

Article

Digital Platforms and the Improvement of Learning Outcomes: Evidence Extracted from Meta-Analysis

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Abstract: Digital platforms are one of the educational resources that were used in education prior to Covid-19 pandemic. Nevertheless, the pandemic has led to a complete shift to learning via digital platforms, and therefore they have become a strategic alternative for sustainable education. Given that previous studies regarding the impact of digital platforms on learning outcomes have yielded conflicting results, the present study aims to determine whether or not digital platforms improve learning outcomes. To achieve this aim, meta-analysis approach was used through the examination of the overall effect size of these platforms on the learning outcomes besides the examination of the effect size of a set of mediating variables including study period, subject area, student rating, and publication type. Thirty studies published between 2015 and 2021 comparing learning via digital platforms and learning in traditional classrooms were accounted for. The focus on this period of time was because the fourth industrial revolution took place in that time where the use of digital platforms in teaching was prosperous. Findings showed that the overall effect size using the random effect model ($g = 0.278$; $p < 0.001$; $\alpha = 0.05$) was small and positive, from (0.123–0.433) in favor of learning via digital platforms, and so no evidence regarding publication bias could be discovered in these data. The result of the current study may be useful to universities and e-learning centers on how to use digital platforms to improve learning outcomes.

Keywords: digital platforms; learning outcomes; meta-analysis



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1. Introduction

Higher education institutions have integrated information and communication technologies (ICT) in the educational process and used the digital platforms to support student learning, teaching methods, and faculty members. Thus, digital platforms use started to grow significantly in the last years, especially in higher education [1]. Concentration was on the digital platforms and their associated cooperative tools to provide opportunities for knowledge-sharing higher-order thinking skills support through methods of conversation and active learning [2]. In addition, the appearance of Covid-19 pandemic has forced the educational institutions in various countries to shift towards e-learning and use digital platforms in the educational process [3,4]. Digital platforms are educational tools that enhance learning processes and provide a set of tools that allow synchronous and asynchronous interaction and communication between students themselves on one hand, and between the teacher and his students on the other hand. They also facilitate participation in different tasks [5].

Digital platforms that can be used in the educational process to provide flexible and reliable learning environment are numerous [6], such as Blackboard, Moodle, Canvas, Edmodo, Google Classroom . . . etc. [7,8]. For the successful use of these digital platforms, they should be adapted to the requirements and needs of teaching and learning [9]. Blackboard platform is one of the most popular and widely common digital platforms used in the educational process because of its ease of use, ability to access the educational resources, the availability of interaction and cooperative tools, the ability to prepare reports and statistics

on student achievement, and many other advantages [10,11]. Furthermore, digital platforms have a set of common characteristics such as the learner's participation-based active interaction and the positive interaction with knowledge and tasks available to students. They are also all flexible, scalable, and versatile of use [12]. In addition to assessment, digital platforms share the possibility to carry out tests and assignments, provide feedback to learners, provide content for each course, support interactive educational resources provide discussion forums, allow live chat between learners and teacher and between learners themselves, and conduct video conferencing [13].

Digital platforms are a vital learning environment to support sustainable education, as they include several tools that motivate students to continue learning [14]. In addition, digital platforms provide tools that enhance participatory construction of knowledge, which helps maintaining the impact of learning and supports the sustainability of learning outcomes [15]. Digital platforms facilitate independent learning skills, and such skills are considered among the most important inputs for sustainable education [16]. Sustainable education entails learning environments that support cognitive thinking and motivation for achievement, which can be obtained through the platforms through the digital tools and strategies of instructional design that can be practiced through these platforms [17]. Digital platforms also have the potential to improve wellbeing [18], which, given the correlation between wellbeing and sustainability [19], highlights the ability of digital platforms in promoting educational sustainability. Recently, many studies have been carried out on digital platforms and their impact on improving different learning outcomes. Different results have been reported by these studies revealing no consensus regarding the effectiveness of these digital platforms in improving learning outcomes. Some of these studies confirmed the positive impact of the digital platforms in improving various learning outcomes such as [20–28]. During COVID-19 pandemic, success of these digital platforms continued in achieving a positive effect on learning outcomes enhancement [17,29]. Other studies such as [30–36] showed no effect of digital platforms on different learning outcomes improvement.

Accordingly, the present study aims to bridge the gap regarding the impact of digital platforms in the enhancement of the learning outcomes based on evidence extracted from previous studies. Due to the pandemic, educational institutions all over the world have moved to online learning, and digital platforms have become the only way for continuing the educational process. Therefore, conducting studies in this aspect has been of great importance where meta-analysis can provide quantitative studies about the impact of digital platforms on the development of learning outcomes. Meta-analysis can also indicate whether intervention has a positive impact on improving learning outcomes [37]. Besides, it can determine the effect strength and whether it is positive or negative in addition to addressing the varied results [38,39].

In short, the present study aims to determine the effect of digital platforms on improving learning outcomes using results of previous studies' meta-analysis and according to some intermediate variables. It mainly aims to answer these questions:

- What is the effect of digital platforms in higher education students' learning outcomes?
- What is the effect of digital platforms regarding the present study's duration on higher education students' learning outcomes?
- What is the effect of digital platforms regarding to the present study's subject area on higher education students' learning outcomes?
- What is the effect of digital platforms regarding students' classification on higher education students' learning outcomes?
- What is the effect of digital platforms regarding the type of publication on higher education students' learning outcomes?

2. Literature Review

Digital platforms are networks that provide an effective learning environment and interactive support for students [40]. A digital platform contains a set of tools that support students' learning, such as videos, discussion forums, chat forums, assignments,

quizzes [41]. Interactions through the digital platforms are not very different from traditional interactions in face-to-face classroom. Through these platforms, students and teachers can exchange concepts and information, and assess and solve problems that may face students during the learning process [42–45].

In education, digital platforms have many advantages. For example, learning through these platforms advocates learner-centered learning approaches and ensures learner's active participation [46]. Moreover, the use of digital platforms facilitates the delivery of content in various ways to account for individual differences between learners [47]. Digital platforms also allow the learner to communicate within a multimedia rich environment that enhances the frequent retrieval of information [48], and provides an educational environment conducive to group thinking and collaborative learning [49], which is beneficial in developing the learner's individual and collaborative skills [50]. Furthermore, they help teachers organize the learning activities and plan their lessons [51]; and they reduce administrative tasks such as attendance registration, and make access to the teacher easier through the means of communication available within the platform [52]. Digital platforms are effective for the learner and well-being [18,53], ability to improve self-regulated learning [54], and motivation [29].

In recent years, many studies have tackled the effect of digital platforms on improving different learning outcomes, but conflicting results were concluded. In this regard, Akbari, Heidari Tabrizi, and Chalak [21] investigated the effect of teaching via digital platforms on improving reading comprehension in English language compared to face-to-face learning methods. Results showed the superiority of students who were taught via digital platforms to students who were taught through the traditional methods. On the contrary, results of Fayaz and Ameri–Golestan [34] showed that traditional teaching methods are more effective than teaching via digital platforms in enhancing English vocabulary acquisition. In addition, Elfaki, Abdulraheem, and Abdulrahim [22] showed that digital platforms are effective in improving the academic performance of nursing students and satisfaction with learning, whilst results of Aalaa, Sanjari, Amini, Ramezani, Mehrdad, Tehrani, Bigdeli, Adibi, Larijani, and Sohrabi [30] concluded that nursing students who study via the use of traditional teaching methods were superior to their colleagues who studied via digital platforms. Whereas, Sáiz-Manzanares, Marticorena-Sánchez, Díez-Pastor, and García-Osorio [25], after investigating the effect of using digital platforms in improving student learning outcomes in hypermedia design skills in comparison with the use of traditional teaching, revealed the effectiveness of digital platforms in improving students' learning outcomes in media skills. On the other hand, Hu–Hui [36] highlighted the ineffectiveness of digital platforms in improving students' learning outcomes in design skills. In addition, it concluded that learning via digital platforms reduced students' satisfaction with the learning process. Handayanto, Supandi, and Ariyanto [28] aimed to determine the impact of learning via the Moodle platform in mathematics education, revealing a significant increase in students' achievement results in mathematics through the digital platform Moodle. Fatmi, Muhammad, Muliana, and Nasrah [33] showed that Moodle digital platform was not effective in promoting the learning outcomes of physics students as students did not fully fulfill the expected goals. Similarly, Jusue, Alonso, Gonzalez, and Palomares [23] evaluated the learning process through the digital platform Moodle for medical students in clinical skills. Findings revealed that performance of students in the experimental group was superior to the performance of their colleagues in the control group who studied via the traditional method. The results of Balakrishnan, Nair, Kunhikatta, Rashid, Unnikrishnan, Jagannatha, Chandran, Khera, and Thunga [31] assured the superiority of student in the group that studied through the traditional ways. That is, digital platforms use was not effective in promoting students' achievement in clinical research units. While Wu, Yu, Yang, Zhu, and Tsai [55] explored the impact of digital platforms on students' skills, particularly computing skills, and ascertained the superiority of students who studied via digital platforms. In other words, digital platforms had an impact on improving students' skills. In addition, Callister and Love [32] showed that

students' skills who studied by the traditional classroom were better than the skills of their colleagues who learned via the use of digital platforms. In brief, conflict or inconsistency in the findings of these previous studies shows the importance of conducting more studies among which is the present study to verify the effect of digital platforms use in improving learning outcomes using the meta-analysis approach of previous studies.

3. Theoretical Framework

The use of technology in general and digital platforms in particular is related to a number of educational theories. For instance, digital platforms are connected to the cognitive theory taking into consideration that the learner's mind processes information in a way that is similar to the computer's way of processing. It perceives and recognizes the information coming from the outside, then it stores this information to be retrieved when needed [56]. On the opposite, the teacher is the manager of the learning process who directs, explains, and organizes this information or knowledge which is an external reality that the learner should integrate into his mental patterns and then reuse instead of acquiring observable behaviors [57,58]. The preferred teaching method, in turn, should allow multiple learning paths that account for the individual differences affecting the way the learner processes information. Furthermore, the theory is usually concerned with the internal mental processes and how they are used to motivate learners to learn as motivation as an important and critical factor for learning [59–61].

However, when talking about digital platforms and their link to educational theories, it is important to consider the constructivist because digital learning platforms are based on the principles of constructivist, which enable the users to build content, and modify and adapt it to support participation and discussion in the digital platform environments where it will be possible for users to build and open forums, start group discussion, and close it at a specific time for the purpose of specific educational activities [62–66]. In addition, digital platforms support the learners' active and collaborative participation where knowledge is built by strengthening participatory learning through discussion and social dialogue with a focus on building knowledge rather than transferring it [67–69].

Moreover, digital platforms are linked to social learning theory which postulates that learners learn better when receiving appropriate support from peers and teachers [70]. Besides, social interactions are of great importance because knowledge is constructed through a joint between two or more people [60,71]. Learning is a social secondary outcome of conversation and negotiation among learners who gain knowledge through their participation in related social activities [72]. Accordingly, digital platforms provide tools for social interaction, including chatting, discussion groups, blogs, and content sharing [73].

On the other hand, connectivism deals with learning as a network of personal knowledge created to engage learners in socialization and online interaction [63]. It postulates that the concept of the learning process consists of several nodes joined by links where nodes represent online information, whether text, audio, or visual information. Links on the other part stand for the learning process itself, which is the effort performed to join these nodes together to form a network of personal knowledge [74,75]. According to connectivism, distance learning environment is largely based on learning design because the design of distance learning environments based on connectivism is not just courses or programs, but based on specific characteristics that encourage the learner to continuous learning, communication, engaging in learning, and active participation [76,77].

4. Materials and Methods

4.1. Methodology

Meta-analysis procedures suggested by Glass, McGaw, and Smith [78], which include the following: collecting relevant studies, coding study features, calculating the effect sizes of the outcome measures for each study, and investigating the moderating effects of study characteristics on the outcome measures were used in the present study.

4.2. Literature Search

A number of terms that describe digital platforms have been used to search for relevant literature related to the study's topic. Terms such as LMS, digital platforms, distance learning, E-learning, Learning Management system, online, learning, education, teaching, and Not Covid-19 were looked for in the titles abstracts, and keywords of previous related studies. The term "Not Covid-19" was used because studies in the time of this pandemic have a special nature which is different from the studies before it. Studies that were accounted for in the present study were those studies carried out from 2015 to 2021 because this period is considered as one of the periods of the fourth industrial revolution that witnessed the boom in the employment of digital platforms in the educational process. Search was conducted through the Web of Science and Scopus databases because they are distinguished by their quality and inclusion of many other databases—Appendix A includes all analyzed references in the selected databases. As mentioned previously, meta-analysis, where studies meeting the inclusion criteria mentioned in the present study, were analyzed.

4.3. Inclusion and Exclusion Criteria

A set of inclusion and exclusion criteria, as shown in Table 1, was developed. The study was assumed to be published between 2015 and December 2021 and not to be in the context of COVID-19 pandemic because it is difficult to standardize the comparison context between digital platforms and educational environments during that pandemic. In addition, the study had to be of an experimental nature and therefore should use either experimental or quasi-experimental research with a design that compares the digital classroom and its effect on the students' outcomes to the traditional one and its effect. The study was applied to undergraduate and postgraduate education. Furthermore, studies chosen for analysis had to include sufficient data to calculate the effect sizes such as means, standard deviations, and sample sizes. In addition, student learning outcomes were being clearly described before the experimentation using quantitative data. Then, the learning content was to be the same for both the digital and traditional classrooms. Finally, the study had to be published in English.

4.4. Identification and Selection of Publications

4.4.1. The First Phase

During the first phase of publications selection, study title and abstract of each study were read to ensure that they were relevant to the digital platforms. Articles of refereed journals and conference papers were only included, and articles not related to digital platforms were excluded with the result that 3899 publications were accounted for. All duplicates in the databases were removed. After data identification and screening, 858 publications were considered in the present study as shown in Figure 1.

4.4.2. The Second Phase

During the second phase, studies that compared face-to-face education across digital platforms and traditional classrooms were identified. Studies that included the implementation of learning via digital platforms have been carefully examined to determine whether they compare learning via digital platforms with traditional face-to-face classes. At the end of the second stage, the number of considered publications was 130 publications.

4.4.3. The Third Phase

During the third phase, methodological designs and data generated from the study were examined. Studies that did not provide sufficient data for calculating the effect sizes (mean, standard deviations, and sample sizes) were excluded. Studies that used different educational content for both digital and face-to-face classes were also excluded. Experimental or quasi-experimental designs whose designs compare the intervention (digital platforms) to control (traditional head-to-head separation) were only included. In

addition, studies that refer to multiple student learning outcome measures, such as a final test score or score on a final project were included as well. In each case, data were used to calculate the effect sizes using appropriate outcome equations. The Data Analysis section provided more details about the specific statistical models used. A PRISMA flowchart adapted [79] to the literature search process and the number of studies identified, screened, and included in the meta-analysis is shown in Figure 1.

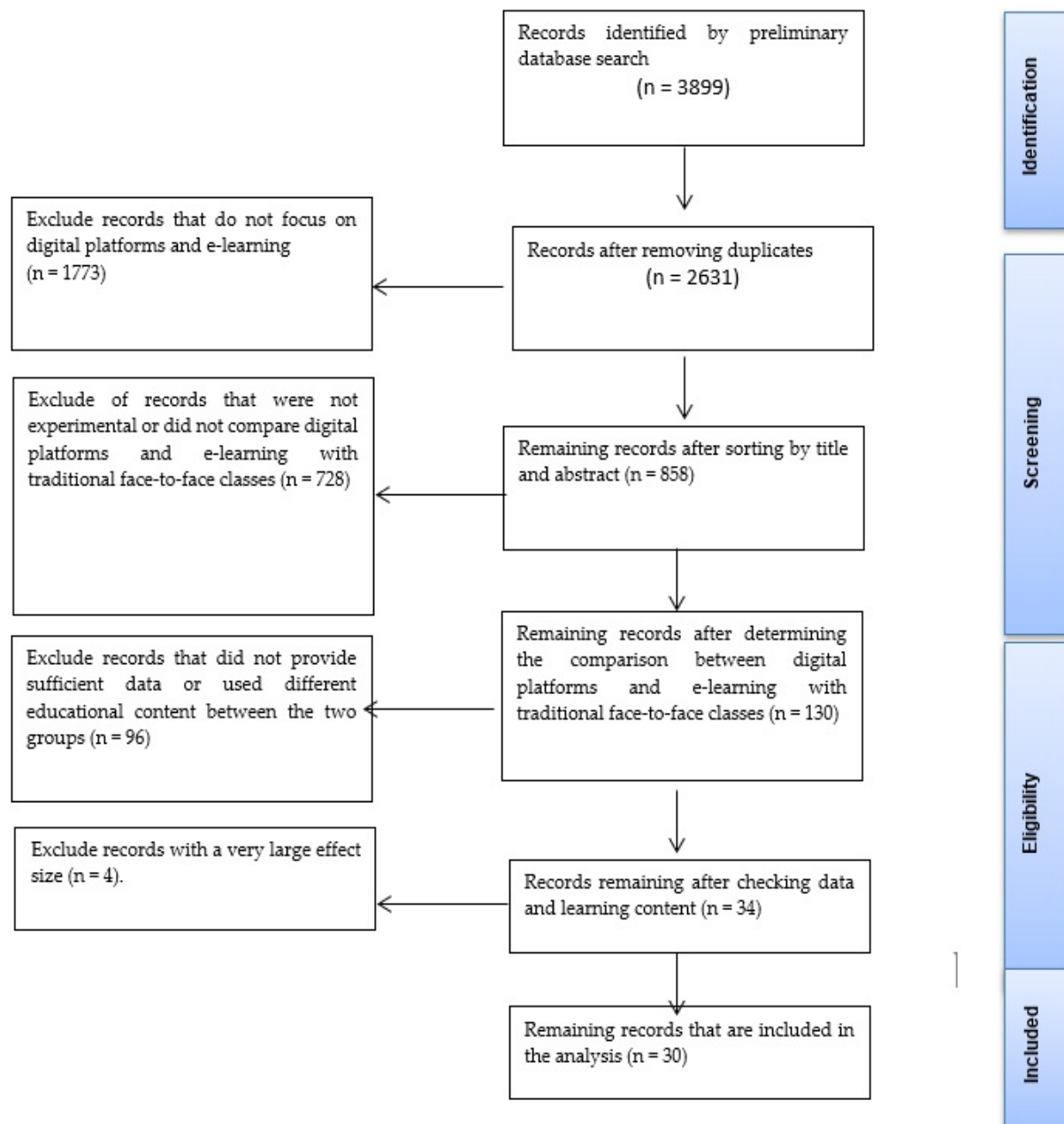


Figure 1. PRISMA flow diagram.

4.5. Coding Features and Procedures

All studies were coded using a set of relevant variables including study time duration, subject area, student classification, and publication type. Data were extracted to calculate effect sizes using the mean scores, standard deviations, and sample size of each study. The final list of coding included, for example, time duration less than a semester, a whole semester, or more; subject areas such as social science, computer science, arts and humanities, health, science, or business; students' classifications, whether undergradu-

ates or postgraduates; and publication type, such as a journal article or conference paper. Therefore, the final list included these criteria:

- Author Details: Author's last name.
- Year: The year the publication was published in.
- Database Source: Database source used to locate the publication.
- Publication Title: Title of the publication.
- Publication place: Name of the journal or conference where the publication was published.
- Publication Type: Type of publication (Journal article or Conference paper).
- Subject Area: Discipline in which the study was conducted (arts and humanities, health, computer sciences, social sciences, science, or business).
- Student classification: Population from which the sample was chosen (undergraduates or postgraduates).
- Study Duration: Length of the study timeframe.
- Quantitative Data: Quantitative data reported by the study to calculate the effect size.

Table 1. Inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
■ Time period	■ Be published between 2015 and 2021. ■ Not related to the context of COVID-19 pandemic	■ Studies outside the defined time period
■ Context	■ Traditional learning context before the pandemic	■ Learning context during the COVID-19 pandemic
■ Literature type	■ Articles and conference papers	■ It is not an article or a conference paper
■ Language	■ English	■ language other than English
■ Study type	■ An applied Study	■ Theoretical study
■ Accessibility	■ Full text available	■ Unable to access the full text
■ Learning content	■ The same learning content	■ Learning content is not the same
■ Implementation	■ The class was carried out via digital platforms	■ The separation is not carried out across digital platforms
■ Research design	■ It should be an experimental or semi-experimental design. ■ It should be a design that compares a digital classroom to a traditional classroom.	■ Non-experimental designs or in-theme design with different educational content
■ Sample	■ Undergraduate or postgraduate students	■ public education
■ Research results	■ Sufficient data to calculate the effect size. N, M and SD should be indicated	■ Not enough statistics
■ Learning outcomes	■ clear learning outcomes	■ There are no clear learning outcomes

Before coding the final list, the research team coded a small sample of articles individually and then discussed the coding scheme and results. Differences in opinions about the best way to accurately encode the variables included in the meta-analysis were discussed. Journal articles were then divided equally among the researchers and coded independently. After reviewing a random sample of publications, the research team developed the coding scheme. The coding procedure was carried out in a process consistent with frequent contact among the researchers participating in the study. The research team was invited to discussion whenever there were questions about coding and a consensus was reached. Through this level of communication consistent, the coding process was guaranteed that it was performed consistently. After finishing the coding process, the quantum coding was reviewed where some errors were identified and corrected.

4.6. Effect Size Extraction and Calculations

Comprehensive meta-analysis (CMA) version 3.0 was used to estimate the effect sizes of the thirty-four publications identified through systematic procedures. Later on, four publications were to be excluded because their effect sizes were too high with the result that only thirty eligible publications were left for analysis. Effect sizes were extracted in three different domains, mainly the cognitive (e.g., achievement), affective (e.g., satisfaction), and behavioral (e.g., retention rates) domains. However, the present study only presents the results of the cognitive domain because the reviewed studies included shortly reported about students' behavioral and emotional outcomes. Whereas the articles included in this present study provides thirty-four effect size comparisons.

Cohen's d is the difference between outcome means with respect to the pooled standard deviations:

$$\text{Cohen}'d = \frac{\bar{X}_1 - \bar{X}_2}{S_p}$$

The pooled standard deviation is calculated based on the standard deviations in groups, s_1 , s_2 :

$$S_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 - 1) + (n_2 - 1)}}$$

Both of Hedge's g and Cohen's d measures work similarly with large sample sizes, but Hedge's g has the best properties for small samples. It is equivalent to Cohen's d multiplied by the correction factor J that adjusts for the bias of the small sample:

$$J = 1 - \frac{3}{4(N - 2) - 1},$$

where N is the total volume of the sample.

$$\text{Hedges}'g = J \times \text{Cohen}'d$$

All data were assumed to be under the model of random effects as ($\alpha = 0.05$) [80]. Models of random effects are more appropriate when the effect sizes of the included studies in the meta-analysis are different from each other. Random effects model was decided to be used in the present study because measures of students' cognitive outcomes differ from one study to another, and analyses of subsequent subgroups were carried out using mixed effects analysis (MEA) as applied in the comprehensive meta-analysis program where the effect size of 0.2 is considered small, 0.5 is considered medium, and 0.8 is considered large [81].

To calculate the probability that the present meta-analysis omitted the insignificant results, a fail-safe N test [82], which is the number of unpublished studies needed to change the estimate of the size of an insignificant effect, was used. In addition, Orwin's fail-safe N test was used to determine the number of missing null studies required to raise the current

effect size to a trivial level [83]. Moreover, publication bias was assessed using fail-safe N, Orwin's fail-safe N test, and through visual inspection of the suppression scheme.

5. Result

According to any meta-analysis, effect sizes must be standardized before starting any analysis process. For this sake, Hedge's g measure was chosen as a standard measure of the effect size for the continuous variables because it is better than Cohen's d in control the bias of the small sample size

The final set of meta-analysis consisted of thirty publications and thirty-four effect sizes that were identified through a process of searching, filtering, coding, and extracting. The total sample size was ($N = 8293$) students who either studied via digital platforms ($N = 3725$) or through traditional face-to-face classes ($N = 4568$). The included samples of studies were published in a wide range of journals and conference proceedings. In addition, included studies were published between 2015 and 2021.

5.1. Overall Effect of Digital Platforms on Students' Learning Outcomes

A total of thirty-four effect sizes were estimated from thirty published studies for the present study. Visual representations of data effect size to effectively present the final results were used [84]. A forest plot as shown in Figure 2 was also used. However, to demonstrate the summary of effect sizes collected in this study as shown in Figure 2, data were arranged in the following order: study author (first author family name), year of publication, Hedge's g , the standard error, variance, confidence interval, Z-value, and p -value. Small squares indicate the point estimates of the effect size in each study, while the horizontal line that intersects each square represents the confidence interval for the study estimate. The diamond at the bottom of the forest plot represents the mean effect size after pooling all studies together with a confidence interval. Figure 2 shows that.

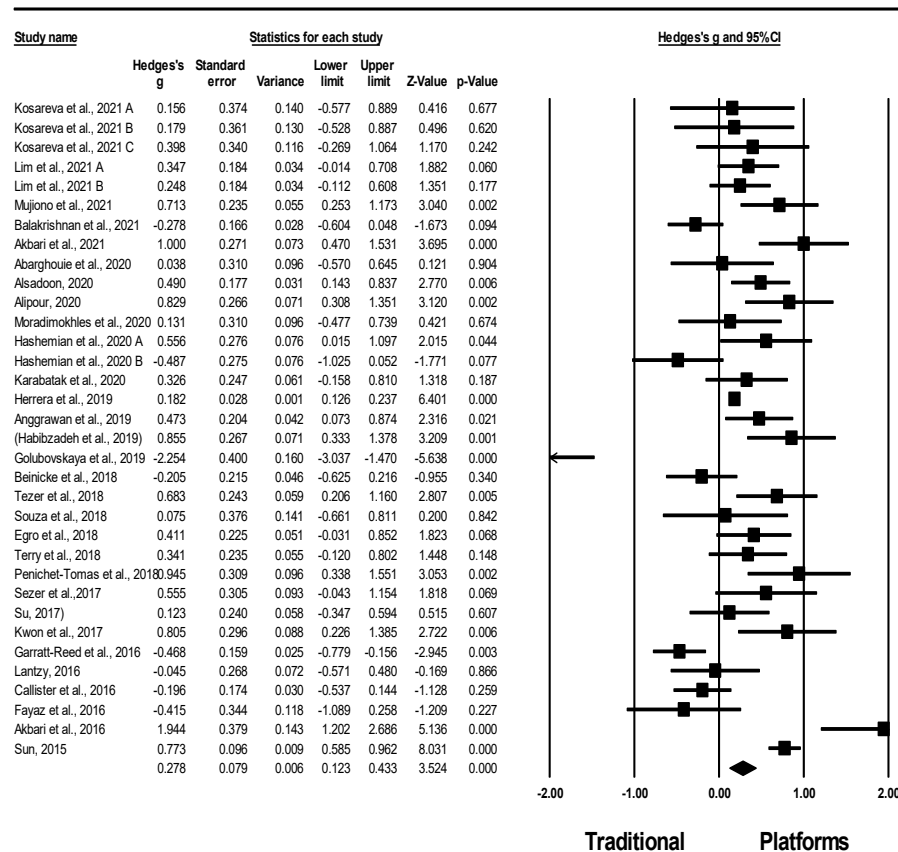


Figure 2. Forest plot of student learning outcomes [20,21,24,31,32,34,35,85–107].

Hedge's g was normally distributed as shown in Figure 3. The overall effect size using the random effects model was $g = 0.278$, which was a small effect size [81]. The overall effect size was statistically significant at Z -value = 3.524, $p < 0.001$ and a 95% confidence interval ranging from 0.123 to 0.433. Nevertheless, the size of the observed effect varied from one study to another, and a certain amount of variance was expected due to sampling error. The Q -statistic value provides a test for the null hypothesis stating that “all studies involved in the analysis share the same effect size [80].” The Q value was 188.16 with 33 degrees of freedom and $p < 0.001$. Thus, the null hypothesis that the true effect size is identical in all studies can be rejected. The value of $I^2 = 82.462\%$ indicates that the observed variance ratio reflects differences in true effect sizes rather than sampling error [80]. Higgins–Thompson [108] suggest that I^2 values around 25%, 50%, and 75% can be interpreted as low, medium, and high, respectively, in heterogeneity. Besides, I^2 of the general model shows a high level of heterogeneity and indicates that one or more mediating variables, other than sampling error, can explain this variance in these data. Thus, exploring potential mediating variables in these data to predict and explain variance is essential. So, exploring the potential intermediate variables in the form of contextual elements of studies is important.

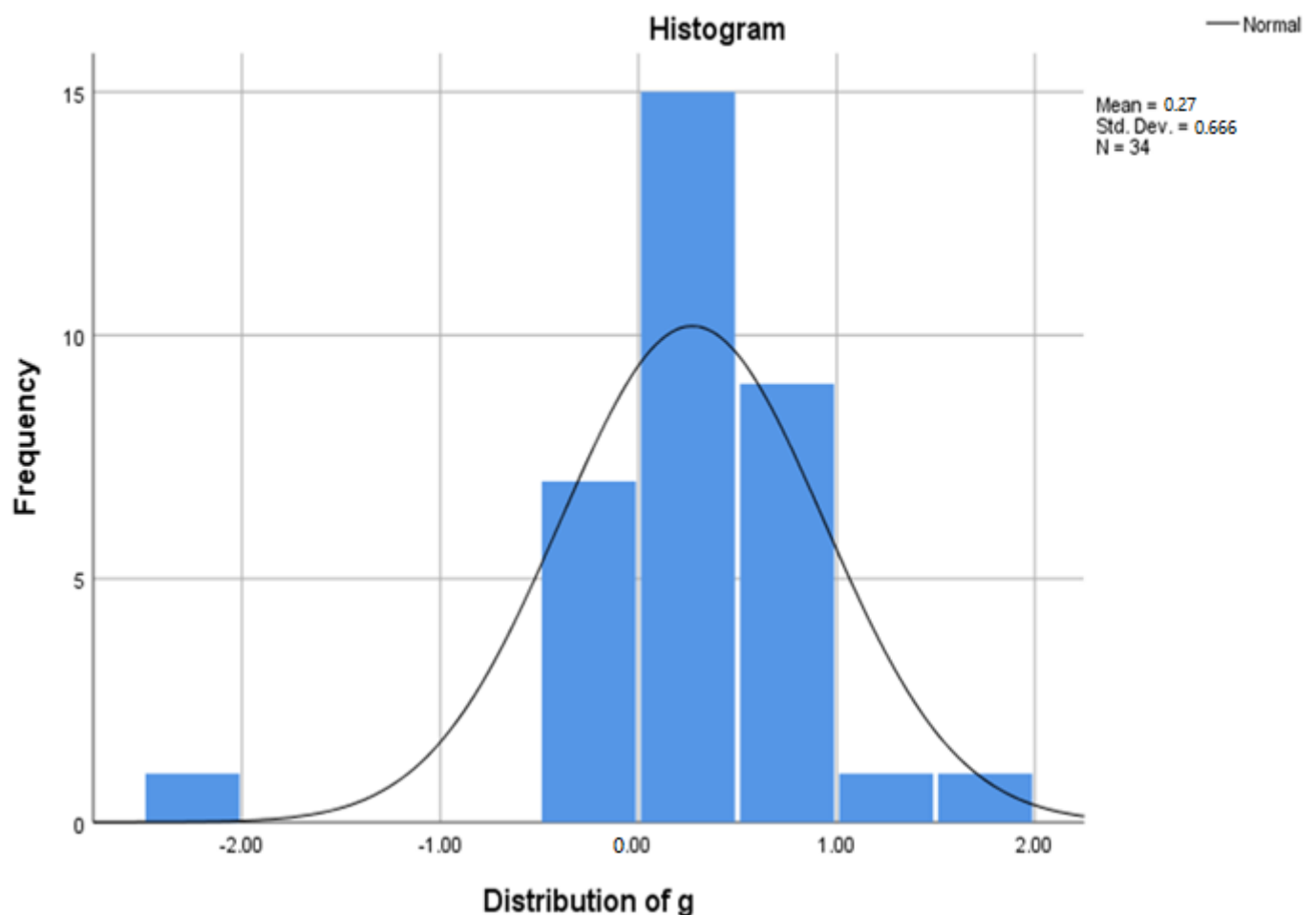


Figure 3. Histogram of effect sizes.

5.2. Study Duration

Table 2 shows the distribution of the effect sizes to study duration. It shows that the largest effect sizes ($k = 18$) were in the “less than a semester” group and the participating students were ($N = 1672$) with a small to medium effect size at $g = 0.424$, $p < 0$. Meanwhile, 14 effect sizes were in the “one or more semesters” group and the participating students were ($N = 6545$) with an effect size $g = 0.111$, $p = 0$. Duration was not mentioned in two studies

only and the participating students were ($N = 76$) with effect size $g = 0.083$, $p = 0$. Students who studied via the digital platforms outperformed peers who learned via traditional classrooms in three studies regarding study duration. The overall effect size of studies that were less than one term ($g = 0.424$, $p < 0.001$) was greater than those that were of one or more terms ($g = 0.111$, $p = 0.380$) and the study that did not determined its duration ($g = 0.083$, $p = 0.865$). In addition, no statistically significant difference due to the difference in study duration Q -value = 3.442, $p = 0.179$ was found.

Table 2. Study Duration Effect Sizes.

Groups	Effect Size and 95% Confidence Interval							Heterogeneity			
	N	K	g	SE	Lower Limit	Upper Limit	Z-Value	p-Value	Q-Value	Df	p-Value
NA	76	2	0.083	0.485	−0.868	1.033	0.170	0.865			
A semester or more	6545	14	0.111	0.127	−0.138	0.361	0.877	0.380			
Less than a semester	1672	18	0.424	0.117	0.195	0.653	3.634	0.000			
Total between									3.442	2	0.179

5.3. Subject Area

Table 3 shows the effect sizes by subject area for the use of digital platforms and traditional classrooms. Subject areas were arts and humanities, business, computer science, health care, science, and social sciences. Their effect sizes were 14, 1, 4, 11, 1, and 3, respectively. The biggest size effects ($K = 14$) were in the field of arts and humanities with a small to medium effect size $g = 0.313$, $p = 0$. The largest effect size was in the field of computer science, that included four studies and the number of participating students was ($N = 308$), at $g = 0.507$, $p < 0$. However, the other four domains were not statistically significant namely, arts and humanities, business, health care, and social sciences, which were not statistically significant with 95% confidence intervals overlapping with zero. These works had a negative effect size ($g = -0.196$, $p = 0.259$) in favor of the traditional classroom condition. Nevertheless, the confidence interval overlapped with zero indicating that this result was not statistically significant. Moreover, statistically significant differences due to the difference in the field of study Q -value = 13.279, $p = 0.02$ were noticed.

Table 3. Subject area effect sizes.

Groups	Effect Size and 95% Confidence Interval							Heterogeneity			
	N	K	g	SE	Lower Limit	Upper Limit	Z-Value	p-Value	Q-Value	Df	p-Value
Arts and humanities	1122	14	0.313	0.190	−0.060	0.685	1.646	0.100			
Business	134	1	−0.196	0.174	−0.537	0.144	−1.128	0.259			
computer sciences	308	4	0.507	0.115	0.282	0.732	4.415	0.000			
Healthcare	872	11	0.165	0.100	−0.031	0.361	1.653	0.098			
Science	4970	1	0.182	0.028	0.126	0.238	6.392	0.000			
Social sciences	887	3	0.402	0.516	−0.609	1.413	0.779	0.436			
Total between									13.279	5	0.021

5.4. Student Rating

Table 4 shows the effect sizes regarding rating of participating students in studies of the effect of digital platforms. Among these effect sizes, there were eight effect sizes for postgraduate students ($k = 8$, $N = 588$) and twenty-six effect sizes for undergraduate students ($k = 26$, $N = 7705$). Results showed superiority of undergraduates regarding the use of digital platforms with a small-to-medium effect size at $g = 0.321$, $p < 0.001$. However, the effect size of postgraduate students' use of digital platforms was s at $g = 0.093$, $p = 0$. Nevertheless, this difference was not statistically significant. In addition, the difference between students' classification was not statistically significant also with Q -value = 0.770, $p = 0.380$.

Table 4. Effect sizes of student rating.

Groups	Effect Size and 95% Confidence Interval						Heterogeneity				
	N	K	g	SE	Lower Limit	Upper Limit	Z-Value	p-Value	Q-Value	df	p-Value
Postgraduate students	588	8	0.093	0.245	−0.388	0.574	0.380	0.704			
Undergraduate students	7705	26	0.321	0.085	0.154	0.488	3.761	0.000			
Total between									0.770	1	0.380

5.5. Publication Type

Table 5 shows the effect sizes in accordance with the type of publication where it is obvious that the scientific articles have represented the vast majority of effect sizes k = Participating students in these articles were ($N = 3141$) with a small-to-medium effect size at $g = 0.317$, $p = 0$. That is, participating students in these articles were superior in the case of digital platforms than others. In contrast, the number of effect sizes of the conference papers was $k = 4$ with a negative effect size at $g = -0.088$, $p = 0.820$ indicating that the performance of students in the traditional classrooms was better than the performance of peers in the digital platforms. However, confidence interval overlapped with zero, which means that this difference according to publication type was not statistically as Q -value = 1.034, $p = 0.309$.

Table 5. Publication type effect sizes.

Groups	Effect Size and 95% Confidence Interval						Heterogeneity				
	N	K	g	SE	Lower Limit	Upper Limit	Z-Value	p-Value	Q-Value	df	p-Value
Article	3141	30	0.317	0.092	0.137	0.497	3.446	0.001			
Conference Paper	5152	4	−0.088	0.387	−0.848	0.671	−0.227	0.820			
Total between									1.034	1	0.309

5.6. Publication Bias

The visual inspection of the funnel plot of the meta-analysis shows generally symmetrical distributions around probable medium effect sizes with a small number of outliers (Figure 4). The funnel plot is a scattered plot of effect sizes estimated from studies in a meta-analysis versus standard error [109]. In the diagram, the horizontal axis is Hedges' g drawn next to the standard error on the vertical axis. A funnel plot, in general, indicates no publication bias in the meta-analysis [110]. But because of the insufficiency of the visual inspection alone the Classic fail-safe N test and Orwin's fail-safe N test were used. The Classic fail-safe N test showed that 513 additional studies about the effect of digital platforms use on students' learning outcomes were required to negate the overall impact in the present meta-analysis. These calculations show that the number of existing or additional studies needed to negate the overall effect sizes found in this meta-analysis are more than $5k + 10$ [111]. Besides, Orwin's fail-safe N test results reveal that the number of null missing studies required to raise the present average overall effect size in the present study to a level ($g = 0.01$) was The consensus between the results of the Classic fail-safe N test, Orwin's fail-safe N test, and the funnel schema prove that publication bias is not a serious threat to the validity of meta-analysis.

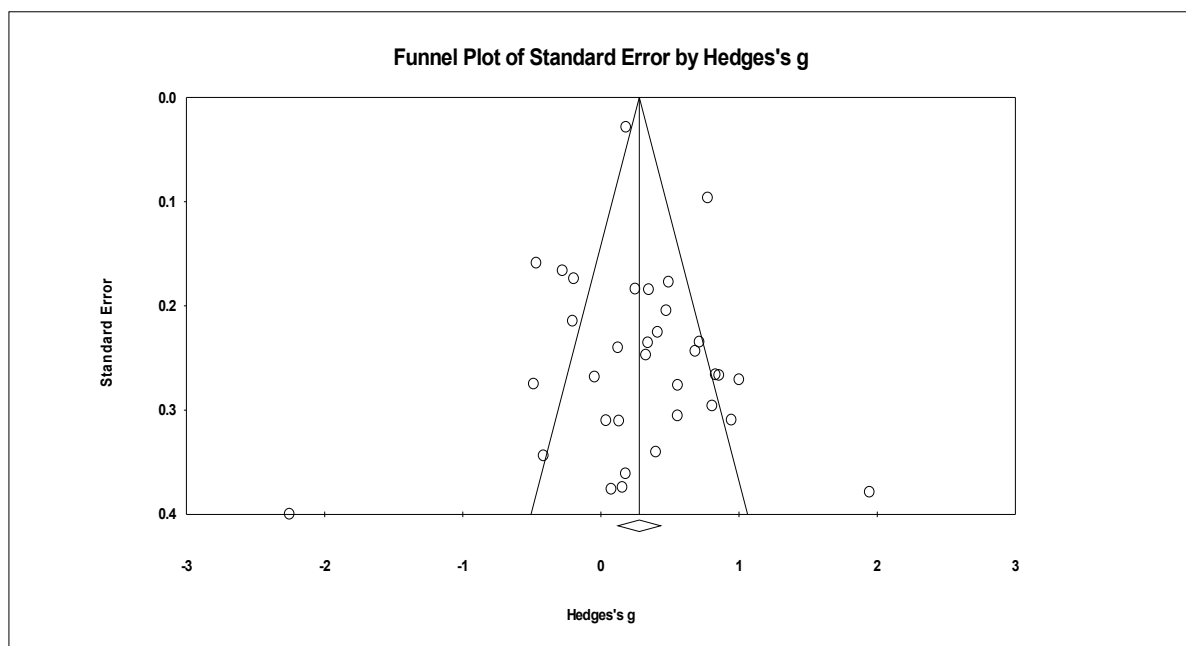


Figure 4. Funnel plot of effect size data.

6. Discussion

Learning via digital platforms has been a strategic and essential alternative in today's educational process since the closure of higher education institutions caused by Covid 19 pandemic, and not only in the emergency times. It is therefore essential to have evidence about the effectiveness of such platforms in improving and maintaining learning outcomes. Thus, the present study aims to shed light on the effectiveness of digital platforms in improving undergraduate and postgraduate students' learning outcomes through a comprehensive review of the previous studies that used digital platforms as an educational environment. It also hopes that its results may contribute to determine, whether or not digital platforms are effective, and shed light on some design elements of digital platforms that can positively affect the improvement of students' learning outcomes.

Basic conclusion of the conducted meta-analysis has indicated that digital platforms have a positive impact on students' learning outcomes. This analysis that consisted of 8293 students, and revealed an effect size of $g = 0.278$ according to the random effects model, which is considered as a small positive effect according to Cohen's criteria [81]. It also showed that there was no publication bias through the use of three bias assessment methods, mainly, visual inspection of the funnel plot, Classic fail-safe N test, and Orwin's fail-safe N test.

This conclusion corroborates the conclusion of previous studies that concluded a positive impact of digital platforms on the learning outcomes [20,21,25–27]. Nonetheless, it disagrees with a set of other studies that did not find any positive effect of the digital platforms on the learning outcomes [30–36].

Besides, this meta-analysis showed that the largest number of effect sizes was found in the groups whose study duration was less than one semester. In all cases, whether the study period was less than one semester or a whole semester or more, students who studied via digital platforms outperformed their peers who studied via traditional classrooms. It also revealed that studies with a shorter duration of intervention had a greater effect size than studies with a longer duration.

In accordance with studies' subject areas in general, the analysis showed statistically significant differences due to the difference in the subject field. Significant differences were found in the field of computer science and science, in particular. The largest effect size was in the field of computer science with a medium size. However, business field was

the only field that had a negative effect size, bearing in mind that this impact size was based on one study in this field as it seems that learning via digital platforms in the field of business was less than other fields. Other domains did not show negative effect sizes in favor of studying via traditional classrooms, taking into account that the size effects of the three domains (arts and humanities; health care; and social sciences) were not statistically significant and overlapped with zero in the 95% confidence interval. On the other part, the field of science resulted in a small and statistically significant effect size. Therefore, these concluded results of the present study call for asking questions, such as the following: Why has the impact of digital platforms been studied in some areas but not in others? Is it because of the nature of the material and learning? Does it need more effort and the use of certain strategies appropriate to these disciplines? Are there reasons related to faculty members and students of these disciplines? Once these questions are considered, they can be referred to as a pathway for future research.

It is worth mentioning that the study sample was limited to undergraduate and postgraduate levels. The largest number of impact sizes was in the classification of university students. Studying through digital platforms showed an outperformance over studying in traditional classes with a small-to-medium statistically significant effect size. On the other side, the effect size for postgraduate students was small and insignificant overlapping with zero in the 5% confidence interval within a relatively few studies.

With regard to the type of publication, inclusion was limited to articles and conference papers. Articles made up the vast majority that met the inclusion criteria related to the study. Study publication type was of small-to-medium effect size but statistically significant. On the other part, conference papers were of a negative effect size as they were in favor of the traditional classrooms instead of digital platforms. Nevertheless, this difference was not statistically significant and the confidence interval overlapped with zero. Generally speaking, there were no statistically significant differences due to the different types of publication.

During the process of research and inclusion in the present study, it was noticed that the majority of studies focused on students' learning outcomes by comparing learning via digital platforms with learning through the traditional classrooms, without any focus on the used design elements and educational strategies, whether via digital platforms or in the traditional classroom. In addition, the majority of studies focused on students' test scores without making clear what skill levels were tested. Therefore, it is hoped that future studies will focus more on the effect of learning via digital platforms on students' higher order thinking skills, mainly application, analysis, evaluation.

One more important aspect is that there was a group of design elements used in some studies that attracted the attention of the researchers during the research and inclusion process, in the digital platforms. These elements were not included in the present study because of their comparison between an experimental group that used the design element of the digital platform and a control group that used digital platforms traditionally besides the absence of a group to be taught in the traditional classrooms. These design elements were divided into technical design elements and educational design elements. Among the most important technical design elements are the following:

- Adaptive Learning, where [112–116] a digital platform that uses a proposed adaptive electronic environment and a digital platform that uses the traditional electronic environment were compared.
- Gamification, where [117,118] used it and its comparison and compared it with traditional e-learning across digital platforms, by including gamification elements in the digital platform such as the Blackboard platform or by developing a special digital platform and including gamification elements in it.

Among the most important educational design elements used in the previous studies via digital platforms:

- Problem-based learning, which a design element that some studies such as [119,120] used and compared with a traditional electronic environment via digital platforms.

- Feedback design element that was used by [121–124]
- Cooperative learning [125], project-based learning [126], self-organized learning [54,127].

In turn, it hoped that future studies will focus more on the different design elements of digital platforms and expand them for potential studies. Finally, it was noticed that Moodle, Blackboard, I spring digital platforms; Skype, Zoom, and Google Plus were embedded in some studies.

There were some limitations that should be accounted while interpreting the results of the present study. This analysis focused on studies that were applied to a sample of undergraduate and postgraduate education students without reference to general education. It also focused on the cognitive learning outcomes rather than the behavioral and emotional one due to the shortage in studies using it. Therefore, this matter must be considered by educational practitioners when making decisions about whether or not to implement learning via digital platforms. In addition, studies related to the context of the COVID-19 pandemic were not included because that period was a special case and exceptional. Learning during this pandemic was entirely remote. In addition, some studies were also excluded because they did not provide sufficient data to calculate effect sizes.

7. Ethical Considerations

The research team declares that they have no material interests or personal relationships that could influence the work presented in the present study. The data can also be accessed by contacting the authors.

8. Conclusions

In this meta-analysis study, studies that focused on digital platforms to evaluate the general effect of the digital platforms on the learners' cognitive learning outcomes in comparison with the effect of the traditional classrooms were used. A small positive impact of studying via digital platforms was found. Some intermediate variables such as study duration, subject area, students' classification, and publication type were also analyzed. Results showed that there were some design elements for digital platforms that affect their performance. Among these elements were technical design elements such as adaptive learning and gamification and educational design elements such as problem-based learning, feedback, collaborative learning, project-based learning, and self-organized learning. Findings of the present study can be used to show how digital platforms are used to enhance cognitive learning outcomes. In the era after Covid-19, educational institutions can rely on the results of this study in redeveloping the digital platform's system, as the general use of digital platforms tend to be useless without considering the adaptive characteristics that these platforms can provide to learners, and the elements of gamification that can be relied upon to enhance students' motivation and to improve the sustainability of digital. It is also important to link the platform tools and the learning strategies. They also can propose future research related to studying the effects of the design elements of the digital platforms on learning outcomes and the structure of variables that make a digital platform better affect learning outcomes. It is also important in future studies to develop instructional design models for adaptive platforms as well as studying motivational platforms and their impact on learning outcomes. Also, a meta-analysis of studies that focused on digital platforms in the era of Covid-19 may lead to new approaches towards the use of digital platforms in education.

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Appendix A

The appendix includes the analyzed studies, including their classification within the Scopus and ISI databases, with full reference citations for each study.

Table A1. List of studies analyzed in Web of Science and Scopus.

No.	Author	Year of Publication	Source		Publication Type
			Web of Science	Scopus	
1	(Kosareva, Demidov, Ikonnikova, & Shalamova, 2021) [85]	2021	✓	✓	Article
2	(Lim & Yi, 2021) [24]	2021	✓	✓	Article
3	(Mujiono & Herawati, 2021) [86]	2021	✓	✓	Article
4	(Balakrishnan et al., 2021) [31]	2021	✓	✓	Article
5	(Akbari, Heidari Tabrizi, & Chalak, 2021) [21]	2021	✓	✓	Article
6	(Abarghouie, Omid, & Ghadami, 2020) [87]	2020	✓	✓	Article
7	(Alsadoon, 2020) [88]	2020	✓	✓	Article
8	(Alipour, 2020) [89]	2020	✓	✓	Article
9	(Moradimokhles & Hwang, 2020) [90]	2020	✓	✓	Article
10	(Hashemian & Farhang-Ju, 2020) [91]	2020	✓	✓	Article
11	(Karabatak & Polat, 2020) [92]	2020	✓	✓	Article
12	(Herrera & Valenzuela, 2019) [93]	2019		✓	Conference Paper
13	(Anggrawan, Yassi, Satria, Arafah, & Makka, 2019) [94]	2019	✓	✓	Conference Paper
14	(Habibzadeh et al., 2019) [95]	2019	✓	✓	Article
15	(Golubovskaya, Tikhonova, & Mekeko, 2019) [96]	2019		✓	Conference Paper
16	(Beinicke & Bipp, 2018) [97]	2018	✓	✓	Article
17	(Tezer & Çimşir, 2018) [98]	2018	✓	✓	Article
18	(Souza, Mattos, Stein, Rosário, & Magalhães, 2018) [99]	2018	✓	✓	Article
19	(Egro, Tayler-Grint, Vangala, & Nwaiwu, 2018) [100]	2018	✓	✓	Article
20	(Terry, Terry, Moloney, & Bowtell, 2018) [101]	2018	✓	✓	Article
21	(Penichet-Tomas, Jimenez-Olmedo, Pueo, & Carbonell-Martinez, 2018) [102]	2018	✓		Conference Paper
22	(Sezer, Karaoglan Yilmaz, & Yilmaz, 2017) [103]	2017	✓		Article
23	(Su, 2017) [104]	2017	✓	✓	Article
24	(Kwon & Block, 2017) [105]	2017	✓	✓	Article
25	(Garratt-Reed, Roberts, & Heritage, 2016) [35]	2016	✓	✓	Article
26	(Lantzy, 2016) [106]	2016	✓	✓	Article
27	(Callister & Love, 2016) [32]	2016		✓	Article
28	(Fayaz & Ameri-Golestan, 2016) [34]	2016	✓		Article
29	(Akbari, Naderi, Simons, & Pilot, 2016) [20]	2016	✓	✓	Article
30	(Sun, 2015) [107]	2015	✓		Article

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