Education and Information Technologies (2022) 27:1725–1745
https://doi.org/10.1007/s10639-021-10640-x

A meta-analysis of the impact of mobile learning on mathematics achievement

Mustafa Güler[1] · Suphi Önder Bütüner[2] · Şahin Danişman[3] · Kadir Gürsoy[1]

Received: 14 March 2021 / Accepted: 16 June 2021 / Published online: 2 August 2021
© Springer Science+Business Media, LLC, part of Springer Nature 2021

Abstract

The technological developments of the twenty-first century have enabled the emergence of alternative teaching-learning models and instructional tools. One of the concepts brought about by such developments is mobile learning. The aim of this study was to test the effect of mobile learning on students' mathematics achievement. A systematic database search that included the Academic Search Complete, Education Resources Information Center (ERIC), EBSCO, JSTOR, ScienceDirect, Taylor & Francis Online, and Web of Science was carried out to examine peer-reviewed articles that met the inclusion criteria. A total of 22 quantitative research papers published between 2010 and 2020 were included in the meta-analysis. The results show that mobile learning has a medium-level positive effect ($g = 0.476$; $p < .001$; with a 95% confidence interval of 0.335–0.616) on students' mathematics achievement. Moderator analyses showed that the effect sizes were not significantly moderated by grade level and implementer, while content area was found to be a moderator. Based on the results, some suggestions are offered for future studies in designed learning environments.

Keywords Mobile learning · Mathematics education · Educational research · Mathematics achievement · Meta-analysis

✉ Mustafa Güler
mustafaguler@trabzon.edu.tr

Suphi Önder Bütüner
s.onder.butuner@bozok.edu.tr

Şahin Danişman
sahindanisman@duzce.edu.tr

Kadir Gürsoy
kadirgursoy@trabzon.edu.tr

Extended author information available on the last page of the article

1 Introduction

Rapid changes in information, communication and wireless technology have paved the way for mobile devices to become widely available, affordable and convenient (Wu et al., 2012). As such, along with increases in accessibility and internet speed, the use of mobile devices has been accepted by most of the world population. With greater numbers of students having mobile devices at their disposal, researchers and educators and researchers have turned their attention to finding educational applications to facilitate the teaching and learning process (Baek & Guo, 2019). As a result, the term mobile learning has entered the literature, and with the ability of mobile learning to overcome limitations of time and place, the use of mobile devices has come to the fore in educational research (Ozcelik & Acarturk, 2011).

In this regard, researchers have focused on the ability of mobile technologies to provide learning opportunities that include new and engaging teaching methods, both beyond the classroom walls (Christensen & Knezek, 2017) and inside the classroom (Chee et al., 2017). In the context of mathematics, which is seen as being difficult and boring for some students (Sam & Ernest, 2000), Chang et al. (2016) underscore the potential of mobile technologies to provide interesting and contemporary teaching methods. Because various studies have revealed that students' perceptions of the learning setting (Fast et al., 2010), as well as motivation and engagement (Singh et al., 2002), are connected to their attitudes towards mathematics and their mathematics achievement, there is a need for teaching methods that have the capacity to overcome students' negative attitudes towards mathematics and increase their academic success. Mobile learning is considered as one alternative to traditional strategies that may have potential in this regard.

2 Mobile learning

Many definitions of mobile learning may be encountered in the literature. The primary reason for these differing definitions is that mobile learning has many applications in areas ranging from business to health, from military to education. For instance, in his definition, Keegan (2005) highlighted the term *mobility* and defined mobile learning as providing education and training through PDAs, palmtops, handhelds, smartphones and mobile phones. Similarly, Traxler (2005), who is most frequently referenced in this field, defined mobile learning as:

> any educational provision where the sole or dominant technologies are handheld or palmtop devices. This definition may mean that mobile learning could include mobile phones, smartphones, personal digital assistants (PDAs) and their peripherals, perhaps tablet PCs and perhaps laptop PCs, but not desktops in carts and other similar solutions. Perhaps the definition should also address the growing number of experiments with dedicated mobile devices such as games consoles and iPod, and it should encompass both mainstream industrial technologies and one-off experimental technologies (pp. 261-262).

Considering the functions of mobile learning, Ally (2009) states that wireless mobile technologies enable people to access information and learning materials without limitation in terms of space. Other definitions also refer to this feature. According to Brown (2005), for example, mobile learning is an extended version of e-learning, while Peters (2007) refers to mobile learning as a subset of e-learning and explains it as a process to make learning "just in time, just enough and just for me" (p. 437). Moreover, in her pedagogical framework, Park (2011) defines mobile learning as the use of mobile and wireless devices for learning "on the move" (p. 17), making a distinction between e-learning and mobile learning. According to Schuck and Maher (2018), mobile devices provided both students and teachers with new roles, as well as lifting them beyond the constraints of traditional learning environments. In this sense, mobile learning designs provided opportunities for seamless learning (Schuck et al., 2017), and as such have been described as a bridge between public and private learning spaces where constraints of time and location are eliminated (Looi et al., 2012).

3 Mobile learning in the educational context

Although the literature on mobile learning literature dates back to early 2000, it was later in the decade that mobile learning tools were first used in instructional contexts. According to Stevens and Kitchenham (2011), the notion of mobile learning was rooted in the early development of hardware devices; however, these were overshadowed by the emergence of computer applications and software. One of the first implementations of mobile learning in education was the extensive use of SMS in North America, Asia and Europe (Prensky, 2005). However, with the increasing use of smartphones, PDAs, iPods and iPads in the previous decade, educational research focusing on mobile learning applications has become more prominent. In this sense, numerous researchers have underscored the potential of mobile learning environments for reducing learning-related problems in educational contexts. For instance, in a study conducted by Kolb (2011), it was reported that secondary teachers perceived the use of mobile devices as decreasing disciplinary problems; moreover, secondary school students expressed both negative and positive impacts of such devices (as cited in Walker, 2013). According to West (2013), moreover, mobile technologies offer opportunities for teachers to create alternative classroom models that support students in taking responsibility for their own learning and allow teachers to focus on problem-solving and critical thinking skills.

The benefits of the use of mobile devices in education have rapidly become apparent in various learning areas, and mathematics education, in particular, has been viewed as a context in which mobile technologies can be used to design learning environments (e.g., network, virtual, interactive) to improve students' mathematical thinking (Açıkgül & Şad, 2021; Borba et al., 2016). In the contexts of mathematics education, it is generally recognized that a constructivist-based, student-centered approach is the most effective way to support learning, but in terms of actual practice, it has been shown that rote learning through a transmissive approach is frequently the norm (Gill & Boote, 2012, as cited in Bano et al., 2018). Given this circumstance, mobile devices offer the potential to enhance learning in terms of authenticity, collaboration and personalisation (Kearney et al., 2020). This potential has led to an increasing prevalence of mobile-

based instructional pedagogies, and numerous countries have begun to implement an iPAC framework (e.g. Australia, Norway, Germany, UK) with support from teacher educators, teachers and school leaders (Kearney et al., 2020). The framework is used to measure or evaluate the use of mobile technologies in learning activities (France et al., 2021). One of the basic ideas underlying the use of mobile technologies in mathematics teaching and learning is that it includes factors such as different representations and various elements for engagement. These support meaningful mathematical understanding and minimize students' perceptions of mathematics terminology as abstract and unfamiliar (Baker et al., 2018; Kluge and Dolonen, 2015).

The literature related to mobile learning in mathematics education has focused on three learning settings: hardware, software, and the mathematical activities carried out through these tools (Calder et al., 2018). The fundamental focus of these studies is on the ways in which learners, assisted by suitable mobile devices, can contribute to the process of gaining new mathematical knowledge, skills, and experiences (Kyriakides et al., 2016). In addition, some researchers have studied mathematics applications (apps) as a part of mobile learning and explored the ways that they are used (e.g. Larkin & Milford, 2018). For example, Namukasa et al. (2016) examined 80 math apps and noted that only four of these centered on building understanding of mathematical concepts. On the other hand, many studies have been conducted on the effects of mobile learning tools on student achievement as a means to understand how and in which cases these tools are effective. According to Sung et al. (2016), although the advantages of mobile learning environments have been underscored, there are many variables relating to the effect of mobile devices on academic achievement. In this regard, studies on the effects of various mobile tools on learning have reported different results. For example, Goodman et al. (2016) investigated student performance in physical and digital versions of spatial mathematics tasks. Physical representations of spatial tasks were found to be more effective at the end of their study. In other studies, research on the effectiveness of mobile learning in terms of grade level have produced different reports. For example, Moh (2013) revealed that the academic success of university students increased significantly thanks to mobile learning tools in comparison to face-to-face applications. However, Hung et al. (2014) did not reach a conclusion that pointed to this effectiveness at the same educational level. As a final remark, in their meta-analysis study that aimed to determine the effect of mobile devices on K-12 students' achievement, Tingir et al. (2017) contended that the role of the implementer might be greater than had previously been reported. According to their findings, some studies indicated a higher effect size when the teacher was the implementer, as opposed to studies conducted by the researchers.

In addition to these inconsistent results, existing meta-analysis studies demonstrate a greater focus on general education rather than on subject domains (e.g., Talan, 2020; Wu et al., 2012). Considering all of these factors, this paper attempted to examine student achievement in a mobile mathematics learning environment and in traditional classrooms in a meta-analytic way. In this sense, traditional classrooms refer to a learning environment in which the instructors use a variety of strategies to engage learners within the classroom (i.e., lecturing, group work, and making presentations) (Lo et al., 2017). On the other hand, mobile learning consists of in- and out-of-school

environments where learners can participate whenever and wherever they choose (Keengwe & Bhargava, 2014; Pegrum, 2019). As the current study is a meta-analysis, we focused on the effects of environments reported as mobile-based instruction, rather than discussing the boundaries of this broad concept. In brief, the current study is expected to fill the above-mentioned gap by seeking responses to the following research questions, guided by this study's design to examine the status of students' cognitive learning outcomes in mobile based instruction:

(1) How does the effectiveness of mobile-based instruction compare to traditional instruction?
(2) What moderator variables (implementer, school level, content area) influence the effectiveness of mobile-based instruction on students' cognitive learning outcomes?

4 Method

4.1 Research design

This meta-analysis study aims to reveal the effect level of mobile learning on student achievement in mathematics compared to traditional teaching and to determine whether the variables of education level, content area and implementer are meaningful moderators on the effect size.

4.2 Search and selection process

The flow chart showing the processes carried out in the current study, from the first screening to the determination of the studies to be included in the analysis, is presented in Fig. 1. First, in the screening phase, the titles and abstracts of the articles located using keywords were read, and the pre-selection process was carried out. For the articles that moved to the second stage, studies that did not contain sufficient statistical values and did not have an experimental-control group were eliminated by reading the full texts of the articles.

4.3 Initial search and screen

Since the mobile learning studies conducted before 2010 provided little classroom research (Qu, 2021), the literature review covered the years between 2010 and 2020. The data sources selected for the study were Academic Search Complete, Education Resources Information Center (ERIC), EBSCO, JSTOR, Science Direct, Taylor & Francis Online and Web of Science. Key descriptors or root forms of mobile device terms (i.e., iPad, tablet, handheld devices, mobile devices, cell phones, smart phones "mobile learning", mlearning, m-learning) were used in combination with key performance indicators (i.e., achievement, performance, success, outcomes, perform*) to search for relevant articles. In addition, mathematical terms (i.e., mathematics, math, math education, mathematics education, geometry, algebra, statistics, numbers, calculus and probability) were included as keywords to identify studies related to mathematics.

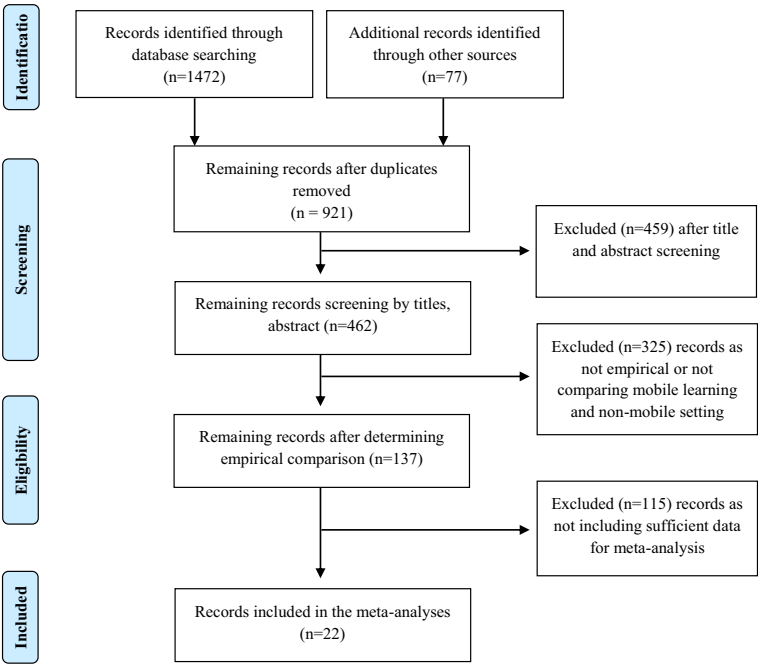


Fig. 1 Flow diagram of the study selection process

4.4 Selection criteria

All articles included in this study were written in English and published in peer-reviewed journals. The studies were also evaluated in terms of the following inclusion and exclusion criteria, as shown in Table 1.

Table 1 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Time period	Published between 2010 and 2020	Published outside this time period
Language	English	Non-English
Literature type	Peer-reviewed journal articles	Non-peer-reviewed journal articles
Research design	Study had an experimental (randomized controlled), or q uasi-experimental design Study had a between-subject design comparing mobile-based and traditional instruction	Non-experimental or not quasi-experimental design or no comparison between mobile-based and traditional instruction
Results of research	Adequate quantitative data for calculating the effect size or reporting the effect size	Not enough quantitative data for calculating the effect size
Educational outcomes	Cognitive learning outcomes	Non-cognitive learning outcomes

4.5 Final selection and data extraction

To extract the relevant data, we drew the following information from the studies, mainly based on the predesigned conceptual framework: study authors and year of publication; sample size; type of subject; design method (quasi-experimental or randomized control); treatment duration; and measurements of cognitive learning outcomes. Two researchers independently performed the data extraction. Discrepancies between the extracted data were resolved through consensus between the two researchers. A total of 22 eligible articles were included in the final meta-analysis.

4.6 Data analysis

In calculating the effect sizes, since Hedge's g is more accurate and less biased than Cohen's d when a sample size is relatively small (Borenstein et al., 2021), we opted to apply Hedges' g calculation for all of the reported effect sizes. A meta-analyst should carefully consider the studies to be added to the meta-analysis. After defining a research question, the researcher should attempt to access all of the studies related to the research question. Publication bias is almost certainly one of the major methodological problems associated with meta-analyses and research reviews. For instance, the differences described in relation to publication type could affect publication bias, since in this meta-analysis, most of the effect sizes considered came from studies published in prestigious scientific journals. It had been well established that studies showing non-significant results are not easily published, and that their results are usually excluded from quantitative reviews of research results (Castro et al., 2015, p. 41). Taking only published studies with significant results into account in a meta-analysis would be considered as biased, as these do not represent the entire population of completed studies. This issue is referred to as "publication bias" or "file-drawer problem" in the meta-analysis literature (Rosenthal, 1979; Begg & Berlin, 1988). Possible publication bias was identified through the visual inspection of a funnel plot, the trim-and-fill method, Egger's linear regression method and Begg's test. In addition, the Classic fail-safe N and Orwin's fail-safe N numbers were also provided. Borenstein et al. (2021) assert that random effect models are more accurate when the effect sizes of the studies included in a meta-analysis are different from each other. With this in mind, in evaluating statistical heterogeneity, the Cochran Q-test and I^2test results were reported. The p value obtained as a result of the Cochran-Q test was less than .05, indicating the presence of heterogeneity. In such a case, the random effects model is recommended (Borenstein et al., 2021). Higgins et al. (2003) similarly evaluated the values I^2 of statistics as 25% having low heterogeneity, 50% having medium heterogeneity and 75% having high heterogeneity. In this study, we calculated the effect sizes according to the random effects model. For the studies reported multiple scores (e.g., two multiplication tests) and these outcomes met the criteria to be included in the same analysis, a mean effect was calculated to ensure that each study contributed only one effect size to any given analysis (Lipsey & Wilson, 2001). Furthermore, moderator analysis was carried out to determine the source of heterogeneity between the effect sizes of the studies. The following moderators were defined, and the analysis was performed using CMA software: school level, content area, and implementer. As a result of the analysis, the ranges put forward by Thalheimer and Cook (2002) were

taken into consideration in the interpretation of the effect sizes. Accordingly, an effect size of 0.15 was considered as negligible, 0.4 as small, 0.75 as medium, 1.10 as large, 1.45 as very large, and values greater than 1.45 were considered as huge.

4.7 Inter-rater reliability

Interrater reliability was calculated based on the agreement among the coders and ranged from 92% (findings) to 96% (study information). Disagreements between the researchers were resolved through an online group meeting with full team participation. When titles, abstracts and keywords of articles provided insufficient information, the researchers read the full-paper versions of the articles and reviewed them to ensure the articles met the criteria.

4.8 Characteristics of the included studies

As noted above, a total of 22 articles were included in this review; the article screenings led to the identification of 22 independent effect sizes. Table 2 (below) describes the main elements of the 22 studies included in the meta-analysis. These studies were conducted in 11 different countries and regions, which indicates that the research on mobile-based instruction is widespread. The studies, which were published from 2010 to 2020, included quasi-experimental or randomized control designs. The sample sizes in the studies ranged from 13 to 461 participants, and most studies were modest in scope, with a sample size of less than 100. The pooled sample size was 2391 (experimental group = 1355, control group = 1036). The study participants represented all levels of education: preschool, primary (1–4), elementary (5–8), high school, and university. The content areas included number and operation, geometry, algebra, trigonometry, data-probability and mixed (for example algebra + geometry).

5 Findings

In the current study, firstly, the findings regarding publication bias and the descriptive statistics regarding the effect sizes were reported. Next, the values calculated according to fixed effects and random effects models (mean effect size values, standard error and variance values, lower-upper limit values at 95% confidence interval, z and p) are presented. Finally, the findings regarding the heterogeneity of the distribution of effect sizes and the findings regarding the moderator analysis are introduced.

5.1 Publication Bias

Borenstein et al. (2021) suggested that funnel plot, trim-fill method and Egger regression tests should be calculated together in the evaluation of publication bias. In this study, in addition to these three strategies, Begg and Mazumdar rank correlation, Classic failsafe N and Orwin's failsafe N numbers were also provided. All of these approaches examined the distribution of effect size estimates according to standard error and evaluated whether they were symmetrical. When the evidence of publication bias was examined in the funnel plot showing the relationship between standard

Table 2 Characteristics of the 22 studies included in the analysis

No	Study(year)	Country	Sample size(E/C)	Content area	School level	Implementer
1	Lan et al. (2010)	Taiwan	28(14/14)	Number-Operation	Primary	Teacher
2	Park et al. (2010)	New Zealand	33(24/9)	Geometry	University	Researcher
3	Carr (2012)	USA	104(56/48)	Mix	Elementary	Researcher
4	Kiger et al. (2012)	USA	87(41/46)	Number-Operation	Primary	Teacher
5	Shih et al. (2012)	Taiwan	118(59/59)	Number-Operation	Elementary	Teacher
6	Liu (2013)	Taiwan	316(158/158)	Geometry	High	Researcher
7	Riconscente (2013)	USA	102(54/48)	Number-Operation	Elementary	Teacher
8	Chang et al. (2016)	Taiwan	58(31/27)	Geometry	High	Teacher
9	Fößl et al. (2016)	Austria	47(24/23)	Mix	Elementary	Teacher
10	Hwang & Lai (2017)	Taiwan	45(24/21)	Geometry	Primary	Teacher
11	Ozdal & Ozdamli (2017)	Turkey	82(41/41)	Mix	Elementary	Teacher
12	Reeves et al. (2017)	USA	28(20/8)	Number-Operation	Preschool	Researcher
13	Etcuban & Pantinople (2018)	Philippines	80(40/40)	Algebra	Elementary	Teacher
14	Fabian et al. (2018)	Scotland	52(24/28)	Geometry	Elementary	Teacher
15	Miller (2018)	Canada	13(7/6)	Number-Operation	Preschool	Teacher
16	Çetinkaya (2019)	Turkey	62(31/31)	Data-Probability	High	Teacher
17	Fabian, Topping (2019)	Scotland	74(35/39)	Geometry	Elementary	Teacher
18	Jelatu et al. (2019)	Indonesia	40(20/20)	Trigonometry	University	Researcher
19	Outhwaite et al. (2018)	UK	389(257/132)	Mix	Preschool	Teacher
20	Yeh et al. (2019)	Taiwan	114(73/41) 334(209/125)	Number-Operation	Primary	Teacher
21	Zhang et al. (2020)	China	45(32/33)	Number-Operation	Primary	Teacher
22	Cai et al. (2020)	China	68(33/35)	Data-Probability	Elementary	Teacher

deviation and effect size, two very high outliers were found (z score above 3.0 or $g \geq 2.34$, Fig. 1). This effect size value was excluded from the analysis because it distorted the symmetrical structure (Belland et al., 2017, p. 322).

The trim-and-fill method used after removing the two outliers that distorted the symmetrical structure estimated that there were only 3 possible missing runs (the red circles in Fig. 2). This finding was confirmed by the results of Begg's rank correlation test (tau b = .29, $p = .055 > .050$) and Egger regression test (IC = 1.44; $p = .051 > .050$). Classic fail-safe N and Orwin's fail-safe N numbers were also provided. For the purpose, the classic fail-safe number was calculated to indicate the number of non-significant effect sizes of unpublished studies which is required to reduce the total effect sizes to insignificance. If the Classic fail-safe number is larger than 5 k + 10, where k is the original number of studies included in the meta-analysis, it is considered robust. For the cases where Classic fail-safe number is robust, it is interpreted that the overall effect size is unlikely to be affected by the

estimated effect sizes of unpublished studies. The Classic fail-safe number for this meta-analysis was found to be 545 at the significance level $\alpha = .05$, according to Rosenthal's procedure (Rosenthal, 1991). This value is larger than 120, which refers that the publication bias is unlikely to be a problem. The value of 8736 found as Orwin's Fail-Safe N referred to the number of studies required for the 0.476 average effect size found as a result of the meta-analysis to reach almost zero effect (i.e., trivial). The difficulty of reaching such a large number of studies shows that the study has weak publication bias (see Fig. 3).

5.2 The overall impact of Mobile learning on academic achievement

In terms of effect size value, Thalheimer and Cook (2002) offered a classification in interpreting the effect size value, as follows: - $0.15 \leq d < 0.15$ negligible $0.15 \leq d < 0.40$ low $0.40 \leq d < 0.75$ medium $0.75 \leq d < 1.10$ large $1.10 \leq d < 1.45$ very large (1.45) d perfectly (huge). Because this classification is more comprehensive than the others (e.g. Cohen, 1988), it is adopted into the study. For the purposes of this study, a total of 27 effect size values from 22 studies were included in the analysis. The five extracted two effect sizes were combined (For instance, as in the study of Kiger et al. (2012), who applied two impact tests to the experimental and control groups. As such, two effect sizes were calculated using the statistical values obtained from the two tests in the analysis, and these effect sizes were combined). Lipsey and Wilson (2001) recommend visual representations of effect size data to illustrate the final results effectively. Accordingly, stem and leaf (Fig. 4), and forest plots (Fig. 5) are presented to show the summary of the effect sizes collected in this study.

From the stem and leaf plot, it can be interpreted that 1 of the 22 effect size values received negative values (in favor of the control group) and 21 effect size values received positive values (experimental group-mobile). There were 2 studies with an effect size above 1, as well as 6 studies with an effect size in the range of $0.5 \leq g < 1$, and 13 studies with an effect size in the range of $0 \leq g < 0.5$.

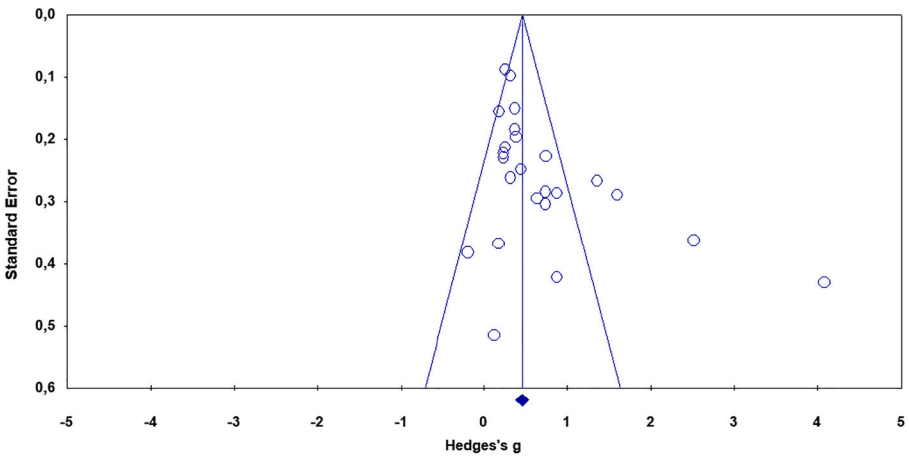


Fig. 2 Funnel plot of standard error by effect size

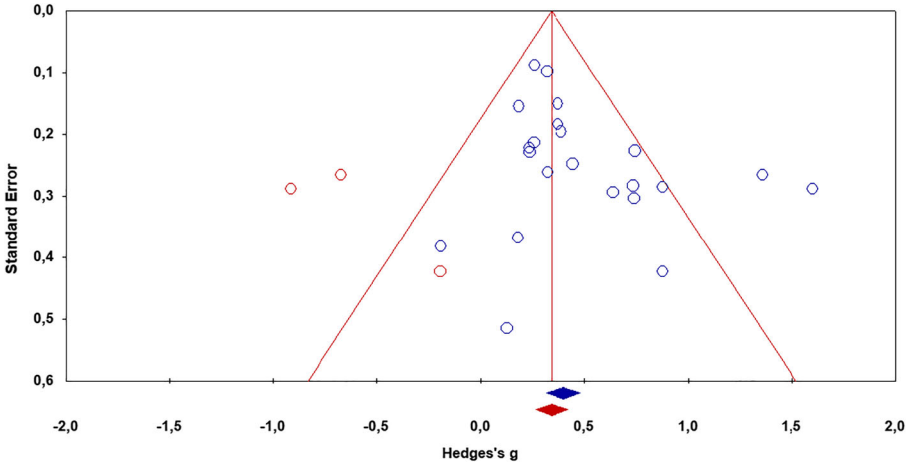


Fig. 3 Funnel plot of standard error by effect size (blue circles represent studies, and red circles represent unpublished studies, as required to eliminate publication bias)

According to the forest plot, while 13 of the 22 effect sizes were significant ($p < .05$), 9 of the effect size values were not significant ($p > .05$). Table 3 shows the number of studies, average effect size value, standard error, variance, lower-upper limit values at 95% confidence interval, z value and heterogeneity test findings.

As the table indicates, the Q-statistics were found to be significant ($p < .001$, $Q = 49.805$ with $df = 21$) and failed to reject the hypothesis of homogeneity at $\alpha = .05$. In addition, the I^2 percentage was calculated as 57.836. Thus, these findings provided evidence for heterogeneity. This indicates that there were factors other than sampling error due to variance. For the fixed effect model, the 95% significance level and the confidence interval of [0.317–0.479] were found to be 0.398. The z value was found to be 9.611 and the corresponding p value was less than 0.001. The weighted average effect size value for the random effect model was found to have a 95% significance level and 0.476 at [0.335–0.616] confidence interval. The z value was found to be 6.634, and the corresponding p value was less than 0.001. Since the distribution of effect sizes is significantly heterogeneous, considering the 0.476 effect size value calculated according to the random effect model, this reveals that mobile learning has a moderate positive effect on academic achievement.

According to Lipsey and Wilson (2001), moderator analysis is appropriate when the distribution of effect sizes is significantly heterogeneous. In this study, since this criteria was met in terms of three categorical moderators (content area, grade level, implementer), moderator analyses were performed.

```
Frequency    Stem &  Leaf

   1,00      -0 .  1
  13,00       0 .  1112222333334
   6,00       0 .  677788
   1,00       1 .  3
   1,00 Extremes    (>=1,6)
```

Fig. 4 Stem and leaf plot of effect sizes

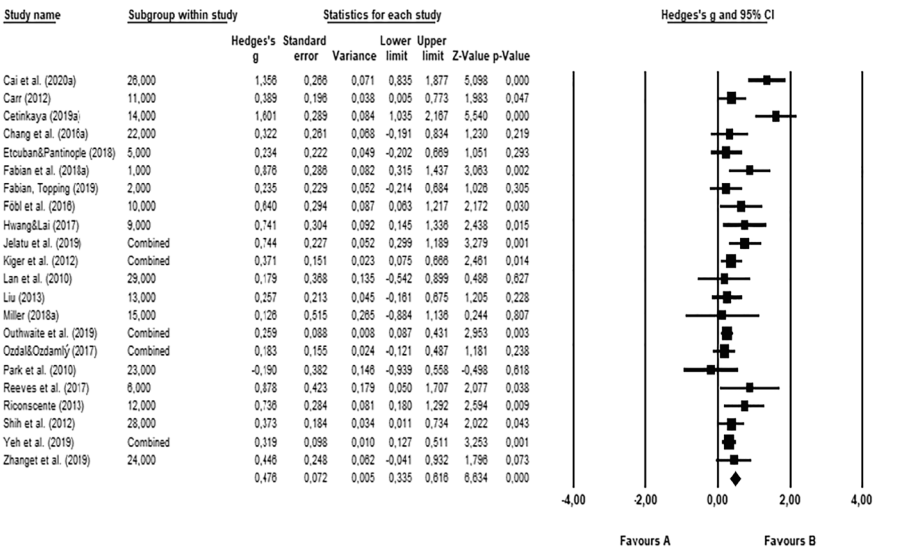


Fig. 5 Meta-analysis data and forest plot

5.3 Moderator analysis findings

5.3.1 School level, implementer, content area moderators

In the moderator analysis, the effect size difference between school levels was not found to be statistically significant ($Q_b = 2.461$; $p > .05$). The average effect size values in terms of the school level variable were 0.299 for preschool, primary school, secondary school, high school and university; respectively, 0.362; 0.516; 0.711; and 0.327. While these effect size values were positive and significant at the preschool, primary school and secondary school levels ($p < .05$), they were not significant at the high school and university level ($p > .05$). Thus, while the mobile learning approach had a low-level positive effect on academic achievement at the preschool, primary school and university levels, it had a moderate positive effect at the secondary and high school levels.

The difference in effect size between the implementer moderator categories was not statistically significant. ($Q_b = 0.181$; $p > .05$). The effect sizes for the teacher and the researcher, who were the implementer moderator groups, were found to be at positive

Table 3 Overall effect sizes

	K	ES	SE	Var.	95% CI		z	p	Test of heterogeneity in effect size			I^2
					Lower	Upper			Q	df(Q)	p	
Fixed	22	0.398	0.041	0.002	0.317	0.479	9611	0.000	49.805	21	0.000	57.836
Random	22	0.476	0.072	0.005	0.335	0.616	6.634	0.000				

and medium levels as 0.493 and 0.421, respectively. On the other hand, the difference in effect size between content areas was found to be statistically significant (Q_b = 35.753, $p < .001$). In terms of learning domain variable, the average effect sizes were found to be significant for all learning domains ($p < .05$) except for the algebra learning domain ($p > .05$). More specifically, while the effect size was positive and low for studies in the Algebra, Geometry, Numbers-Operations and Mixed categories, it was positive and moderate for Trigonometry, and positively high for Data and Probability. The results are summarized in Table 4.

6 Discussion and conclusion

A total of 22 studies were included in this meta-analysis, which was designed to examine the magnitude of the effect size of mobile learning on students' mathematics achievement. The results of the meta-analysis revealed that the effect sizes of the studies ranged from −1.45 and 3.43. Moreover, the majority of the effect sizes (95%hat) were in favor of experimental groups t included treatments with mobile

Table 4 School level, number of participants, content area moderator analysis

School Level	N	ES	SE	%95 CI	p
Categories					
Pre-school	3	0.299	0.118	[0.067–0.530]	0.011
Primary school	5	0.362	0.074	[0.217–0.507]	0.000
Middle School	9	0.516	0.120	[0.280–0.752]	0.000
High school	3	0.711	0.410	[−0.092–1.514]	0.083
University	2	0.327	0.464	[−0.583–1.238]	0.481
General	22	0.386	0.055	[0.279–0.493]	0.000
Note	Q_B = 2.461, df=4, p=0.652				
Practitioner	N	ES	SE	%95 CI	p
Categories					
Teacher	17	0.493	0.083	[0.330–0.657]	0.000
Researcher	5	0.421	0.148	[0.130–0.712]	0.005
General	22	0.476	0.073	[0.334–0.619]	0.000
Note	Q_B = 0,181, df=1, p=0.671				
Content area	N	ES	SE	%95 CI	p
Categories					
Algebra	1	0.234	0.222	[−0.202–0.669]	0.293
Data-Probability	2	1.468	0.196	[1.085–1.852]	0.000
Geometry	6	0.383	0.134	[0.120–0.646]	0.004
Mixed	4	0.281	0.069	[0.146–0.417]	0.000
Numbers-Operations	8	0.375	0.067	[0.244–0.506]	0.000
Trigonometry	1	0.744	0.227	[0.299–1.189]	0.001
General	22	0.400	0.043	[0.316–0.483]	0.000
Note	Q_B= 35.753, df=5, p=0.000				

learning devices. An examination of the effect sizes showed that 13 (59%) of them were statistically significant, while the remaining 9 (41%) of them were not. This distribution may seem to be predictable, since researchers have suggested that mobile learning may offer many advantages to both students and teachers (Churchill & Churchill, 2008; Trinder et al., 2008; West, 2013), in addition to various disadvantages and limitations (Butcher, 2014; Huang et al., 2008; Pollara, 2011; Rossing et al., 2012). The effect sizes may also be a result of school level, implementer and content area, as well as sample size, duration of the implementation, use of pedagogical approaches or instructional tools, or choice of mobile device. The educators should take these variables into consideration during implementation.

The results of the meta-analysis also revealed that mobile learning has a moderate positive effect on students' mathematics performance, as the included studies demonstrated a moderate overall effect in this regard. This result coincides with the findings of other researchers, such as Sommerauer and Müller (2014), as well as other studies reporting the effectiveness of mobile learning environments on student achievement in comparison with traditional classrooms (Al-Qahtani & Higgins, 2013; Furio et al., 2014; Joo-Nagata et al., 2017). The moderate positive effect found in this study may be considered as logical, as mobile learning is not fully a remedy in spite of its considerable positive impact (Criollo-C et al., 2018). In addition, studies point to a positive effect of mobile learning on students' self-efficacy (Shank & Cotten, 2014) and motivation (Ciampa, 2014; Sun, 2014). Moreover, such an increase in students' self-efficacy and motivation resulting from mobile learning may also have a positive impact on their achievement (Castillo-Merino and Serradell-López, 2014). Furthermore, this effect size found in the study may be a result of the novelty effect. In other words, the traditionally employed a textbook format might be less engaging for students than technological tools. When introduced to a mobile learning tool, the perceived novelty effect may increase the motivation and interest of the participants (Jeno et al., 2019), thus contributing to students' engagement and achievement. Another aspect of the studies was their use of instructional tools. Although not all of the studies reported the instructional tools or models they employed, some reported use of infographics, games, visualizations, augmentation and problems/exercises designed by teachers. Use of such instructional tools may also have affected the student achievement. In this sense, educators are recommended to keep student engagement and motivation in mind while planning mobile learning activities with different instructional tools. Moreover, the duration of the implementation should be extensive enough to eliminate the novelty effect.

Other moderator variables considered in this study included school level, implementer and learning. The moderator analysis carried out with respect to school level showed that the level of effect of mobile learning on students' mathematics achievement was not statistically significant for sub-categories of school level. However, the studies with middle school and high school levels reported higher effect sizes than studies with preschool, primary school and university undergraduate levels. Furthermore, the effect sizes for the preschool, primary school and middle school were statistically significant, while those for high school and the undergraduate level were not. In this sense, Sharples et al. (2002) contend that mobile learning may help teachers to draw the attention of students who are disengaged in more traditional settings. Likewise, Leung (2007) highlighted the potential of mobile learning in

creating learning environments that continually engage learners. Leung's results suggest that students attending lower-level schools may be motivated more easily through the use of mobile technologies, as with other studies showing that mobile learning devices may be effective educational resources (Attewell, 2005; Stead et al., 2006). Educators may benefit from mobile learning environments in all school levels, but the level of engagement, attention span and concentration of students should be taken into consideration for effective learning experiences.

A further moderator variable considered in this analysis was the implementer of the study. According to findings, the implementer variable was not found to be a significant moderator in the effect of mobile learning on students' mathematics achievement. Moreover, the effect sizes for both groups were found to be moderate and statistically significant. This finding suggests that the effect sizes did not differ significantly from each other with respect to the implementers, thus implying that the implementation of a mobile learning method is independent from the implementers' identity as a researcher or a teacher. In the literature on mobile learning, the primary focus is on the learning environment, as opposed to other components of education. For instance, Mishra (2013) asserts that mobile learning provides an educational environment that is flexible, accessible and personalized. This supports the inference that the effectiveness of mobile learning is not directly related to the instructor's identity, as the mobile media is the leading component of the learning environment. Thus, as long as the instructor has the required pedagogical competency, learning may not differ according to the implementer's role as teacher or researcher. Moreover, mobile learning also offers opportunities outside the classroom, where the role of the implementer is lesser than with in-class instruction. In this regard, Straub (2009) points out that mobile devices may support learning outside the classroom, as well as in school. The contribution of mobile implementations to the learning process may be independent from the implementer as long as the learning activities have been planned with this in mind. Mobile learning's independence of time and location may have resulted in such a conclusion, as it has its own characteristics that differ from face-to-face education.

On the other hand, statistically significant results were found through the moderator variable analysis for content area in regard to differences between effects in different content areas of mathematics. With reference to the effect sizes of studies, it can be concluded that this significant difference was in favor of the studies related to the content areas of data-probability, geometry, numbers-operations, trigonometry and mixed mathematical subjects. Furthermore, the effect size found for the data-probability was considerably higher than the in other areas. This may be the result of the complicated structure of this content area (Danişman & Tanışlı, 2017); namely, the mobile learning environment may have contributed to students' understanding in this subject area, which is seen as being difficult to learn in traditional environments. In this sense, Franklin and Peng (2008) reported that mobile technologies may be useful in that they allow students to learn difficult concepts through visualization. The fact that use of mobile technologies may contribute to the visualization of data-probability, trigonometry and geometry may have resulted in higher achievement, hence yielding higher effect sizes. This may also be the result of additional pedagogies used in the studies. In addition, according to Skiada et al. (2014), mobile learning in mathematics instruction is has an advantage in that the design of the course material can eliminate confusion by making information sources easier to reach (Skiada et al., 2014). Thomas (2005),

moreover, argues that mobile learning may encourage students with their potential to offer more flexible and accessible learning; while Pandey and Singh (2015) point out that mobile learning has numerous advantages for mathematics learning that make it preferrable to the traditional classroom (Pandey & Singh, 2015). Trifonova (2003), moreover, suggests that area/domain specific content delivered in time makes mobile learning efficient, as it is available to help students and teachers whenever necessary. These views on the flexibility and freedom provided by mobile learning may explain the significant results of the categories for the content area moderator.

7 Limitations and future research

Although the current study has important implications concerning the effects of mobile learning on academic achievement, there are significant limitations to be considered. The most important of these is the limitation in terms of existing databases. In this regard, future studies may be carried out with the inclusion of additional databases; moreover, meta-synthesis studies may be conducted to gain deeper understanding about the effect of variables determined as moderators on academic achievement. In addition, given the results obtained from this study, it can be suggested that the reasons for the differences and similarities of effect sizes may be studied in detail for different moderator variables. Moreover, additional moderator variables such as publication type or year may be examined in terms of the effect of mobile learning on student achievement. As such, the factors relating to the effect of mobile learning on student achievement may be determined so that the effectiveness of mobile learning may be enhanced. Furthermore, thirteen of the mobile-learning studies included in the analysis may have benefited from additional approaches, such as constructivist, collaborative, problem-based, game-based, and interactive, while the rest of the studies reported no additional approaches. The effect size of the studies may have been influenced by these learning approaches. However, since not all of the studies reported the pedagogical approaches, and the number of the included studies is small, we could not conduct a moderator analysis on this factor, as the categories did not include a great enough number of studies. Moreover, some of the studies may have used more than one pedagogical approach, as noted by Bano et al. (2018). Further meta-analysis studies on mobile learning may use pedagogical approaches as moderator variable when the number of studies examined is sufficient to do so. Moreover, it is recommended that researchers report on the pedagogical approaches used to support mobile learning implementations. A further limitation of the study is that the included studies had different periods of implementation, ranging from two weeks to two years. The duration of the implementations may also impact the effect size. Although this is a limitation with respect to the originally-included studies, further meta-analysis studies may be carried out to include this as moderator variable when the number of studies examined is sufficient to do so.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Note: (* marked references are the studies that are included in the meta-analysis)

Açıkgül, K., & Şad, S. N. (2021). High school students' acceptance and use of mobile technology in learning mathematics. *Education and Information Technologies*, 1–21.

Al-Qahtani, A. A. Y., & Higgins, S. E. (2013). Effects of traditional, blended and e-learning on students' achievement in higher education. *Journal of Computer Assisted Learning, 29*(3), 220–234. https://doi.org/10.1111/j.1365-2729.2012.00490.x.

Ally, M. (Ed.). (2009). *Mobile learning: Transforming the delivery of education and training*. Athabasca University Press.

Attewell, J. (2005). Mobile technologies and learning. Learning and Skills Development Agency.

Baker, E. J., Bakar, J. A. A., & Zulkufli, A. N. (2018). Engagement elements for mobile augmented reality application. *International Journal of Engineering & Technology, 7*(3.20), 800–805.

Baek, E. O., & Guo, Q. (2019). Instructional design principles for mobile learning. In Y. A. Zhang & D. Cristol (Eds.), *Handbook of Mobile Teaching and Learning (pp. 1–22)*. Springer.

Bano, M., Zowghi, D., Kearney, M., Schuck, S., & Aubusson, P. (2018). Mobile learning for science and mathematics school education: A systematic review of empirical evidence. *Computers & Education, 121*, 30–58.

Begg, C. B., & Berlin, J. A. (1988). Publication bias: A problem in interpreting medical data. *Journal of the Royal Statistical Society Series A (Statistics in Society), 151*(3), 419–463.

Belland, B. R., Walker, A. E., Kim, N. J., & Lefler, M. (2017). Synthesizing results from empirical research on computer-based scaffolding in STEM education: A meta-analysis. *Review of Educational Research, 87*(2), 309–344. https://doi.org/10.3102/0034654316670999.

Borba, M. C., Askar, P., Engelbrecht, J., Gadanidis, G., Llinares, S., & Aguilar, M. S. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM, 48*(5), 589–610. https://doi.org/10.1007/s11858-016-0798-4.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons.

Brown, T. H. (2005). Towards a model for m-learning in Africa. *International Journal of ELearning, 4*(3), 299–315.

Butcher, J. (2014). Can tablet computers enhance learning in further education? *Journal of Further and Higher Education, 40*(2), 207–226.

*Cai, S.; Liu, E.; Shen, Y.; Liu, C.; Li, S.; Shen, Y. (2020) Probability learning in mathematics using augmented reality: Impact on student's learning gains and attitudes. Interactive Learning Environments, 28(5), 560–573, https://doi.org/10.1080/10494820.2019.1696839.

Calder, N., Larkin, K., & Sinclair, N. (2018). Mobile technologies: How might using mobile technologies reshape the learning and teaching of mathematics? In I. N. Calder, K. Larkin, & N. Sinclair (Eds.), *Using Mobile Technologies in the Teaching and Learning of Mathematics (pp. 1–7)*. Springer.

*Carr, J. M. (2012). Does math achievement h'APP'en when iPads and game-based learning are incorporated into fifth-grade mathematics instruction?. Journal of Information Technology Education: Research, 11, 269–285.

Castillo-Merino, D., & Serradell-López, E. (2014). An analysis of the determinants of students' performance in e-learning. *Computers in Human Behavior, 30*, 476–484. https://doi.org/10.1016/j.chb.2013.06.020.

Castro, M., Expósito-Casas, E., López-Martín, E., Lizasoain, L., NavarroAsencio, E., & Gaviria, J. L. (2015). Parental involvement on student achievement: A meta-analysis. *Educational Research Review, 14*, 33–46. https://doi.org/10.1016/j.edurev.2015.01.002.

*Çetinkaya, L. (2019). The effects of problem based mathematics teaching through mobile applications on success. Education and Science, 44(197), 65–84.

*Chang, K. E., Wu, L. J., Lai, S. C., & Sung, Y. T. (2016). Using mobile devices to enhance the interactive learning for spatial geometry. Interactive Learning Environments, 24(4), 916–934. https://doi.org/10.1080/10494820.2014.948458.

Chee, K. N., Yahaya, N., Ibrahim, N. H., & Hasan, M. N. (2017). Review of mobile learning trends 2010-2015: A meta-analysis. *Journal of Educational Technology & Society, 20*(2), 113–126.

Christensen, R., & Knezek, G. (2017). Readiness for integrating mobile learning in the classroom: Challenges, preferences and possibilities. *Computers in Human Behavior, 76*, 112–121. https://doi.org/10.1016/j.chb.2017.07.014.

Churchill, D., & Churchill, N. (2008). Educational affordances of PDAs: A study of a teacher's exploration of this technology. *Computers & Education, 50*(4), 1439–1450.

Ciampa, K. (2014). Learning in a mobile age: An investigation of student motivation. *Journal of Computer Assisted Learning, 30*(1), 82–96. https://doi.org/10.1111/jcal.12036.

Criollo-C, S., Luján-Mora, S., & Jaramillo-Alcázar, A. (2018, March). Advantages and disadvantages of m-learning in current education. Paper presented at the *IEEE World Engineering Education Conference (EDUNINE),* , Argentina.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum.

Danişman, Ş., & Tanışlı, D. (2017). Examination of mathematics teachers' pedagogical content knowledge of probability. *Malaysian Online Journal of Educational Sciences, 5*(2), 16–34.

*Etcuban, J. O., & Pantinople, L. D. (2018). The effects of Mobile application in teaching high school mathematics International Electronic Journal of Mathematics Education, 13(3), 249-259. https://doi.org/10.12973/iejme/3906.

*Fabian, K., Topping, K. J. (2019). Putting "mobile" into mathematics: Results of a randomised controlled trial. Contemporary Educational Psychology, 59, 1–12.

*Fabian, K., Topping, K. J., & Barron, I. G. (2018). Using mobile technologies for mathematics: Effects on student attitudes and achievement. Educational Technology Research and Development, 1–21. https://doi.org/10.1007/s11423-018-9580-3, 66.

Fast, L. A., Lewis, J. L., Bryant, M. J., Bocian, K. A., Cardullo, R. A., Rettig, M., & Hammond, K. A. (2010). Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance? *Journal of Educational Psychology, 102*(3), 729–740. https://doi.org/10.1037/a0018863.

*Fößl, T., Ebner, M., Schön, S., & Holzinger, A. (2016). A field study of a video supported seamless-learning-setting with elementary learners. Educational Technology & Society, 19(1), 321–336.

France, D., Lee, R., Maclachlan, J., & McPhee, S. R. (2021). Should you be using mobile technologies in teaching? Applying a pedagogical framework. *Journal of Geography in Higher Education, 45*(2), 1–17.

Franklin, T., & Peng, L.-W. (2008). Mobile math: Math educators and students engage in mobile learning. *Journal of Computing in Higher Education, 20*(2), 69–80.

Furio, D., Juan, M.-C., Seguí, I., & Vivo, R. (2014). Mobile learning vs. traditional classroom lessons: A comparative study. *Journal of Computer Assisted Learning, 31*(3), 189–201. https://doi.org/10.1111/jcal.12071.

Goodman, S. G., Seymour, T. L., & Anderson, B. R. (2016). Achieving the performance benefits of hands-on experience when using digital devices: A representational approach. *Computers in Human Behavior, 59*, 58–66.

Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *Bmj, 327*(7414), 557–560.

Huang, Y. M., Kuo, Y. H., Lin, Y. T., & Cheng, S. C. (2008). Toward interactive mobile synchronous learning environment with context-awareness service. *Computers and Education, 51*(3), 1205–1226.

Hung, I. C., Yang, X. J., Fang, W. C., Hwang, G. J., & Chen, N. S. (2014). A context-aware video prompt approach to improving students' in-field reflection levels. *Computers & Education, 70*, 80–91.

*Hwang, G.-J., & Lai, C.-L. (2017). Facilitating and bridging out-of-class and in-class learning: An interactive E-book-based flipped learning approach for math courses. Educational Technology & Society, 20(1), 184–197.

*Jelatu, S., Kurniawan, Y., Kurnila, V. S., Mandur, K., & Jundu, R. (2019). Collaboration TPS learning model and m-learning based on android for understanding of trigonometry concepts with different cognitive style International Journal of Instruction, 12(4), 545-560. https://doi.org/10.29333/iji.2019.12435a.

Jeno, L. M., Vandvik, V., Eliassen, S., & Grytnes, J. A. (2019). Testing the novelty effect of an m-learning tool on internalization and achievement: A self-determination theory approach. *Computers & Education, 128*, 398–413. https://doi.org/10.1016/j.compedu.2018.10.008.

Joo-Nagata, J., Abad, F. M., Garcia-Bermejo Giner, J. & Garcia-Penalvo, F. J. (2017). Augmented reality and pedestrian navigation through its implementation in m-learning and e-learning: Evaluation of an educational program in Chile. Computers and Education, 111, 1–17, 1.

Kearney, M., Burden, K., & Schuck, S. (2020). Rationale for a Mobile pedagogical framework. In *Theorising and implementing Mobile learning* (pp. 53–69). Springer.

Keegan, D. (2005). *Theoretical principles of distance education*. Routledge.

Keengwe, J., & Bhargava, M. (2014). Mobile learning and integration of mobile technologies in education. *Education and Information Technologies, 19*(4), 737–746.

*Kiger, D., Herro, D., & Prunty, D. (2012). Examining the influence of a mobile learning intervention on third grade math achievement. Journal of Research on Technology in Education, 45(1), 61–82.

Kluge, A., & Dolonen, J. (2015). Using mobile games in the classroom. In H. Crompton & J. Traxler (Eds.), *Mobile Learning and Mathematics: Foundations, Design, and Case Studies (pp. 106–121)*. Routledge.

Kyriakides, A. O., Meletiou-Mavrotheris, M., & Prodromou, T. (2016). Mobile technologies in the service of students' learning of mathematics: The example of game application ALEX in the context of a primary school in Cyprus. *Mathematics Education Research Journal, 28*(1), 53–78. https://doi.org/10.1007/s13394-015-0163-x.

*Lan, Y. J., Sung, Y. T., Tan, N. C., Lin, C. P., & Chang, K. E. (2010). Mobile-device-supported problem-based computational estimation instruction for elementary school students. Journal of Educational Technology & Society, 13(3), 55–69.

Larkin, K., & Milford, T. (2018). Mathematics apps—Stormy with the weather clearing: Using cluster analysis to enhance app use in mathematics classrooms. In N. Calder, K. Larkin, & N. Sinclair (Eds.), *Using mobile technologies in the teaching and learning of mathematics* (pp. 11–30). Springer.

Leung, L. (2007). Unwillingness-to-communicate and college students' motives in SMS mobile messaging. *Telematics and Informatics, 24*(2), 115–129.

Lipsey, M. W., & Wilson, D. B. (2001). Practical meta-analysis. SAGE.

*Liu, N. (2013). Ipad infuse creativity in solid geometry teaching. TOJET: The Turkish Online Journal of Educational Technology, 12(2), 177–192.

Lo, C. K., Hew, K. F., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. *Educational Research Review, 22*, 50–73. https://doi.org/10.1016/j.edurev.2017.08.002.

Looi, C. K., So, H. J., Chen, W., Zhang, B., Wong, L. H., & Seow, P. (2012). Seamless learning. In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. Springer. https://doi.org/10.1007/978-1-4419-1428-6_251.

Shank, D. B., & Cotten, S. R. (2014). Does technology empower urban youth? The relationship of technology use to self-efficacy. *Computers and Education, 70*, 184–193. https://doi.org/10.1016/j.compedu.2013.08.018.

Moh, C. (2013). *Development and assessment of Mobile device support for certification exam preparation* (Doctoral dissertation, Nova Southeastern University).

*Miller, T. (2018). Developing numeracy skills using interactive technology in a play-based learning environment. International Journal of STEM Education, 5(1). https://doi.org/10.1186/s40594-018-0135-2, 39.

Mishra, S. K. (2013). Quality education for children, youth, and adults through mobile learning. In J. Keengwe (Ed). *Pedagogical Applications and Social Effects of Mobile Technology Integration* (pp. 225–237). IGI Global.

Namukasa I. K., Gadanidis G., Sarina V., Scucuglia S., & Aryee K. (2016). Selection of apps for teaching difficult mathematics topics: An instrument to evaluate touch-screen tablet and smartphone mathematics spps. In P. Moyer-Packenham (Ed.), International perspectives on teaching and learning mathematics with virtual manipulatives (pp 275–300). Springer. https://doi.org/10.1007/978-3-319-32718-1_12

*Outhwaite, L. A., Faulder, M., Gulliford, A., and Pitchford, N. J. (2018). Raising early achievement in math with interactive apps: A randomized control trial. Journal of Educational Psychology, 111(2), 284–298. https://doi.org/10.1037/edu0000286.

Ozcelik, E., & Acarturk, C. (2011). Reducing the spatial distance between printed and online information sources by means of mobile technology enhances learning: Using 2D barcodes. *Computers & Education, 57*(3), 2077–2085.

*Ozdal, H., & Ozdamli, F. (2017). The effect of infographics in mobile learning: Case study in primary school. Journal of Universal Computer Science, 23(12), 1256–1275.

Pandey, K., & Singh, N. (2015). Mobile learning: Critical pedagogy to education for all. In Y. Zhang (Ed.), *Handbook of Mobile teaching and learning* (pp. 107–132). Springer.

*Park, J., Parsons, D., & Ryu, H. (2010). To flow and not to freeze: Applying flow experience to mobile learning. IEEE Transactions on Learning Technologies, 3(1), 56–67.

Park, Y. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. *The International Review of Research in Open and Distance Learning, 12*(2), 78–102.

Pegrum, M. (2019). *Mobile lenses on learning*. Springer.

Peters, K. (2007). M-learning: Positioning educators for a mobile, connected future. *International Journal of Research in Open and Distance Learning, 8*(2), 1–17.

Pollara, P. (2011). Mobile learning in higher education: A glimpse and a comparison of student and faculty readiness, attitudes and perceptions (*Doctoral dissertation).* Louisiana State University.

Prensky, M. (2005). *Adopt and adapt school technology in the 21st century*. http://www.edutopia.org/adopt-and-adapt-shaping-tech-for-classroom

Qu, J. (2021). Research on mobile learning in a teaching information service system based on a big data driven environment. *Education and Information Technologies*, 1–19.

*Reeves, J. L., Gunter, G. A., & Lacey, C. (2017). Mobile learning in pre-kindergarten: Using student feedback to inform practice. Educational Technology & Society, 20(1), 37–44.

*Riconscente, M. M. (2013). Results from a controlled study of the iPad fractions game motion math. Games and Culture, 8, 186–214.

Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin, 86*, 638–641.

Rosenthal, R. (1991). *Meta-analytic procedures for social research*. Sage.

Rossing, J., Miller, W., Cecil, A., & Stamper, S. (2012). iLearning : The future of higher education? Student perceptions on learning with mobile tablets. *Journal of the Scholarship of Teaching and Learning, 12*(2), 1–26.

Sam, L. C., & Ernest, P. (2000). A survey of public images of mathematics. *Research in Mathematics Education, 2*(1), 193–206.

Schuck, S., Kearney, M., & Burden, K. (2017). Exploring mobile learning in the third space. *Technology, Pedagogy and Education, 26*(2), 121–137.

Schuck, S., & Maher, D. (2018). Creating opportunities for untethered learning. *Technology, Pedagogy and Education, 27*(4), 473–484. https://doi.org/10.1080/1475939X.2018.1510788.

Sharples, M., Corlett, D., & Westmancott, O. (2002). The design and implementation of a mobile learning resource. *Personal Ubiquitous Computing, 6*(3), 220–234.

*Shih, S.-C., Kuo, B.-C., & Liu, Y.-L. (2012). Adaptively ubiquitous learning in campus math path. Educational Technology & Society, 15(2), 298–308.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*(6), 323–332.

Skiada, R., Soroniati, E., Gardeli, A., & Zissis, D. (2014). EasyLexia: A mobile application for children with learning difficulties. *Procedia Computer Science, 27*, 218–228.

Sommerauer, P., & Müller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. *Computers and Education, 79*, 59–68.

Stead, G., Sharpe, B., Anderson, P., Cych, L., & Philpott, M. (2006). Emerging technologies for learning. Becta.

Stevens, D., & Kitchenham, A. (2011). An analysis of mobile learning in education, business, and medicine. In A. Kitchenham (Ed.) *Models for interdisciplinary mobile learning: Delivering information to students* (pp. 1–25). IGI Global.

Straub, E. T. (2009). Understanding technology adoption: Theory and future directions for informal learning. *Review of Educational Research, 79*(2), 625–649.

Sun, J. C.-Y. (2014). Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Computers and Education, 72*, 80–89. https://doi.org/10.1016/j.compedu.2013.10.010.

Sung, Y. T., Chang, K. E., & Liu, T. C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education, 94*, 252–275.

Talan, T. (2020). The effect of Mobile learning on learning performance: A meta-analysis study. *Educational Sciences: Theory and Practice, 20*(1), 79–103.

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research: A simplified methodology. *Work-Learning Research, 1*, 1–9.

Thomas, S. (2005). Pervasive, persuasive eLearning: Modeling the pervasive learning space. Proceedings of the *3rd international conference on pervasive computing and communications workshops (PERCOMW'05)* (pp. 332–336). Kauai Island, Hawai'i: IEEE Computer Society.

Tingir, S., Cavlazoglu, B., Caliskan, O., Koklu, O., & Intepe-Tingir, S. (2017). Effects of mobile devices on K–12 students' achievement: A meta-analysis. *Journal of Computer Assisted Learning, 33*(4), 355–369.

Traxler, J. (2005, June). *Defining mobile learning*. Paper presented at ADIS international conference Mobile learning, Qawra, . (Retrieved January 6, 2012 from http://www.iadis.net/dl/final_uploads/200506C018.pdf).

Trifonova, A. (2003). Mobile learning: Review of the literature. *Technical Report DIT-03-009,* Informatica e Telecomunicazioni, University of .

Trinder, K., Guiller, J., Marggaryan, N., Littlejohn, A., & Nicol, D. (2008). *Learning from digital natives: Bridging formal and informal learning*. Glasgow Caledonian University, The Higher Education Academy.

Walker, R. (2013). "I don't think I would be where I am right now". Pupil perspectives on using mobile devices for learning. *Research in Learning Technology, 21*, 1–12.

West, D. M. (2013). Mobile learning: Transforming education, engaging students, and improving outcomes. Center for Technology Innovation at Brookings.

Wu, W. H., Wu, Y. C. J., Chen, C. Y., Kao, H. Y., Lin, C. H., & Huang, S. H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59*(2), 817–827.

*Yeh. C. Y., Hercy N. H. Cheng, Zhi-Hong Chen, Calvin C. Y. Liao and Tak-Wai Chan. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. Research and Practice in Technology Enhanced Learning, 14(1), 1–19.

*Zhang, L., Shang, J., Pelton, T., & Pelton, L. F. (2020). Supporting primary students' learning of fraction conceptual knowledge through digital games. Journal of Computer Assisted Learning, 36(4), 540–548. https://doi.org/10.1111/jcal.12422.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Affiliations

Mustafa Güler[1] · Suphi Önder Bütüner[2] · Şahin Danişman[3] · Kadir Gürsoy[1]

[1] Department of Mathematics Education, Fatih Faculty of Education, Trabzon University, Trabzon, Turkey

[2] Department of Mathematics Education, Faculty of Education, Yozgat Bozok University, Yozgat, Turkey

[3] Department of Mathematics Education, Faculty of Education, Düzce University, Düzce, Turkey



Education and Information Technologies

The Official Journal of the IFIP Technical Committee on Education

Editorial board Aims & scope Journal updates

This is the official journal of the IFIP Technical Committee on Education. It covers the complex relationships between information and communication technologies and education. The journal provides perspectives at all levels, from the micro of specific applications or instances of use in classrooms to macro concerns of national policies and major projects; from classes of five year olds to adults in tertiary institutions; from teachers and administrators, to researchers and designers; from institutions to open, distance and lifelong learning. — show all

Editor-in-Chief
Arthur Tatnall

Publishing model
Hybrid (Transformative Journal). How to publish with us, including Open Access

3.666 (2021)
Impact factor

3.605 (2021)
Five year impact factor

22 days
Submission to first decision (Median)

3,174,835 (2021)
Downloads

Latest issue



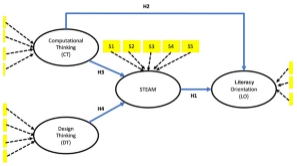
Volume 27

Issue 9, November 2022

View all volumes and issues ›

Latest articles

A validity and reliability study of the formative model for the indicators of STEAM education creations



Ting-Chia Hsu, Yu-Shan Chang ... Cheng-Yen Yu

OriginalPaper | Open Access | Published: 29 December 2022

Using a teacher scheme for educational dialogue analysis to investigate student–student interaction patterns for optimal group activities in an artificial intelligence course



Xiaoyong Hu, Wei He ... Li Zhao

OriginalPaper | Published: 28 December 2022

Emergency remote teaching technology and pedagogy at covid outbreak: different perspectives of students, parents, and teachers in Hong kong

Kit-Tai Hau, Wen Jie Wu ... Ming Ho Ng

OriginalPaper | Open Access | Published: 28 December 2022

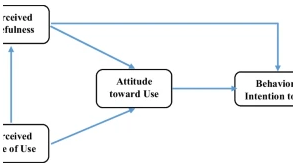
The effect of digital game-based learning on secondary level students' learning of Internet literacy



Hakan Tüzün, Sedef Sert & Ömer Demir

OriginalPaper | Published: 28 December 2022

[An examination of the effect of technology-based STEM education training in the framework of technology acceptance model](#)



Kibar Sungur Gül & Hüseyin Ateş

OriginalPaper | Published: 28 December 2022

This journal has 299 open access articles

View all articles >

Journal updates

Call for Papers: Special Issue on Educational technology and functional diversity: teaching skills and digital resources to assist students with educational needs

Submission deadline: extended to 1 December 2022

Guest Editors: Francisco David Guillén Gámez, Silvia Abad Merino

Call for Papers: What will be the new normal? Digital competence and 21st century skills: critical and emergent issues in education

Guest editors: Fazilat Siddiq, Anders D. Olofsson, J. Ola Lindberg, Lukasz Tomczyk

Call for Papers: Special Issue on Disruption, Innovation and Resiliency in Immersive Learning

Submission deadline: extended to 15 November 2022

Guest editors: Anasol Peña-Rios, Daphne Economou, Dennis Beck

Call for Papers: Special Issue on Information Technology Education

Guest editors: Yong Zheng, Marc Dupuis, Michael Liut, Chi Zhang, Per Lauvas

Submission deadline: extended to 31 January 2022

View all updates >

Societies, partners and affiliations

IFIP Technical Committee on Education



You have access to our articles

For authors

Submission guidelines

Manuscript editing services

Ethics & disclosures

Open Access fees and funding

Contact the journal

Submit manuscript



Working on a manuscript?

Avoid the most common mistakes and prepare your manuscript for journal editors.

Learn more →

Explore

Online first articles

Volumes and issues

Collections

Sign up for alerts

About this journal

Electronic ISSN 1573-7608

Print ISSN 1360-2357

Abstracted and indexed in

ACM Digital Library
BFI List
Baidu
CLOCKSS
CNKI
CNPIEC
Current Contents / Social & Behavioral Sciences
DBLP
Dimensions
EBSCO British Education Index
EBSCO Discovery Service
EBSCO Education
EBSCO Education Research Complete
EBSCO Education Source
ERIC
ERIH PLUS
Google Scholar
INSPEC
Japanese Science and Technology Agency (JST)
Journal Citation Reports/Social Sciences Edition
Naver
Norwegian Register for Scientific Journals and Series
OCLC WorldCat Discovery Service
Portico
ProQuest-ExLibris Primo
ProQuest-ExLibris Summon
SCImago
SCOPUS
Social Science Citation Index
TD Net Discovery Service
UGC-CARE List (India)
WTI AG
Wanfang

Copyright information
Rights and permissions
Springer policies
© Springer Science+Business Media, LLC, part of Springer Nature

Springer

Publish with us

Authors & Editors

Journal authors

Publishing ethics

Open Access & Springer

Discover content

SpringerLink

Books A-Z

Journals A-Z

Video

Other services

Instructors

Librarians (Springer Nature)

Societies and Publishing Partners

Advertisers

Shop on Springer.com

About Springer

About us

Help & Support

Contact us

Press releases

Impressum

Legal

General term & conditions

California Privacy Statement

Rights & permissions

Privacy

How we use cookies

Manage cookies/Do not sell my data

Accessibility

Not logged in - 78.176.239.203

Yozgat Bozok Üniversitesi Kutuphane ve Dok, Daire Baskanligi (3000164433) - Erisiminiz TUBITAK ULAKBIM Tarafindan Saglanmaktadir (3001744230) - Tubitak Ulakbim OJA (3000526817)

SPRINGER NATURE

© 2022 Springer Nature Switzerland AG. Part of Springer Nature.

Clarivate

Web of Science™

Search > Results for suphi önder

Full text at publisher

11 of 11

MENU

A meta-analysis of the i
achievement

By: Guler, M (Guler, Mustafa) [
(Danisman, Sahin) [3] ; Gursoy

View Web of Science Resea

EDUCATION AND INFORMA

Volume: 27 **Issue:** 2 **Page:**
DOI: 10.1007/s10639-021-106
Published: MAR 2022
Early Access: AUG 2021
Indexed: 2021-08-09
Document Type: Article

Abstract

The technological developmer
alternative teaching-learning r
about by such developments is
mobile learning on students' mathematics achievement. A systematic database search that included the Academic Search Complete, Education Resources Information Center (ERIC), EBSCO, JSTOR, ScienceDirect, Taylor & Francis Online, and Web of Science was carried out to examine peer-reviewed articles that met the inclusion criteria. A total of 22 quantitative research papers published between 2010 and 2020 were included in the meta-analysis. The results show that mobile learning has a medium-level positive effect (g = 0.476; p < .001; with a 95% confidence interval of 0.335-0.616) on students' mathematics achievement. Moderator analyses showed that the effect sizes were not significantly moderated by grade level and implementer, while content area was found to be a moderator. Based on the results, some suggestions are offered for future studies in designed learning environments.

Keywords

Author Keywords: Mobile learning; Mathematics education; Educational research; Mathematics achievement; Meta-analysis
Keywords Plus: STUDENTS ACHIEVEMENT; TECHNOLOGIES; PERFORMANCE; SCHOOL; DEVICES; CONTEXT; ENVIRONMENT; MOTIVATION; EDUCATION; SCIENCE

Author Information

Corresponding Address: Guler, Mustafa (corresponding author)

Trabzon Univ, Fatih Fac Educ, Dept Math Educ, Trabzon, Turkey

Addresses:

1 Trabzon Univ, Fatih Fac Educ, Dept Math Educ, Trabzon, Turkey

2 Yozgat Bozok Univ, Fac Educ, Dept Math Educ, Yozgat, Turkey

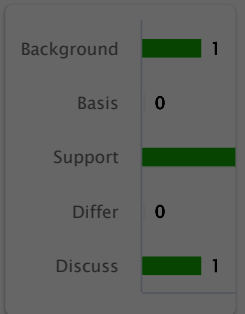
3 Duzce Univ, Fac Educ, Dept Math Educ, Duzce, Turkey

E-mail Addresses: mustafaguler@trabzon.edu.tr; s.onder.butuner@bozok.edu.tr; sahindanisman@duzce.edu.tr; kadirgursoy@trabzon.edu.tr

Categories/Classification

classification

Breakdown of how this article has been mentioned, based on available citation context data and snippets from 3 citing item(s).



You may also like...

GUZZETTI, BJ; SNYDER, TE; GAMAS, WS; et al. PROMOTING CONCEPTUAL CHANGE IN SCIENCE - A COMPARATIVE META-ANALYSIS OF INSTRUCTIONAL

17

CLOSE JOURNAL INFORMATION

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	3.605

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	1.82

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

Research Areas: Education &

Citation Topics : 6 Social Sciences

Journal information

EDUCATION AND INFORMA

ISSN: 1360-2357
eISSN: 1573-7608
Current Publisher: SPRINGER NY 10004, UNITED STATES
Journal Impact Factor: Journ
Research Areas: Education &
Web of Science Categories: E

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	3.605

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	1.82

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

Noortgate, W; Desmet, P; Captioned video for L2 listening and vocabulary learning: A meta-analysis SYSTEM

See all

Most Recently Cited by

Bernardo, ABI; Cordel, MO; Chua, UC; et al. Contrasting Profiles of Low-Performing Mathematics Students in Public and Private Schools in the Philippines: Insights from Machine Learning JOURNAL OF INTELLIGENCE

Kandemir, MA; Franklin, T; Yildiz, Y; et al. Developing a Mobile Learning Acceptance Scale for Mathematics

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

If you would like to improve the quality of the data in this record, please Suggest a correction

102 Cited References

Showing 30 of 102 View as set of results

(from Web of Science Core Collection)

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more

EDUCATION AND INFORMATION TECHNOLOGIES

Journal Impact Factor ™

2021	Five Year
3.666	**3.605**

JCR Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	62/270	Q1

Source: Journal Citation Reports 2021. Learn more

Journal Citation Indicator ™

2021	2020
1.9	**1.82**

JCI Category	Category Rank	Category Quartile
EDUCATION & EDUCATIONAL RESEARCH *in SSCI edition*	61/743	Q1

The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles and reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).

Learn more