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Review Article

Assessing the effectiveness of smartphones in education: A Meta-analysis of recent studies

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ABSTRACT

The usage of mobile devices is increasing in frequency and scope. The percentage of students who use smartphones is quite high, in particular among those attending institutions of higher education. Like they would with any other technology, educators are doing research on the efficacy of using smartphones in the classroom. Studies have been conducted on the efficacy of using smartphones in face-to-face education as well as in the process of distant education, which has grown more common as a direct result of COVID-19. The purpose of this study is to do a meta-analysis of the data from previous experimental studies that looked at how well smartphones have been used over the past five years. The total effect size that has been calculated is 3.73. Since p = 0.05, this effect's size is statistically important. This finding has a big effect, as can be seen. For each study, an effect size calculation was done based on Hedges' g. The size of the effect is between -8 and 25.70.

Keywords: smartphone, learning outcome, meta-analysis

INTRODUCTION

The advancement of technology has also led to an increase in the number of educational possibilities available. The limits of space, which were formerly imposed on educational activities because they had to take place in a certain location, have been lifted as a result of mobile technologies (Kryukova et at., 2022; Pesha, 2022; Qarkaxhja et al., 2022). In addition, learners can be presented with potentially hazardous and expensive learning scenarios in a more secure and cost-effective manner using virtual realities. The sector of education makes extensive use of smartphones because of the mobility capabilities they provide and the variety of applications they can run (Chorosova et al., 2020; Oschepkov et al., 2022; Sorakin et al., 2022). The purpose of this research was to investigate the use of smart phones in educational settings. A meta-analysis research was favored for this aim because of its breadth of coverage.

Smartphones are also called the next-generation, multifunctional cell phones because they make it easier to process data and connect wirelessly. Smartphones can do more things, like play different kinds of internet content and media files. One innovative thing about smartphones is that users can download apps, which are short for mobile applications, onto their phones (Jung, 2014; Sarker, 2019).

Smartphones have become a vital part of contemporary life, providing users with a vast array of perks and advantages. With a smartphone, you can stay in touch with the outside world, gain access to a huge array of information and services, and remain organized and on top of your schedule (Kacetl & Klímová, 2019; Kim & Park, 2019). A smartphone is very useful and is turning into a mobile device that can be used for many things. It can help people with their personal and professional tasks. Many people use their smartphones to access the Internet and learn new things (Anshari et al., 2017). Smartphones also provide users with a variety of communication choices, such as audio and video conversations, messaging, and social networking, allowing you to remain in contact with friends, family, and coworkers regardless of your location (Jia & Chen, 2020).

Students at higher education institutions are digital natives who cannot function without their smartphones. They cannot be parted from their smartphones (Faimau et al., 2022). Students spend a significant amount of time online, and many choose to access the Internet through their smartphones over other devices. They typically carry their mobile smartphones to schools and lectures (Anshari et al., 2017). Due to the adaptability and widespread usage of smartphones, educational research has focused increasingly on their application in the classroom (Mella-Norambuena et al., 2021). Some students utilize smartphone cameras to take lecture notes or other notes produced or distributed by instructors. It is excellent that they are participating in relevant activities in the classes. However, smartphones may also create a great deal of pain in the classroom if students use them for distractions rather than focusing on the lecture (Anshari et al., 2017). It is still unclear if students utilize smartphones effectively as a resource. Therefore, it remains uncertain whether the usage of cellphones by students enhances or hinders learning (Mella-Norambuena et al., 2021).

The correlation between the use of smartphones and academic performance has piqued the interest of academics, as seen by the rise in the number of academic research conducted in this area over the course of the past decade (Faimau et al., 2022). The findings of research examining the association between smartphone use and academic performance and student outcomes are often contradictory. According to Junco (2012), there is a negative correlation between smartphone usage and academic achievement among university students. College students who use smartphones for academic purposes have lower cumulative grade point averages (Foen Ng et al., 2017). The results of meta-analyses indicate that mobile phone use has a little detrimental impact on educational achievements (Kates et al., 2018).

On the other hand, according to Shakoor et al. (2021), smartphones assist students in improving their academic performance and completing projects and tasks effectively. Smartphone functions, such as smartphone applications, multimedia service messages (MMS), short service messages (SMS), and warp-speed processing, have a positive effect on university students' academic achievement (Ahmed et al., 2020). Utilizing a smartphone and engaging in self-directed study have tremendous favorable benefits on individual impact (Tao et al., 2018).

Furthermore, there are studies which find no connection between smartphone use and academic achievement (Sumathi et al., 2018). Whether smartphone usage has a favorable or detrimental impact on the lives of students, it is crucial for scholars to perform further study in this area (Singh & Samah, 2018). In the

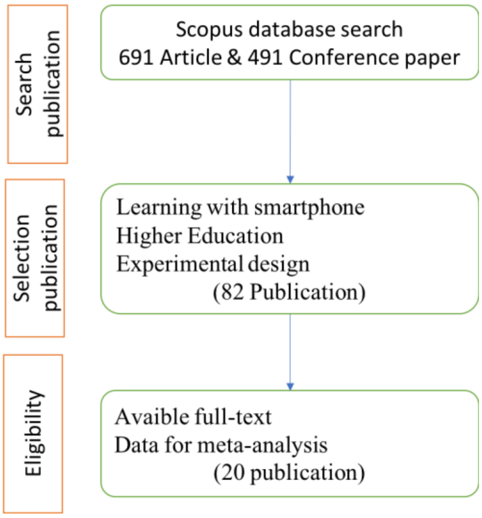

Figure 1. Publication selection process (Source: Authors)

study done with medical students, it was established that the usage of smartphones had no major impact on their academic performance (Kumar et al., 2021).

A meta-analysis is an examination of the results of a number of researches with the purpose of integrating the findings of these investigations (Hedges, 1992; Schmidt, 2008). A technique that is utilized to synthesize research is called a meta-analysis. Combining separate data sets from several research projects in order to look for an answer to a particular research topic is basically what this method entails (Field & Gillett, 2010; Normand, 1999).

In this study, an attempt was made to incorporate the findings of previous studies that investigated the impact that smartphones had on educational outcomes. In order to aggregate the results of the individual meta-analysis studies, the effect size of each study must first be computed. In the context of a meta-analysis, the term "effect size" refers to both the intensity and the direction of the association that exists between two variables (Hedges, 1992).

METHOD

Data Collection Tools

The Scopus database was used to obtain the publications required for the meta-analysis study. It has attempted the ("smartphone" OR "cellphone" AND "learning" AND "Higher education" OR "University") search keywords for their respective publications. As a result of the search, 1184 publications were obtained. First of all, the titles and abstracts of the publications were examined. Review criteria:

a) smartphones should be used for learning purposes,

b) studies on smartphone addiction have been removed,

c) publications not related to higher education have been removed.

Then, the full texts of the studies were reached, and it was checked whether there was data for meta-analysis. As a result of the review, 20 studies suitable for meta-analysis were determined. In some studies, if two different variables (for example, knowledge test, academic performance) were included in the outcome measurements, both data were added. A total of 26 data was analyzed.

Data Analysis

Effect size was determined using MAJOR modules in the Jamovi 2.3.2 software (The jamovi project, 2022). It was chosen to employ standardized averages due to the fact that different measurement instruments and measurement units were used in the investigations. Afterwards, Hedges' g value was computed for each study (Rosenthal & DiMatteo, 2001). In the studies, a value of 0.05 was considered as the reliability value. The Chi-Square heterogeneity test with (k-1) degrees of freedom developed by Cochran, which is the simplest and

Table 1. Effect size interpretation

Effect size	Criteria
< 0.2	Small effect size
0.2 – 0.8	Medium effect size
> 0.8	Large effect size

Table 2. Descriptive information on the studies

Variables	Subgroups	N	%
Outcome Type	Academic Performance	11	42.3 %
	Final Score	3	11.5 %
	Knowledge test	10	38.5 %
	Objective Structured Clinical Examination	2	7.7 %
Region code	Asia	12	46.2 %
	Europe	4	15.4 %
	Middle East	6	23.1 %
	North America	2	7.7 %
	South America	2	7.7 %
App type	Special App	14	53.8 %
	Not-Specific App	4	15.4 %
	VR&AR	6	23.1 %
	WhatsApp	2	7.7 %
Field	All	2	7.7 %
	EFL	3	11.5 %
	Engineering	5	19.2 %
	Health	15	57.7 %
	Non-Science	1	3.8 %
Sample size	<100	18	69.2 %
	>100	8	30.8 %
Publication year	2016	2	7.7 %
	2017	2	7.7 %
	2018	6	23.1 %
	2019	4	15.4 %
	2020	3	11.5 %
	2021	4	15.4 %
	2022	5	19.2 %

most prevalent method, was utilized to determine whether or not there is heterogeneity among studies. The heterogeneity test evaluates the null hypothesis that all studies evaluate the identical effect (Rosenthal & DiMatteo, 2001; Schmidt, 2008). In the classification of effect size, evaluation was made according to the criteria presented in **Table 1**.

FINDINGS

Descriptive Statistics

In the study, the subgroup variables were classified according to what was measured as the output of the study, the region where the implementation was done, the apps, the higher education department, the number of participants, and the years of publication (see **Table 2**). Academic performance measurements were mostly used in the studies. When analyzed by regions, the most work was done in the Asia region, while the apps used in the studies were specific apps. When the departments were examined, it was mostly done in the field of health. The number of studies with a sample size of 100 or more is higher. Most publications were made in 2018.

As the end measure, the mean difference was utilized in the analysis. To the data, a random-effects model was fitted. The degree of heterogeneity (tau^2) was calculated using the Hedges' estimator. A high Tau^2 number, such as 49.9124, suggests a substantial amount of heterogeneity between studies in the effect sizes being evaluated. This indicates that there is a broad variety of effect sizes across the studies included in the meta-analysis and that the studies do not all measure the same thing or provide comparable results. The standard error of the Tau2 estimate is 14.9025, which may be used to measure the estimation's accuracy. A smaller

Table 3. Heterogeneity Statistics

Tau	Tau²	I²	H²	df	Q	p
7.065	49.9124 (SE= 14.9025)	99.97%	2870.232	25.000	1546. 689	< .001

Table 4. Overall average effect size

	Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Intercept	3.73	1.42	2.64	0.008	0.958	6.512

Note. Tau² Estimator: Hedges

standard error number suggests a more exact estimate. Overall, the Tau² value of 49.9124 (SE= 14.9025) indicates that there is a significant degree of heterogeneity between studies in the meta-analysis and that the included studies do not provide similar results. This may imply that further research is required to determine the causes of this heterogeneity and to better interpret the meta-overall analysis's conclusions. A meta-analysis with an I-squared score of 99.97% suggests a very high degree of heterogeneity between studies. I-squared is the fraction of overall variance in effect sizes that is attributable to actual between-study variation, as opposed to sampling error. The Q value of 1546.68 and the p-value of .001 indicate that there is a high amount of heterogeneity between studies in the effect sizes being assessed, which might make it difficult to draw conclusions from the meta-analysis.

The random effect-size approach was preferred to determine the total effect value according to the examination results of the indices in **Table 3**. As can be seen in **Table 4**, the total effect size is calculated at 3.73. Since p 0.05, this effect size is statistically significant. This result can be evaluated as having a large effect size.

For each study, an effect size calculation was made based on Hedges g (**Figure 2**). The greatest effect value is 25.70 [16.51; 34.89] on the use of chatbots in nurse education (Chang et al., 2022). The lowest effect value, with -8 [-13.02;-2.98], was obtained in the study on the use of WhatsApp by medical students (Clavier et al., 2019). When the sampling variance is examined, the biggest contribution was made by 5 studies (Jackson et al., 2019; Jaramillo et al., 2022; Lobos et al., 2021; Loeffler et al., 2019; Park & Kim, 2018) with 4.02%. The lowest contribution was from the study of Chang et al. (2022). When the classification of effect sizes was made, it was determined that seven (27%) studies (Briz-Ponce et al., 2016; Clavier et al., 2019; Jackson et al., 2019; Kim et al., 2017; Park & Kim, 2018) had a small effect size. The rate of studies (Chuang et al., 2018; Jaramillo et al., 2022; Lobos et al., 2021; Loeffler et al., 2019) with a medium effect size is 15% (4). The remaining 15 studies (Alghazzawi et al., 2021; Arain et al., 2018; Bell et al., 2018; Chang et al., 2022; Chuang et al., 2018; Dabbour, 2016; Daliri et al., 2021; Jia & Chen, 2020; Kim et al., 2017; Shen, 2021; Sultan et al., 2020; Wang et al., 2022; Zakian et al., 2022) have a large effect size (58%).

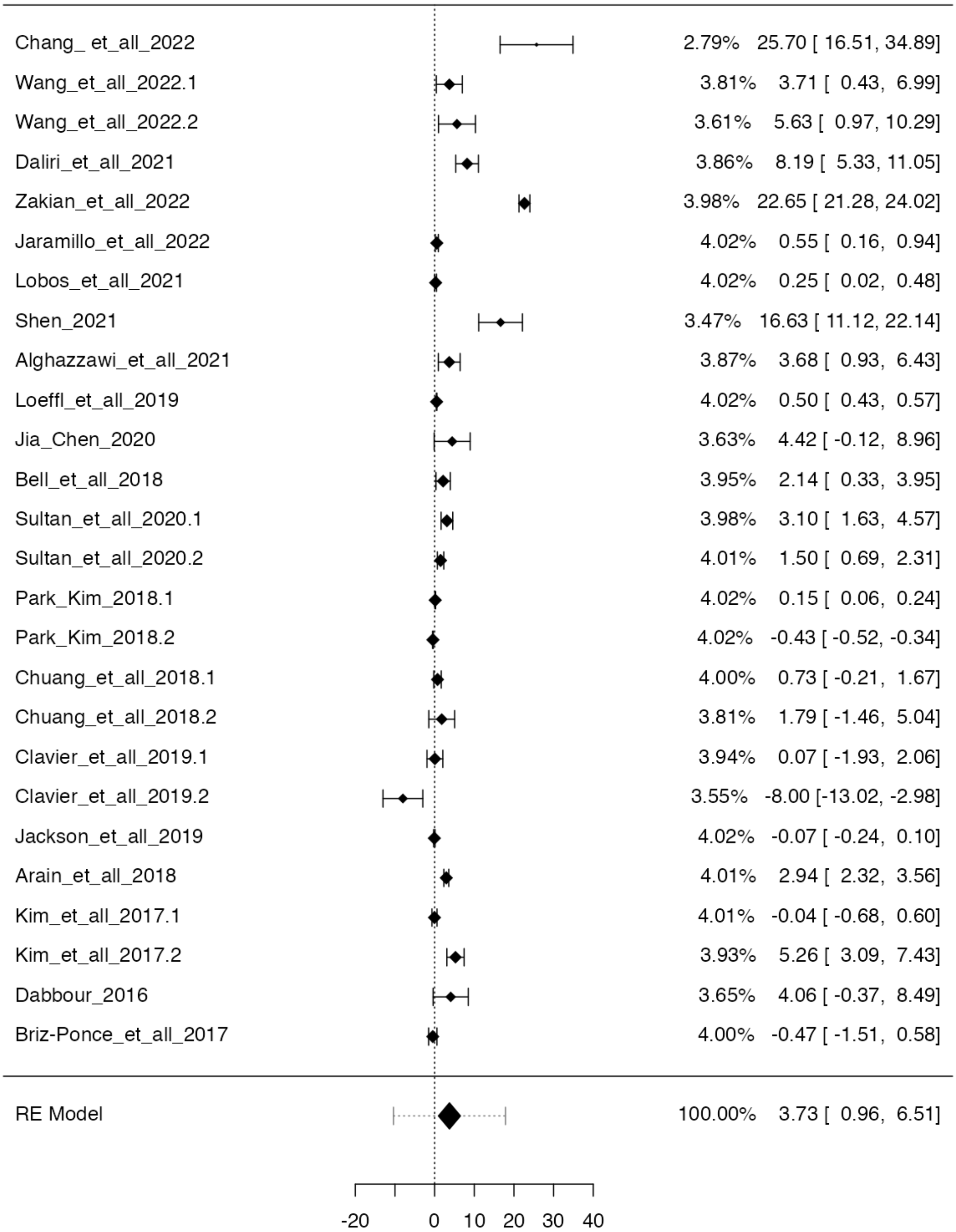

Figure 2. Forrest plot based on effect size (Source: Created using Jamovi software based on study data)

Publication Bias

In order to determine whether there is bias in the studies, Fail-Safe N, Begg and Mazumdar Rank Correlation, Egger's Regression, and Trim and Fill Number of Studies values were examined together with the Funnel plot (see **Figure 3**).

The phrase "Trim and Fill" refers to a method that is used in meta-analysis to adjust for the possibility of publication bias. This bias occurs when studies that find positive findings are more likely to be published than studies that find negative or non-significant findings. "Trim and Fill" is a method that is used to adjust for the possibility of publication bias. The number of studies that are imputed, or "filled in," to correct for the potential influence of publication bias on the pooled estimate of effect is referred to as the "Trim and Fill Number of Studies." A measure of the degree to which publication bias is present in the meta-analysis, the Trim and Fill

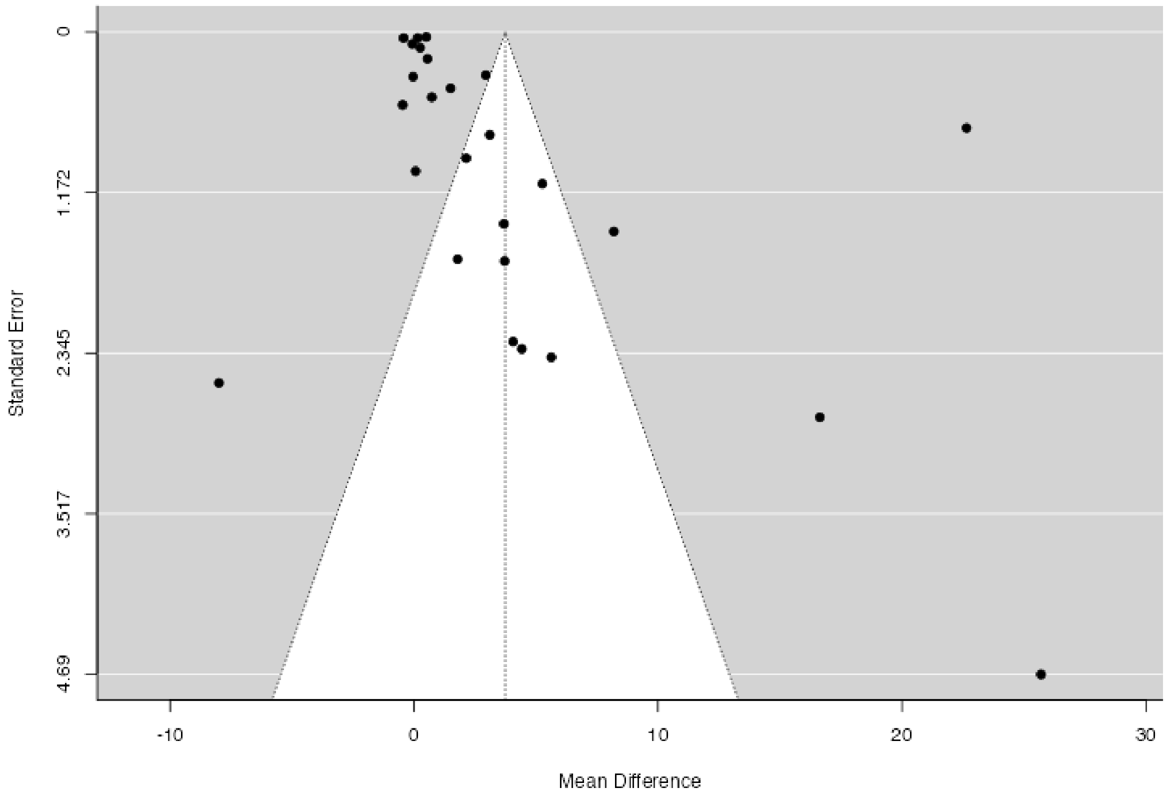

Figure 3. Funnel plot (Source: Created using Jamovi software based on study data)

Number of Studies can be used to show how much the pooled estimate of effect may be affected by the bias. The Trim and Fill Number of Studies was calculated as 0 in the study. The coefficient for Egger's Regression is 2.71 and the p-value for the test is 0.012. These results suggest that publication bias may exist in the studies included in the meta-analysis, as the p-value is less than 0.05, and that small studies are more likely to have larger effect sizes than large studies. The Begg and Mazumdar rank correlation is utilized to detect publication bias. There is a small positive correlation between the standard errors of the effect sizes and their corresponding precisions (inverse variances) in the studies included in the meta-analysis, as indicated by the correlation coefficient of 0.169. The p-value of 0.237 indicates that this correlation is not statistically significant at the alpha level of 0.05, indicating that there is insufficient evidence of publication bias in the included studies. A fail-safe N of 422 indicates that if the meta-analysis excluded 422 studies with null results (i.e., no effect), the overall effect would no longer be statistically significant. A p-value of 0.001 indicates that the overall effect is highly statistically significant, even if many studies with null results are missing. A low fail-safe N value may indicate that the evidence for the overall effect is weak and that there may be a significant number of missing studies with null results that would alter the conclusion of the meta-analysis. As result, we may conclude that there is no publication bias in the studies.

Effect Size as Measured by Moderator

In all subgroups except publication years, a p-value smaller than 0.05 suggests that there is no statistically significant evidence (at the alpha level of 0.05) to support a difference in the mean effect size between the subgroup of studies and the overall population of studies (**Table 5**). It is important to note that a non-significant p-value does not imply the absence of an effect, but rather that there is insufficient evidence to suggest a difference between the subgroup and the overall population. The confidence intervals of the estimate can also be helpful in interpreting the results and assessing the possibility of a true effect. The subgroup estimate for the continuous variable (years of publication) is 1.70, which is the mean value for the

Table 5. The effect size based on moderators

		Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Field	Intercept	8.99	4.94	1.82	0.069	-0.692	18.667
	Moderator	-1.55	1.40	-1.11	0.267	-4.295	1.189
Apps	Intercept	7.44	2.82	2.64	0.008	1.915	12.962
	Moderator	-2.02	1.34	-1.51	0.131	-4.634	0.602
Outcome type	Intercept	4.466	3.28	1.361	0.174	-1.966	10.898
	Moderator	-0.338	1.38	-0.245	0.806	-3.039	2.363
Region	Intercept	4.958	2.80	1.773	0.076	-0.522	10.438
	Moderator	-0.558	1.10	-0.507	0.612	-2.715	1.598
Year	Intercept	-3.69	3.171	-1.16	0.245	-9.902	2.527
	Moderator	1.70	0.672	2.53	0.011*	0.382	3.018
Sample size	Intercept	6.01	4.30	1.396	0.163	-2.426	14.438
	Moderator	-1.72	3.08	-0.559	0.576	-7.767	4.321

** p is smaller than 0.05*

subgroup of studies being analyzed. The standard error (SE) of this estimate is 0.672, a measure of the estimate's precision. The Z-score of 2.53 represents the number of standard deviations by which the estimate deviates from the overall mean value of the continuous variable. A p-value of 0.011 indicates that there is statistically significant evidence (at the alpha = 0.05 level) to support a difference in the mean value of the continuous variable between the subset of studies and the entire study population. The z-score of 2.53 exceeds the critical value of 1.96, which is the significance threshold for a two-sided test with a 5% level of significance. This result suggests that the mean value of the continuous variable for the subgroup differs significantly from that of the entire population. It is essential to note that this result should be interpreted in light of the study's design and other variables that may have influenced the outcome.

DISCUSSION

Reviews of different studies show that students use smartphones for many different reasons. Most students use their smartphones to have fun, stay in touch with friends and learn (Singh & Samah, 2018). There are studies that claim using smartphones has a good influence on students' learning (Ahmed et al., 2020; Tao et al., 2018; Zhdanov et al., 2022), but there are other studies that claim it has a detrimental effect on students' learning (Faimau et al., 2022; Foen Ng et al., 2017; Junco, 2012; Platonova et al., 2022). The study's data were aggregated based on the random effect you. The computed overall impact size is 3.73. Since p 0.05, the magnitude of this impact is statistically significant. This finding can be assessed as having a large effect size. Based on Hedges' g, an effect size calculation was performed for each research. The magnitude of the impact ranges between 25.70 and -8. When effect sizes were classified, it was revealed that seven (27%) of the studies had a low effect size. 15% of studies demonstrate a medium impact size (4). The remaining 15 studies (58%) show a substantial impact size. The findings of the study conducted by Lin et al. (2021) provide evidence for the argument that the usage of mobile applications does have a direct effect on academic achievement. The activities of using social media and consuming music and videos, playing mobile games, and reading entertainment books all exhibit adverse effects, which is consistent with previous studies that reported a detrimental impact of entertainment-oriented system use on academic achievement. While mobile learning and news both have a positive effect on academic performance, activities such as using social media, consuming music and videos, playing mobile games, and reading entertainment books all have negative effects. According to the meta-analysis study conducted by Kates et al. (2018), a low correlation value was calculated between smartphone use and learning outcomes.

While trying to measure different learning outcomes (Academic Performance, Final Score, Knowledge test, Objective Structured Clinical Exam) in the studies, different smartphone apps (Special App, Not-Specific App, VR&AR, WhatsApp) were used according to the purpose of the study. In the meta-analysis study by Kim and Park (2019), grouping was made according to learning outcomes (cognitive load, confidence in performance, knowledge, learning attitudes, learning satisfaction, and skills). Except for cognitive load, the p-value was less than 0.05 in other groups. In the analysis, the differentiation according to the outputs was not investigated. The effect, which is generally calculated in the sub-groups of learning outcomes, is at the level of confidence.

The study's other moderator variables include the areas where the research was done and the students' departments. There was no distinction based on these characteristics. As a result of the study conducted by Kates et al. (2018), there is no differentiation by region. In the meta-analysis study by Kim and Park (2019) on the use of smartphones in nurse education, no differentiation by country could be obtained. Note that a non-significant p-value does not imply the lack of an effect, but rather that there is insufficient evidence to establish a difference between the subgroup and the entire population.

CONCLUSION

The data for the study were put together based on the random effect. The total effect size that has been calculated is 3.73. Since p = 0.05, this effect's size is statistically important. This finding has a big effect, as can be seen. For each study, an effect size calculation was done based on Hedges' g. The size of the effect is between -8 and 25.70. When the effect sizes were put into groups, it was found that 7 of the studies, or 27%, had a low effect size. 15% of the studies show a medium size effect (4). The other 15 studies (58%) show that the size of the impact is large. To see if there was bias in the studies, Fail-Safe N, Begg and Mazumdar Rank Correlation, Egger's Regression, Trim and Fill Number of Research values, and Funnel plot were used. Because of this, we can assume that there was no publication bias in the study. A p-value of less than 0.05 means that there is no statistically significant evidence (at the alpha level of 0.05) to show a difference in the mean effect size between the subgroup of studies and the overall research population, except for the publication years. Note that a p-value that is not significant does not mean that there is no effect. Instead, it means that there is not enough evidence to say that there is a difference between the subgroup and the whole population.

The fact that the research only looked at papers that were found in the Scopus databases is the primary drawback of the study. There are researches that contribute to the topic that are not indexed by this database but yet exist. The findings of the study were derived from research that was conducted using an experimental methodology. It is advised that future research use meta-analysis, which should include correlational investigations.

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Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analysed during this study are available from the authors on request.

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