantly higher scores for studies without control groups (*d* = 1.20).

Table 4. Primary Effect Size Moderators: Design Elements

Design Element	Number Studies	Point estimate	Lower limit	Upper limit	p-value	Q-value	df	p-value
WWC Standards								
Meets standards	12	0.34	0.15	0.52	0.00	4.40	2	0.11
Meets with reservations	6	0.56	0.05	1.06	0.00			
Does not meet standards	10	0.72	0.40	1.04	0.00			
Type Control Group								
No intervention	20	0.45	0.25	0.64	0.00	13.87	2	0.00
Other iPad apps	4	0.23	-0.03	0.49	0.08			
No control group	4	1.20	0.76	1.64	0.00			
Assessment Type								
Researcher made	22	0.54	0.32	0.75	0.00	2.25	1	0.13
Standardized test	6	0.33	0.17	0.50	0.00			
Measurement								
Accuracy	18	0.60	0.35	0.86	0.00	4.21	2	0.12
Efficiency	4	0.27	0.04	0.50	0.02			
Standardized score	6	0.33	0.17	0.50	0.00			

Note: All studies were pre-post designs with the exception of Risconscente (2013)

An additional analysis examined the effect sizes of the different grade levels by the intervention levels (no specific app versus specific app) (see Table 5).

Table 5. Grade Level by Intervention Level and Outcome Measure by Intervention Level Effect Size Measures

Variable	No Specific Intervention	Specific Intervention
Grade		
Pre-Primary	0.72	0.77
Lower Primary	0.14	0.45
Upper Primary	0.20	0.14
Dependent Variable		
Math problems correct	0.14	0.59
Scores on standardized assessment	0.36	0.38

When examining different grade levels, all the effect size measures for the 'specific' intervention group are significantly higher than those for the 'no specific' intervention group. A separate analysis examined the dependent variable levels by the intervention levels (no specific app versus specific app). The results indicate that those in the ‘specific’ intervention group are significantly higher than those for the ‘no specific’ intervention group. The dependent variable level ‘Correct Math Communication’ skills was not included in this analysis because that level was represented by only one study.

Discussion

The purpose of this study was to analyze the effects of using a tablet to deliver math interventions found across the existing literature. Specifically, the current investigation examined what characteristics and design elements exist in the published literature, what the effects are on academic skills when using tablets for math practice or interventions, and what study characteristics or design elements increase the effects of the intervention. Results from the effect size measures were mostly positive, suggesting tablets can be effectively used to deliver interventions or practice to increase math skills. The omnibus effect size of .486 indicates an overall moderate effect. The results also suggest the tablets can be successfully used across grade, gender, settings, and socio-economic status to increase math skills.

The issue of missing demographic data is prevalent across all studies, as eight studies did not provide socio-economic status and 13 studies did not provide the race/ethnicity of participants. Additionally, gender was not specified in four of the studies. This failure to report participant demographic data is an area of concern in the studies examined. Without the inclusion of participant characteristics, researchers risk assuming that an intervention created for one subgroup of the population will be effective for everyone. At the very least, participant age, gender, race/ethnicity, SES, and language spoken should be identified (Hammer, 2011).

Pre-primary made greater gains when using tablets to complete math interventions than did students in the Lower or Upper Primary grades, although not at a significant level. Why this is the case is unclear, but one hypothesis is that younger students may engage more with the novelty of the devices. Potentially, the apps developed for younger children are more “fun” and “engaging” and provide students with age-appropriate academic reinforcements without losing their interest (Blackwell, 2014; Schacter & Jo, 2017). Additionally, it may be easier to create apps based on early mathematical concepts such as number sense, one-to-one correspondence, shapes, basic measurement, and simple addition (Neumann & Neumann, 2014). Because there were no studies with students older than 13 or at the Secondary level, it would be difficult to understand if the impacts found can also be seen when using technology to support higher order mathematic skills. There is no known existing research examining the use of tablets to help increase math abilities in Secondary school settings using group design methodologies.

Many of the studies used the tablet as a conduit to provide instruction via a specific app, but several studies did not specify which app or program was used (see Table 1). One of the most popular features of tablets is the ability to implement downloadable, inexpensive apps that are freely available (Ok & Kim, 2017). Although several math apps were mentioned (e.g., Math Creations, Math Shelf, Motion Math, Masamu, Bedtime Math, Zorbit Math, Splash Math), most apps were only used within a single study, making it difficult to analyze the effects of any one app. It is concerning that several of the studies did not specify which apps or programs were used (e.g., Carr, 2012; Park, et al., 2016; van der Ven, Segers et al., 2017).

In several instances, the independent variable was listed as tablet game, math game, or tablet math practice, making replication of these studies extremely difficult. In many of the other studies, the specific app was named but the procedures listed in the study were not clear enough to ensure an effective replication. For instance, Berkowitz and colleagues (2015) mention the app that was used, but did not discuss what exactly the students did in the app, just that they played the app. Similarly, in Kosko and Ferding's study (2016), the specific procedures for playing the app were described, but the amount of time the students spent using the app was not. Excluding important information from the procedures of a study leads to questions about the generalizability of the study's methodology to other settings or applications.

Significant differences in the effects of using a specific app versus not using a specific app demonstrate the importance of explicitly choosing an app to use during an intervention and not simply allowing the tablet itself to be an intervention. This is because technology in and of itself is only a means to deliver an intervention, not the intervention itself. The differences become more obvious when comparing grades and outcome measures in studies that used specific app and those that used no specific app. In all three grade levels categories, studies that used a specific intervention had much higher effect sizes than studies that did not specify an intervention. Similarly, effect sizes for the dependent variables were higher when using a specific intervention. When selecting apps it is important to choose a specific app to use that is appropriate for the particular student (Ok & Kim, 2017).

The inclusion of a control group when performing a pre-posttest design is a best practice (Institute of Education Sciences, 2017), but control groups were not included in several of the studies. However, studies without a control group had higher effects than those with control groups. Similarly, analyzing scores from a researcher-made assessment with no reliability or validity measures did not correspond to lower effect sizes than scores from a standardized test. Researcher-made assessments typically closely corresponded with the actual problems completed through the app (Riconscente, 2013; Schacter & Jo, 2017; Zhang et al., 2015). However, standardized assessments typically do not align specifically with the material being systematically taught within an intervention, even if they do have adequate reliability and validity (Carr, 2012; Hassler Hallstedt et al., 2018).

Although best practice suggests only including those studies that are methodologically sound (Institute of Education Sciences, 2017), the current investigation included those studies that did not meet WWC standards in our analysis to allow for examination of all published studies. Although randomized control trial research is typically viewed as the most methodologically rigorous, it is important not to marginalize or devalue studies that use quasiexperimental, correlational, or qualitative methods. There were no significant differences between those studies that did not meet WWC standards and those that did, although studies that did not meet standards had slightly higher effects.

Implications for Educators

Tablets are being incorporated into classroom intervention and even instruction at increasingly higher rates. In fact, in several schools, students are provided tablets as part of their school materials. At other schools, carts of tablets are accessible to teachers for use in their classrooms. With the increase of tablet use in schools, it becomes vital for educators to understand whether the programs and apps used can help increase student performance. Educators are often tasked with the role of suggesting and implementing interventions for struggling students. As shown in the identified studies, tablets can be used as a medium to provide interventions for students in general education classrooms. Advantages of using the iPad and tablets for students include increased engagement (Haydon et al., 2012), increased self-management of interventions (Bryant et al., 2015), and a portable video modeling tool (Creech-Galloway, Collins et al., 2013).

Within a Response to Intervention (RtI) approach, educators may be asked to suggest universal interventions for targeted classrooms or school-wide. The identified studies provide evidence that iPad/tablet interventions can be implemented across entire classrooms or even schools in order to increase student math performance. Even interventions implemented at home as part of a home-school alliance can be beneficial for student math growth (e.g., Berkowitz et al., 2015; Kosko & Ferding, 2016). Additionally, educators working outside of the United States will be encouraged that several of the identified studies were conducted with students in other countries with no differences in effects from those conducted in the United States (e.g., Outhwaite et al., 2017; Pitchford, 2015; Yang et al., 2016). Educators should be careful when choosing interventions for the iPad/tablet to select programs or apps that are appropriate for teaching the desired skills (Ok & Kim, 2017). Although technological devices can be used as a method to implement effective instruction or intervention, additional supports or scaffolds may be necessary while students are learning to navigate the device.

Limitations

There are several limitations within the present study. When selecting inclusionary criteria for the study, we chose to include studies that did not meet WWC standards but did not include other publications such as dissertations or white papers. Including studies that did not meet WWC standards provides a broader picture of the published studies that use tablets. Also, the current investigation only included group design studies published in English in peer-reviewed journals. Therefore, findings provided in unpublished dissertations or theses, studies not using a group design methodology, and articles in other languages were excluded.

Another limitation is the lack of our study to compare specific apps or programs using a moderator analysis. Because there were so many different apps used, several studies compared different apps, and several studies did not mention a specific app, it was difficult to quantitively analyze the data comparing specific apps. A final limitation is the lack of replication of the procedures described in most of the studies. Therefore, the generalizability of each study is questionable and more research should be conducted to ensure that the specific iPad/tablet intervention implemented is an effective practice for increasing math abilities.

Future Directions

The studies examined in this article provide a list of programs and apps that can be added to a school psychologist's toolbox of effective practices. However, more research is needed in order to validate the specific apps and how they are implemented in each level of intervention in an RtI model (e.g., universal, secondary, tertiary, special education). Within the selected studies, there were only three apps that were used across more than one study (Math Shelf, Motion Math, math app through onebillion [although the actual app was not named]). Therefore, replication of studies using the other apps is needed. In order for possible replication, it would be prudent for future studies to provide all necessary methodological information such as the actual app used, procedures for implementing the app, and amount of time students spent playing the app. Most studies focused on improving basic skills and failed to address higher level thinking skills. Future studies investigating apps that engage students in higher-level thinking would promote student engagement in more of the Common Core Standards, therefore deepening knowledge of mathematical content and applying math concepts in meaningful ways.

A specific area of concern within the current study is the lack of any group design studies using students in special education. Although several studies have investigated the use of math interventions delivered through a tablet for students with disabilities (e.g., Bryant et al., 2015; Creech-Galloway et al., 2013; Haydon et al., 2012), none of these were group designs. Future studies should attempt to replicate interventions conducted in general education classrooms with students with disabilities. Additionally, interventions or apps created for students with disabilities could be examined within a group setting in order to evaluate their results with larger populations of students.

Conclusion

The results of the current investigation provide promise for the integration of tablets into mathematics instruction. While not all the extant research on technology integration provided evidence of a positive impact, the overwhelming result from the synthesis of existing research indicates that students can experience a moderate level of positive impact on required assessments and daily problem solving. As the use of tablets become a greater part of mathematics pedagogy, the potential for positive impacts can expand as educators advance their skill in facilitating students' use of these technological devices and the growing number of academic applications in supporting every student's mathematics literacy.

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