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A meta-analysis of the impact of technology on learning effectiveness of elementary students

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A R T I C L E I N F O

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A B S T R A C T

The existing studies suggest that if technology is interwoven comprehensively into pedagogy, it can act as a powerful tool for effective learning of the elementary students. This study conducted the meta-analysis by integrating the quantitative findings of 122 peer-reviewed academic papers that measured the impact of technology on learning effectiveness of elementary students. The results confirmed that the technology has a medium effect on learning effectiveness of elementary students. Further, this study analysed the effect sizes of moderating variables such as domain subject, application type, intervention duration, and learning environment. Finally, the impact of technology at different levels of moderating variables has been discussed and the implications for theory and practice are provided.

1. Introduction

1.1. Technologies in education

Advancements in information technology (IT) have led to the development of various applications that help in better understanding of concepts, phenomenon, and theories by students (Bakırcı, Bilgin, & Simsek, 2011; Koong & Wu, 2011; Li & Lim, 2008). The development of innovative and interactive technological applications have changed the learning methods (Furió, Juan, Seguí, & Vivó, 2015) by offering an active learning environment to the students for various domain subjects such as mathematics, language etc. (de Koning-Veenstra, Steenbeek, van Dijk, & van Geert, 2014). Learning effectiveness fosters the students with certain key competences such as critical thinking and problem-solving skills (Voogt & Roblin, 2012). Researchers articulate that students can learn better when they are actively involved and can relate the concepts to their real life. Therefore, lab or experimental environment involving electronic-learning (e-learning) facilitates the students to learn effectively (Taşkm & Kandemir, 2010).

Several methods of e-learning in elementary schools have been studied and suggested by the researchers as information obtained via e-learning is much more permanent than the traditional learning (Hwang, Chiu, & Chen, 2015; Taşkm & Kandemir, 2010). For example, computer simulations (Bakırcı et al., 2011) and animated cartoons (Dalacosta, Kamariotaki-Paparrigopoulou, Palyvos, & Spyrellis, 2009) are effective in inculcating scientific thinking, computer delivered reading comprehension instructions may diminish the challenges related to implementing several complex reading strategies in the classroom (Lysenko & Abrami, 2014; Potocki, Ecalle, & Magnan, 2013), Internet enables the learners to observe an object from

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several perspectives and build their own learning experience in addition to providing audio, video, and written resources simultaneously (Segers & Verhoeven, 2009), electronic-portfolio (e-portfolio) contributes in improving writing performance (Nicolaidou, 2013), and game-based learning engages the learners in an authentic and enacted problem solving by providing enjoyable and motivating learning experiences (Barzilai & Blau, 2014). Moreover, mobile technology has further extended the learning paradigm by enabling inside as well as outside classroom learning (Su & Cheng, 2013).

Today, various school districts in countries such as the USA are investing a considerable amount of their annual budgets on technologies in education with an objective of improving academic performance. Most of the public schools have access to the Internet connected computers and thus, schools are in a much better position to implement technologies in classrooms. (Cheung & Slavin, 2013; SETDA, 2010). However, successfully integrating technologies in educational system is not about merely providing the Internet connected computers in the classrooms. Technological integration has not yet been achieved in a planned way in most of the schools. Very few schools have shared commitment to technologies among various stakeholders such as school managers, teachers and parents (Lim, Zhao, Tondeur, Chai, & Tsai, 2013). According to AdvancED's recent report, students are not actively using technologies for learning in spite of technologically well-equipped classrooms. There may be a number of factors to it such as teachers' preparation and training, effect of technology on school culture, and concerns regarding the availability of technology at home that could increase inequalities among students from varying socio-economic backgrounds (Broekhuizen, 2016).

Moreover, it is important for the schools to be aware of the principles and guidelines for the successful implementation of technologies in classrooms. There should be an effort towards improving classroom instruction to more effectively leverage technology for learning (Schaffhauser, 2016). Teachers should be engaged in developing school-based technology plan as it will give them the opportunity to reflect on their specific educational use of technology. Further, schools should give importance to leadership in developing a commitment to change. Crucial building blocks for integrating technologies in education are the close collaboration among the actors in the school community and a shared vision about the use of technologies. Additionally, teachers' training should be a priority for developing a technology-related professional environment (Lim et al., 2013).

With the increasing growth of technologies in education, there has been a significant rise in research papers measuring the impact of technology on learning effectiveness of elementary students (see Fig. 1). These papers constitute a large set of unexplored studies for the meta-analysis. Meta-analysis examines the quantitative results of several empirical studies and provides significant insights. It is a rigorous alternative to the narrative-based and qualitative literature reviews and therefore has been encouraged by the prominent journals in the field of social and behavioral sciences (Eden, 2002; King & He, 2006). In an attempt to provide comprehensive view of the impact of technology on learning effectiveness, meta-analysis has previously been conducted by various researchers.

1.2. Previous meta-analyses of impact of technology on learning effectiveness

Researchers have extensively studied the impact of technology on learning effectiveness of students. A number of meta-analyses have evaluated the students' learning effectiveness in multiple domain subjects, while some reviews have considered only single domain subject such as mathematics (Cheung & Slavin, 2013; Rakes, Valentine, McGatha, & Ronau,

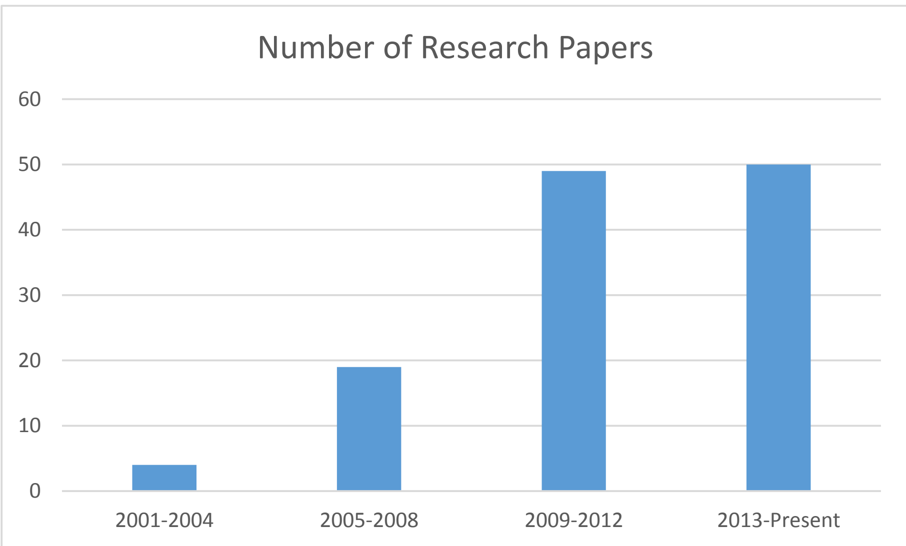

Fig. 1. Year wise distribution of research papers (till April 2016).

2010; Li & Ma, 2010; Slavin & Lake, 2008) and language (Archer et al., 2014). Furthermore, a majority of meta-analyses have been conducted on multiple grade levels such as elementary to college (Liao, 1999, 2007; 1998; Kulik & Kulik, 1991; Rakes et al., 2010; Ahmad & Lily, 1994; Fletcher-Finn & Gravatt, 1995; Li & Ma, 2010; Sung, Chang, & Liu, 2016a), elementary to secondary or middle school (Archer et al., 2014; Becker, 1992; Cheung & Slavin, 2013).

Table 1 summarises the meta-analyses of the impact of technology on learning effectiveness of students, extracted for elementary students. The existing meta-analyses found the positive impact of technology on learning effectiveness with effect sizes ranging from +0.16 to +0.78.

Though previous meta-analyses suggest that technology is effective for the learning of elementary students, the findings must be utilized cautiously because of a number of reasons. First, some of the previous meta-analyses had set the criteria of reviewing only those studies that took place in actual classrooms or school settings (Kulik & Kulik, 1991; Kulik, 2003; Kulik, Kulik, & Bangert-Drowns, 1985; Niemiec, Samson, Weinstein, & Walberg, 1987), however, learning via technology can take place anywhere as it is not confined to the formal educational institutes nowadays. Learning outside the classrooms may be just as meaningful as formal and structured learning inside the classrooms (Sandberg, Maris, & de Geus, 2011). Therefore, there are a number of recent studies in which experimental group of elementary students were free to learn electronically at unrestricted places (Aksoy, 2012; Barzilai & Blau, 2014; Hansen et al., 2012; Kalelioğlu, 2015; Zheng & Warschauer, 2015).

Second, there are meta-analyses that had considered the effect of specific type of technological device or application on students learning achievement, e.g., the effect of hypermedia (computer simulators, computer based interactive videos or multimedia) (Liao, 1998; 1999), mobile devices (Sung, Liao, Chang, Chen, & Chang, 2016a), microcomputer applications (Ahmad & Lily, 1994; Christmann & Badgett, 2003; Ryan, 1991), and computer-assisted instructions (Fletcher-Finn & Gravatt, 1995). Third, some of the previous meta-analyses had reviewed only those studies that took place at a particular geographic area (Liao, 2007).

1.3. Purpose of this study

While reviewing the existing meta-analyses of the impact of technology on learning effectiveness of elementary students, following two limitations were encountered. First, the majority of meta-analyses considered multiple grade levels and hence, there was a lack of study which particularly focused on elementary students. However, technology has become more popular in elementary schools nowadays (Chang, 2013). Researchers have articulated that if technology is integrated into the pedagogy of elementary students, it can act as a powerful tool to engage them into meaningful activities (Slavin, Lake, Chambers, Cheung, & Davis, 2009) and hence lead to high learning effectiveness (Su & Cheng, 2013). This study takes a step further by looking for specific moderating variables that influence the effect of technology on learning effectiveness of elementary students. Second, existing meta-analyses are quite dated and thus don't incorporate new literature. However, recent literature has incorporated new educational technologies that did not exist previously. As depicted in Fig. 1, there has been a significant rise in research interest on the impact of technology on learning effectiveness of elementary students and this large study set has not been analysed in detail.

With the above background, this study aims to: (1) recover, synthesize, and integrate the existing literature measuring the impact of technology on learning effectiveness of elementary students, (2) get an overview of the frequency of research conducted in this area in different geographic locations and published in different journals, and (3) find out how various moderating variables (i.e. domain subject, application type, intervention duration, and learning environment) influence the impact of technology on learning effectiveness of elementary students.

Table 1
Meta-analyses of the impact of technology on learning effectiveness of students (extracted for elementary students).

Studies	Years covered	Subjects	Sample size	Effect size
Ahmad and Lily (1994)	1988–1992	Multiple	9	0.34
Archer et al. (2014)	1978–2009	Language	38	0.18
Becker (1992)	1977–1989	Multiple	30	0.30
Cheung and Slavin (2013)	1980–2010	Mathematics	45	0.17
Christmann and Badgett (2003)	1966–2001	Multiple	39	0.34
Fletcher-Finn and Gravatt (1995)	1987–1992	Multiple	27	0.26
Kulik and Kulik (1991)	1966–1986	Multiple	16	0.46
Kulik (2003)	1990–1996	Multiple	16	0.38
Kulik et al. (1985)	1968–1984	Multiple	28	0.47
Li & Ma (2010)	1990–2006	Mathematics	48	0.78
Liao (1998)	1986–1997	Multiple	8	0.30
Liao (1999)	1987–1998	Multiple	10	0.22
Liao (2007)	1983–2003	Multiple	20	0.41
Niemiec et al. (1987)	1968–1982	Multiple	Unspecified	0.66
Rakes et al. (2010)	1968–2008	Mathematics	36	0.16
Ryan (1991)	1984–1989	Multiple	58	0.30
Slavin and Lake (2008)	1971–2006	Mathematics	38	0.19
Sung et al., 2016a	1993–2013	Multiple	38	0.65

This study employed a meta-analytic approach for fulfilling the above mentioned research objectives by providing a comprehensive picture of a large body of empirical research. In this study, a meta-analysis of 215 mean scores and standard deviations of experimental and control groups from a total of 122 different studies was conducted. The mean scores and standard deviations of experimental and control groups were used as the metric for estimating effect sizes.

The rest of this paper has been organized as follows: Section 2 gives an overview of review process. Section 3 presents the results of the review. Section 4 provides the concluding remarks, implications for theory and practice, limitations of this research, and recommendations for future research.

2. Review process

The review process for this study followed the guidelines suggested by Kitchenham and Charters (2007). The recommended guidelines include several activities such as protocol development, selection of research papers for review, data extraction and synthesis of results from the selected papers, and reporting the findings. Next, explanation to these activities has been provided in detail.

2.1. Protocol development

Protocol development determines the criteria to be used for searching the research papers for review. The papers were searched from the following prominent online databases: ProQuest, Sciencedirect, JSTOR, SpringerLink, ACM Digital Library, EBSCO, Emerald, Wiley Interscience, Informs, and Google Scholar. The papers published in or after year 2000 were extracted from these databases through the advanced search option by using a combination of search terms. The key categories and their respective search terms are listed in Table 2.

The search terms for each key category were combined by using the Boolean "AND" operator. Thus, each possible combination of search terms from Category Type 1 AND Category Type 2 AND Category Type 3 was utilized. This entire process was followed to make sure that the extracted papers had the phrases belonging to "elementary education", "technology", and "experimental study" together. This step resulted into a total of 1398 papers which were published on or before April 2016.

2.2. Inclusion decision on the basis of title and keywords

The papers resulted from the above mentioned search protocol were further filtered on the basis of title and keywords. The title and keywords of all the extracted papers were manually scanned so that the apparently irrelevant papers could be removed. This step resulted into a total of 724 peer-reviewed academic papers.

2.3. Inclusion decision on the basis of abstract

In this step, the abstract of each paper was read. This process resulted into the elimination of duplicate papers, qualitative papers, review papers, non-English articles, comments, editorials, news, prefaces etc. and those papers which didn't address the objective of this study but just mentioned the key categories in their text. It resulted into a total of 380 peer-reviewed academic papers.

2.4. Final selection

In this step, complete text of each paper was read so that only those papers were included which met the following criteria:

a) The paper should have mentioned its research objective clearly.
b) The central concept of the paper should have been to study the impact of technology on learning effectiveness for the domain subjects. To ensure relevance, the objective of the paper should have been to deal with the content mastery among the elementary students. In other words, the dependent variable should be related to the learning effectiveness of elementary students.
c) The study should have conducted pre-test and post-test with a technological intervention for learning.
d) The paper should have the sufficient information for calculating effect size, such as standard deviations, mean scores, number of people in experimental group, and number of people in control group (if applicable).

Table 2
Search terms used in this review.

Type	Category	Search terms
1	Elementary Education	Elementary Education, Elementary School, Elementary student, Primary Education, Primary School, Primary Student
2	Technology	Computer, Technology, Mobile, Laptop, Software, Digital
3	Experimental Study	Experimental, Control, Quasi-experimental, Pre-test, Post-test, Pretest, Posttest, Pre test, Post test

The above mentioned criteria led to the selection of 122 peer-reviewed academic papers. Next, the reference list of each paper was scanned, but it didn't result into identification of any other relevant paper. Thus, a total of 122 peer-reviewed academic papers constituted the sample for this study and the meta-analysis was conducted on them to statistically integrate their findings. The entire selection process and the number of research papers identified at each step are depicted in Fig. 2.

2.5. Data extraction and synthesis

In order to make sure that each paper was analysed consistently, the information such as mean scores, standard deviations, and sample sizes of experimental and control groups were noted down. This entire information was useful for calculating effect size, weighted mean effect size, confidence interval for the mean effect size, and for conducting the heterogeneity tests of Q and I^2 in order to identify whether the effect size is influenced by any moderating variable (Borenstein, Hedges, Higgins, & Rothstein, 2009).

Following Cohen's d formula (Cohen, 1988) was used to determine the effect size for experimental research without pre-test:

$$d = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{(n_1+n_2-2)}}}$$

Where, $\overline{X}_1$ and $\overline{X}_2$ are the mean scores, n_1 and n_2 are the sample sizes, and s_1^2 and s_2^2 are the variances of the experiment and control groups respectively.

For calculating the effect size for experimental research with pre-test, following formula was used in order to mitigate the selection bias as suggested by Morris (2008).

$$ES_{\frac{Pre}{Post}\text{Test Two Groups}} = \frac{\left(\overline{X}_{1_{Post}} - \overline{X}_{1_{Pre}}\right) - \left(\overline{X}_{2_{Post}} - \overline{X}_{2_{Pre}}\right)}{SD_{Post}}$$

Where, $\overline{X}_{1_{pre}}\overline{X}_{1_{Post}}$ are the mean scores of the pre-test and post-test of the experimental group respectively, $\overline{X}_{2_{pre}}$ and $\overline{X}_{2_{post}}$ are the mean scores of the pre-test and post-test of the control group respectively, and SD_{Post} is the pooled standard deviation for the post-test samples.

$$SD_{Post} = \sqrt{\frac{\left(n_{2_{Post}} - 1\right)s^2_{2_{Post}} + \left(n_{1_{Post}} - 1\right)s^2_{1_{Post}}}{\left(n_{2_{Post}} + n_{1_{Post}} - 2\right)}}$$

Where, $n_{1_{Post}}$ and $n_{2_{Post}}$ are the sample sizes of the experimental and control groups respectively for the post test, and $s^2_{1_{Post}}$ and $s^2_{2_{Post}}$ are the variances of the experimental and control groups respectively for the post test.

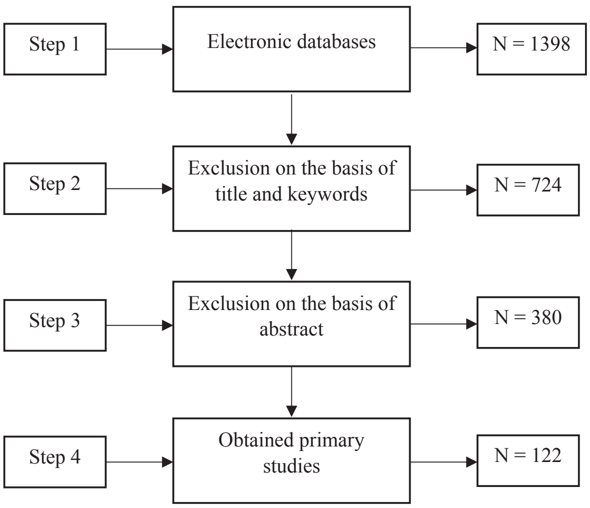

Fig. 2. Steps of the research papers selection process.

3. Results

3.1. Overview of research papers

All the selected peer-reviewed academic papers employed standardized tests. Out of them, 82 studies employed experimental design, while 40 studies employed quasi-experimental design. In an experimental design, participants are randomly assigned to either the treatment or the control group, whereas they are not randomly assigned in a study employing quasi-experimental design (Avolio, Reichard, Hannah, Walumbwa, & Chan, 2009). There were 68 studies with control group, while 54 studies were without control group. Table 3 provides the details of the type of tests conducted in peer-reviewed academic papers selected for this research.

Table 4 presents the distribution of selected papers for meta-analysis. As a measure to ensure the validity of tests, the papers extraction focussed on high quality journals publishing peer-reviewed academic papers. The journal "Computers & Education" had published the maximum number of papers which are relevant for this study. Table 5 provides the frequency with which selected research studies were conducted at different geographical locations. The total number of countries is greater than the number of research papers as one of the researches was conducted in two countries.

3.2. Overall effect size for learning effectiveness

One of the popular methods for meta-analysis in behavioral and social sciences, i.e., Hedges-Olkin technique (King & He, 2006) was used in this study. The distribution of 215 effect sizes of 122 research papers is shown in Fig. 3. Out of 215 effect sizes, there were three unusually high effect sizes of 15.744 (Kobsiripat, 2015), 4.817 (Navarro et al., 2003), and 5.995 (Thurston, Duran, Cunningham, Blanch, & Topping, 2009). These effect sizes were greater than the mean effect size of the entire sample by more than three standard deviations, and hence were excluded from this study (Lipsey & Wilson, 2000).

The combined effect size of 212 samples was calculated using random-effects model. Random-effect model assumes that the samples for each research paper has been taken from the population with varying effect sizes (Borenstein, Hedges, & Rothstein, 2007). The overall mean effect size was found to be 0.546 with a 95% confidence interval of 0.627–0.466. Cohen (1992) suggested that the effect size of 0.20 is small, 0.50 is medium, and 0.80 is large, hence the technology was found to have a medium effect on learning effectiveness of elementary students.

Further, the heterogeneity tests of Q and I^2 were conducted for all the effect sizes. When the meta-analysis is performed on the large number of studies, Q statistic has a tendency of highlighting even the small heterogeneity (Huedo-Medina, Huedo-Medina, Marin-Martinez, & Botella, 2006). With the objective of overcoming this weakness of Q statistic, Higgins and Thompson (2002) recommended I^2 index which measures the degree of true heterogeneity. The I^2 index signifies the between-studies variability, i.e., the percentage of the total variability due to true heterogeneity in a set of effect sizes (Huedo-Medina et al., 2006). As depicted in Table 6, the Q statistic was found significant, which indicated the rejection of null

Table 3
Type of tests conducted in reviewed papers.

Type of tests	Experimental	Quasi-experimental	Total
With Control Group	41	27	68
Without Control Group	41	13	54
Total	82	40	122

Table 4
Distribution of research papers in different journals.

Journal name	Number of studies
Computers & Education	46
Procedia-Social and Behavioral Sciences	14
Educational Technology & Society	10
Computers in Human Behavior	8
Journal of Computer Assisted Learning	6
Educational Technology Research and Development	6
The Turkish Online Journal of Educational Technology	3
Computer Assisted Language Learning	2
Learning and Instruction	2
Journal of Educational Computing Research	2
Interactive Learning Environments	2
The Electronic Library	2
Annals of Dyslexia	2
British Journal of Educational Technology	2
Others	15
Total	122

Table 5
Frequency of research conducted at different geographic locations.

Geo-spatial coverage	Frequency of publications	%
Taiwan	50	40.65%
Turkey	15	12.20%
Netherlands	10	8.13%
USA	10	8.13%
Spain	5	4.07%
Chile	4	3.25%
Cyprus	3	2.44%
England	3	2.44%
Canada	3	2.44%
Israel	2	1.63%
Mexico	2	1.63%
Thailand	2	1.63%
Singapore	1	0.81%
Romania	1	0.81%
Greece	1	0.81%
Malaysia	1	0.81%
Scotland	1	0.81%
Iran	1	0.81%
South Korea	1	0.81%
Hong Kong	1	0.81%
Ethiopia	1	0.81%
India	1	0.81%
France	1	0.81%
Indonesia	1	0.81%
Nigeria	1	0.81%
Italy	1	0.81%
Total	123	100.00%

Note. The total number of countries (123) is greater than the number of research papers (122) as one of the researches was conducted in more than one country.

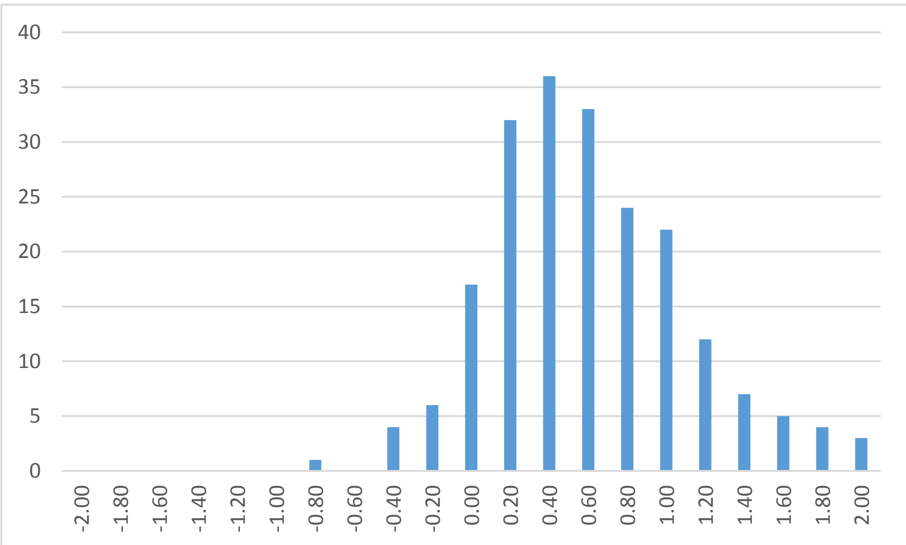

Fig. 3. Histogram of effect sizes.

hypothesis of homogeneity. Additionally, I^2 estimate indicated high heterogeneity as per the classification proposed by Huedo-Medina et al. (2006). Hence, the tests of heterogeneity supported the assumption of random-effects model.

3.3. Moderating variables analysis

Following is the description of each variable that has been taken as the moderator in this study (Sung et al., 2016a):

Table 6
Summary of effect size of path coefficients for all the studies.

	Overall
Number of samples (k)	212
Total sample size (N)	32,096
Effect Size	0.546
Z	13.297
p(effect size)	0.000
Heterogeneity test (Q)	1453.1
p(Heterogeneity)	0.000
I^2	0.855
95% upper	0.627
95% lower	0.466

1. Domain Subject: Domain subject was considered in order to establish the relative learning effectiveness of different subjects such as general (when technology was used in learning more than one subject), language, mathematics, music, science, science and technology, social studies, and art.
2. Application Type: Application type was considered to understand whether the impact of technology on learning effectiveness differs for the learning oriented and general applications. General applications refer to those technological applications which had not been designed specifically for learning purposes such as Microsoft office, while learning oriented technologies were designed especially for achieving educational goals.
3. Intervention duration: Different intervention durations were taken into account for establishing their relative learning effectiveness for elementary students. The interventions were considered for the different durations: $\leq$ 1 week duration, > 1 week and $\leq$4 weeks, > 1 month and $\leq$6 months, > 6 months, and “not mentioned”.
4. Learning environment: Learning environment was considered to understand whether the impact of technology on learning effectiveness differs in formal (classroom, laboratory), informal (home, temple, park, playground, outside), and unrestricted (encompassing both formal and informal) settings.

Thus, in order to conduct moderator analysis, the information such as the domain subject, application type, intervention duration, and learning environment were noted down for each reviewed paper. Next, the findings for each moderating variable has been discussed in detail:

3.3.1. Domain subject

The reviewed papers were grouped according to domain subjects in order to conduct the moderator analysis. Table 7 shows the estimation of effect sizes for all the domain subjects along with the Z-values, p-values, and confidence intervals. Fig. 4 depicts the 95% confidence interval for the effect sizes of each domain subject. General ($g = 0.605$, $Z = 3.718$, $p < 0.001$) and science ($g = 0.727$, $Z = 7.462$, $p < 0.001$) had the high effect size, while social studies ($g = 0.273$, $Z = 2.143$, $p < 0.05$) had the low effect size. Subjects such as language ($g = 0.448$, $Z = 7.108$, $p < 0.001$), mathematics ($g = 0.469$, $Z = 7.733$, $p < 0.001$), and science and technology ($g = 0.435$, $Z = 3.480$, $p < 0.001$) had the medium effect sizes. This suggests that the use of technology leads to medium learning effectiveness for language, mathematics, and science and technology, while low learning effectiveness for social studies. On the other hand, technology leads to high learning effectiveness for general subjects and science.

Further, effect sizes were found significant for the all the domain subjects except music and arts. It should be noted that the number of research papers pertaining to music and arts were quite small and therefore the results may be less reliable for them.

3.3.2. Application type

The review papers were grouped according to application types for conducting moderator analysis. Table 8 shows the estimation of the effect sizes for both the application types along with Z-values, p-values, and confidence intervals. Effect sizes were found significant and medium for learning oriented ($g = 0.565$, $Z = 11.260$, $p < 0.001$) as well as general ($g = 0.488$,

Table 7
Moderator analysis by domain subject.

	General	Language	Mathematics	Music	Science	Science & technology	Social studies	Art
Number of samples (k)	27	77	41	1	42	15	5	4
Total sample size (N)	3325	18,474	4581	186	2861	1235	1068	366
Effect Size	0.605	0.448	0.469	0.483	0.727	0.435	0.273	0.598
Z	3.718	7.108	7.733	NA	7.462	3.480	2.143	1.032
p(effect size)	0.000	0.000	0.000	NA	0.000	0.001	0.032	0.302
95% upper	0.923	0.571	0.588	NA	0.918	0.680	0.522	1.733
95% lower	0.286	0.324	0.350	NA	0.536	0.190	0.023	−0.537

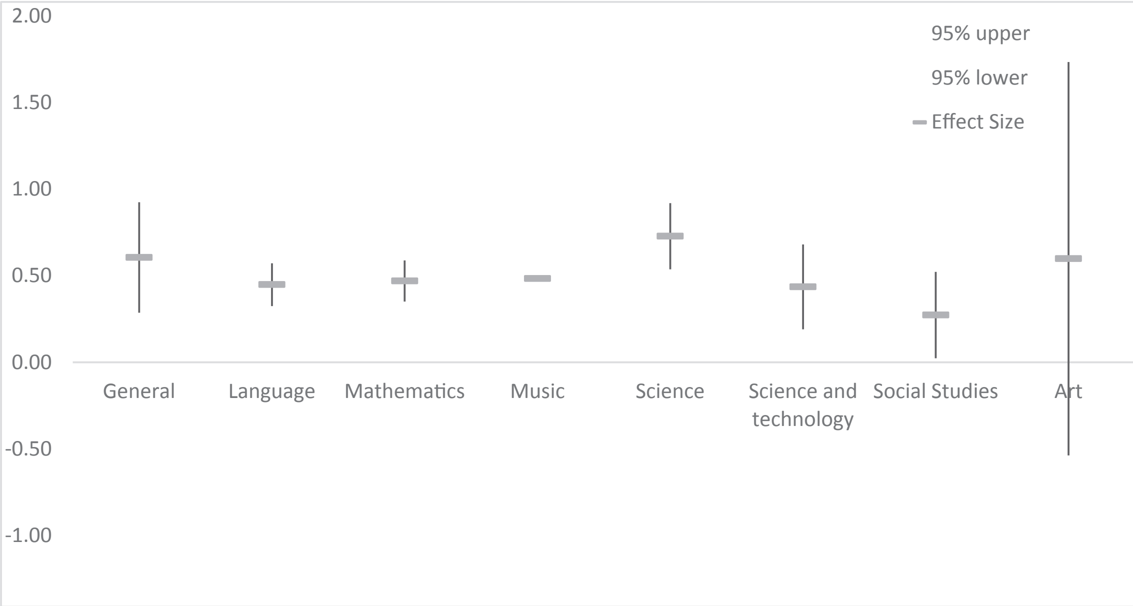

Fig. 4. Moderation – domain subject.

Table 8
Moderator analysis by application type.

	Learning oriented	General
Number of samples (k)	155	57
Total sample size (N)	19,418	12,678
Effect Size	0.565	0.488
Z	11.260	6.791
p(effect size)	0.000	0.000
95% upper	0.664	0.629
95% lower	0.467	0.347

$Z = 6.791$, $p < 0.001$) application types. This suggests that general as well as learning oriented applications have medium impact on learning effectiveness.

Fig. 5 depicts the 95% confidence interval for the effect sizes of both the application types. The most noteworthy finding is the significant overlap between learning oriented and general applications.

3.3.3. *Intervention duration*

The review papers were categorized into various intervention durations in order to conduct moderator analysis. Table 9 shows the estimation of the effect sizes for all the intervention durations along with Z-values, p-values, and confidence intervals. Fig. 6 depicts the 95% confidence interval for the effect sizes of all the intervention durations. The effect sizes were found significant and high for "≤ 1 week" ($g = 0.704$, $Z = 6.757$, $p < 0.001$) and "> 6 months" ($g = 0.616$, $Z = 9.077$, $p < 0.001$) durations, while significant and medium for "> 1 week and ≤4 weeks" ($g = 0.546$, $Z = 5.805$, $p < 0.001$) and "> 1 month and ≤6 months" ($g = 0.483$, $Z = 8.267$, $p < 0.001$) durations.

One of the most noteworthy findings is that the impact of technology on learning effectiveness of elementary students is high for the long intervention duration of "> 6 months" and the small intervention duration of "≤ 1 week". This finding is contrary to the existing literature according to which brief intervention duration tends to have a larger impact than long intervention duration as highly artificial conditions can be created by the experimenters for a short period (Cheung & Slavin, 2013).

3.3.4. *Learning environment*

The review papers were clustered into various types of learning environments for conducting moderator analysis. Table 10 shows the estimation of the effect sizes for all the learning environments along with Z-values, p-values, and confidence intervals. Fig. 7 depicts the 95% confidence interval for the effect sizes of all the learning environments. Effect sizes were found high for informal settings ($g = 0.700$, $Z = 6.813$, $p < 0.001$), medium for unrestricted settings ($g = 0.430$, $Z = 4.827$, $p < 0.001$), and low for formal settings ($g = 0.534$, $Z = 11.272$, $p < 0.001$).

Fig. 5. Moderation – application type.

As the effect size of informal learning environment is higher than other learning environments, it implies that the places such as outdoor location, playground, park, home, and temple have a higher impact on learning effectiveness of elementary students as compared to classroom and computer laboratory. This finding is in consistency with Sandberg et al. (2011) who articulated that currently learning is not restricted to the formal educational institutes as children can learn informally out of school as well. Sometimes, informal learning environment outside the school offers significant learning opportunities as compared to the structured learning environment inside the school.

Another worthwhile finding emerged from the cross analysis of learning environment with application type (see Table 11). Learning oriented applications had high effect size in informal settings, while medium effect size in formal and unrestricted settings. Also, the effect size of learning oriented applications was found higher than the general applications in each environment. It implies that the learning oriented applications are more effective than general applications and learning oriented applications have the maximum effectiveness in informal settings.

As per the cross analysis of learning environment with intervention duration, another important finding (see Table 11) was that the formal settings have high effect size, while informal settings have medium effect size for ≤ 1 week intervention duration. However, it was found that for a long intervention duration of >1 month and $\leq$6 months, informal settings have high effect size, while formal settings have medium effect size. It implies that formal settings lead to high learning effectiveness for short intervention duration. On the other hand, informal settings lead to high learning effectiveness for long intervention duration.

3.4. Evaluation of publication bias

Quantitative reviews such as meta-analysis have the potential to be affected by the publication bias. The most common publication bias is the tendency of journals to publish studies with only statistically significant results, i.e., success stories (Rosenberg, 2005). There are some measures which test whether publication bias exists in the results of meta-analysis. This

Table 9
Moderator analysis by intervention duration.

	$\leq$1 week	>1 week, $\leq$4 weeks	>1 month, $\leq$6 months	>6 months
Number of samples (k)	45	50	90	18
Total sample size (N)	4334	4980	11,330	10,582
Effect Size	0.704	0.546	0.483	0.616
Z	6.757	5.805	8.267	9.077
p(effect size)	0.000	0.000	0.000	0.000
95% upper	0.909	0.730	0.598	0.749
95% lower	0.500	0.361	0.369	0.483

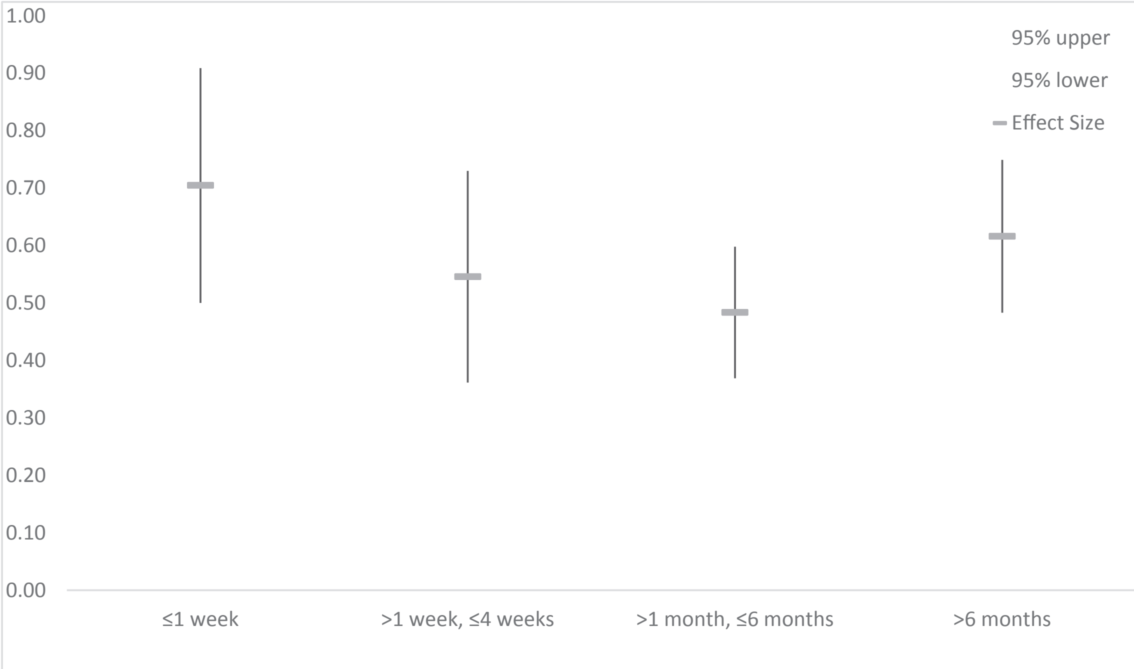

Fig. 6. Moderation – intervention duration.

study used the classic fail-safe number of Rosenthal (1991) to calculate how many insignificant effect sizes of unpublished studies would be required to reduce the total effect size to the insignificant level. Fail-safe number is basically a procedure to evaluate whether publication bias (if it exists) can be safely ignored (Rosenberg, 2005). A fail-safe number is usually considered robust if it is larger than 5n+10, where n is the original number of studies included in the meta-analysis. If the fail-safe is larger than 5n+10, it indicates that the estimated effect size of unpublished studies is unlikely to impact the overall effect size of the meta-analysis. In addition to this, this study also calculated the fail-safe number of Rosenberg (2005).

As shown in Table 12, the classic fail-safe number determined that a total of 108,100 studies with insignificant results would be required to nullify the effect size. Further, the results of Rosenberg's fail-safe number test show that the number of studies with null results required to bring the overall effect size to the insignificant level was 1295. Both the tests suggest that the publication bias is unlikely to be the problem for this meta-analysis.

4. Conclusions

The objective of this study was to integrate the findings of multiple independent research papers measuring the impact of technology on learning effectiveness of elementary students and to draw the general conclusions from them. This study was an attempt to find the mean effect sizes of research studies that experimentally introduced the technology to elementary students and quantitatively compared their learning effectiveness with the control group which underwent traditional learning. This study further attempted to discover the moderating variables that influence the effect of technology on learning effectiveness of elementary students. The review of the present literature encompassed 122 peer-reviewed academic papers with 212 samples and more than 32,000 observations. The findings of these research papers acted as input to the empirical data analysis for this study.

Table 10
Moderator analysis by learning environment.

	Formal settings (classroom, laboratory)	Informal settings (home, temple, park, playground, outside)	Unrestricted
Number of samples (k)	167	21	24
Total sample size (N)	27,431	1985	2680
Effect Size	0.534	0.700	0.430
Z	11.272	6.813	4.827
p(effect size)	0.000	0.000	0.000
95% upper	0.626	0.902	0.604
95% lower	0.441	0.499	0.255

Fig. 7. Moderation – learning environment.

While reviewing and analysing the existing literature, technology was found leading to the learning effectiveness of elementary students. The mean effect size for this study was found medium and significant ($g = 0.546$, $p < 0.001$). Thus, it can be concluded that technology leads to effective learning of elementary students. Further, a significant variability was found in the effect sizes of samples which suggested the need to look for the moderating variables. From the literature, domain subject, application type, intervention duration, and learning environment were found as the moderating variables.

Use of moderating variables provided a number of recommendations. First, technology is highly effective for learning general subjects and science, moderately effective for learning language, mathematics, and science and technology, while poorly effective for learning social studies. Second, the impact of technology on learning effectiveness of elementary students is high for long intervention duration of "> 6 months" as well as for small intervention duration of "≤ 1 week". Third, the

Table 11
Cross analysis of application type and intervention duration with learning environment.

		Learning environment		
		Formal settings (classroom, laboratory)	Informal settings (home, temple, park, playground, outside)	Unrestricted
Application Type	General	0.528	−0.069	0.376
	Learning Oriented	0.532	0.782	0.513
Intervention Duration	≤1 week	0.720	0.550	NA
	>1 week, ≤4 weeks	0.580	0.442	0.433
	>1 month, ≤6 months	0.400	0.926	0.662
	>6 months	0.655	NA	0.300

Table 12
Results of the fail-safe number tests.

Confidence level (alpha)	5%
Number of observed studies	212
Fail safe number (Rosenthal, 1991)	108,100
Fail safe number (Rosenberg, 2005)	1295

informal settings in a learning environment leads to higher learning effectiveness for elementary students compared to formal settings. Fourth, the cross analysis of moderating variables suggests that learning oriented applications are highly effective in informal settings. Lastly, informal settings are more effective for long intervention duration, while formal settings are more effective for short intervention duration. These findings contribute to a better understanding of the conditions that lead to high learning effectiveness of elementary students.

4.1. Implications for theory and practice

This study showed the growing trend towards the understanding of the impact of technology on learning effectiveness of elementary students. From the theoretical implications perspective, the findings of this study may offer the researchers in the area of e-learning with a ready reference of the present research papers measuring the impact of technology on learning effectiveness of elementary students. Apart from integrating the findings of these research papers, this study also attempted to differentiate the results on the basis of domain subject, application type, intervention duration, and learning environment. The most common domain subjects studied in the existing research papers were language, science, and mathematics, followed by general, science and technology, and social studies. The domain subjects such as art and music were least studied. The researchers had extensively studied the effectiveness of learning oriented applications and formal learning environment. Thus, the findings of this review may act as a useful source of information for the researchers, especially if they wish to learn more about a particular domain subject, application type, intervention duration, and learning environment. Further, the findings may also help new researchers in the field of e-learning to identify more appropriate journals to refer to and to publish their research.

This study also provided significant implications from practical perspective. The findings indicate the effectiveness of technology for different domain subjects, application types, intervention durations, and learning environments for elementary students. For example, under domain subject's category, technology was found most effective for science. It suggests that there should be a focus to encourage use of technology in teaching science to the elementary students. Further, learning oriented as well as general applications were found moderately effective, with marginally higher effectiveness of learning oriented applications, suggesting the need to design the learning oriented applications. Thus, more research efforts should be laid on designing such applications. Teachers should also be encouraged to utilize research based learning oriented applications in their class (Sung et al., 2016a). Further, high effectiveness of informal learning environment suggests that school authority should lay more focus on holding a number of informal learning activities using technology than just equipping their classrooms with technology. Such informal activities also offer the significant learning opportunities to the students (Sandberg et al., 2011).

Findings from the cross analysis suggest that the learning environment found successful for an application type and a particular intervention duration may not work for the other. Thus, the suitable combination of learning environment with application type and intervention duration should be utilized. For example, informal settings were found useful for learning oriented applications as well as long intervention duration. It implies that the school authorities should teach the students using learning oriented applications in informal settings such as outdoor locations. Further, they should also hold such activities for long duration for more effective learning. Apart from that school authorities should also emphasise on imparting training to the teachers on the use of technology in classrooms as teachers are supposed to empower the students with the benefits offered by technology (Gülbahar, Ilkhan, Kilis, & Arslan, 2013). Lastly, researchers and practitioners will find this study a valuable source of information, specifically if they wish to gain more knowledge on various facets relating to the existing research measuring the impact of technology on learning effectiveness of elementary students.

4.2. Limitations and future research

This study employed rigorous methodology, but still there are certain limitations that should be taken into consideration by future researchers and practitioners. The findings of this study should be interpreted within the context of those limitations. Furthermore, this section discusses the directions of future research.

Firstly, the research papers for meta-analysis were extracted from some of the popular online databases by using a set of key search terms. However, based on those limited key search terms, some of the relevant research papers may not have been extracted. Additionally, some other relevant research papers published in the journals that were not part of these online databases may have not been considered for this study.

Secondly, the findings of this study may be influenced by the “publishing bias”. This is because of the fact that the research papers with significant findings have more chances of getting published. Thus, the research papers with insignificant findings could not be analysed in this study. Further, this study may also be impacted by “sampling bias” as only those research papers were analysed which had sufficient information available for calculating effect size.

Thirdly, this study could not explore the moderating impact of domain subjects such as music and arts as the sample was insufficient to measure the impact of technology on learning these subjects. Therefore, in order to understand the impact of technology on the learning effectiveness for these subjects, future researches can be conducted. Also, there is a lack of research which studies the effect of unrestricted learning settings for small intervention duration of $\leq$1 week and informal settings for long intervention duration of >6 months.

Lastly, though this study examined the effect of moderating variables such as domain subject, application type, intervention duration, and learning environment, there might exist other characteristics such as cultural differences that may act as the moderating variables. These potential moderating variables were not considered due to scarcity of details about them in the research papers considered for review. Future researchers can perform investigation on such aspects also.

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