

Impact of Blended Learning Approach on Students' Metacognition and Academic Achievement in Science: A Meta-analysis During the COVID-19 Pandemic

Garren Jude V. Aquino¹, Michael Kennedy G. Camarao² and Fe Aiza D. Domaol³

Abstract

Blended learning has become the new standard in education that combines both face-to-face and online-based instructions. As this learning approach emerged as a prominent trend in both K to 12 and higher education during the COVID-19 pandemic, its relative usefulness to different learning outcomes must be revisited. The current meta-analysis focuses on studies that answer a gap on the post-test effects of blended learning approach on students' metacognition and academic achievement in science in comparison to the conventional teaching approach. It includes eligible studies with a total of 25 experiments and 25 effect sizes. The literature is reviewed through different electronic databases to access relevant studies within a ten-year period. The study focused mainly on secondary and tertiary students with 1359 respondents under metacognition and 1082 under academic achievement. The results show that blended learning approach has a small effect size on students' metacognition (Hedges' $g = 0.25$) and a large effect size on academic achievement (Hedges' $g = 0.94$). Rosenthal's fail-safe N also shows large number of unpublished studies with zero mean effect that would be required to make the obtained overall effect statistically nonsignificant. Thus, blended learning approach may help facilitate educational continuity amidst potentially disruptive crises.

Keywords: Blended Learning Approach, Metacognition, Academic Achievement, COVID-19, Pandemic, Science Education, Meta-analysis

Introduction

The global education sector faced unprecedented challenges as a result of the COVID-19 pandemic (Crawford et al. 2020). In an effort to stop the spread of the virus and lower infection rates, the majority of nations temporarily shuttered their educational facilities (Tria, 2020). The pandemic has brought a big impact on about 98.5% of the world's student population (UNESCO, 2020). In the United States, the shift to online learning has staggeringly accelerated in preschools, K to 12 schools, and universities (Fausett, Nierenberg, & Pasick, 2020). Consequently, the major progress in the widescale roll-out of COVID-19 vaccines (WHO, 2023) have slowly facilitated the reopening of schools on a small scale (UNICEF, 2021). With this limited in-person schooling, blended learning is one of the teaching approaches that was employed to deliver

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instructional activities and enhance different learning outcomes while ensuring the safety of students and teachers (Garment, 2021).

Blended learning approach (BLA) has also become increasingly prevalent in Philippine education, particularly amidst the COVID-19 pandemic. The Department of Education (DepEd) has prioritized the transition to BLA, which combines traditional face-to-face teaching methods with online-based instructions. DepEd has been instrumental in implementing policies and providing support to facilitate the shift to blended learning. This includes the distribution of learning materials, the utilization of various online platforms for virtual classes, and the training of teachers to adapt to new teaching methodologies (Ignacio, 2021).

Despite the challenges posed by the digital divide and infrastructure limitations, many countries have made strides in embracing blended learning as the “new normal” in education. It not only provides flexibility but also enhances the in-person and online learning experiences of students. The transformative potential of BLA reported an increase in metacognitive knowledge, skills, and experiences (Camarao & Monterola, 2021) and academic achievement of students (Alsalihi, Eltahir, & Al-Qatawneh, 2019). These results have been accounted for the best elements of BLA that benefits both teachers and students such as the equal opportunities to thrive in a blended learning environment (equity); unforeseen disruptions that can be easily facilitated through centralized learning management system which can be reviewed by the students any time (flexibility); active engagement that encourages collaborative work and more accurate teacher’s monitoring of students’ completion of assigned work (engagement); centralized place to access instructional and leaning materials that can be reviewed by the students at their own pace (access); and greater opportunities for cost-efficiency since fewer classroom and school resources are needed (cost) (Garment, 2021).

Now that blended learning has emerged as a major trend in both K-12 and higher education, research studies on its different learning models before and during the pandemic should be investigated. This meta-analysis study was designed to produce a statistical synthesis of different empirical studies, within a ten-year period, related to the effects of blended learning on students’ metacognition and academic achievement in science. The statistical significance of the combined effect might now be examined as pieces of evidence that this specific intervention significantly improves learning outcomes. The meta-analytic results can also be the basis of a policy decision to invest in this type of educational intervention.

Literature Review

Blended learning is an approach that integrates e-learning into traditional classroom learning (Kavitha & Jaisingh, 2018). Similarly, it is a form of learning that combines the best of direct classroom learning in face-to-face setup and online-based learning through digital applications (Volchenkova, 2016). It uses more than one method to communicate information and activate learning outcomes through the interaction of students and teacher (Dziuban et al., 2018).

Several researchers have mentioned the advantages of BLA. It provides flexibility and convenience in the learning environment; increases academic achievement, knowledge permanence, learners’ interest, motivation, and interaction; and is cost efficient (Lilje & Peat, 2007). It also offers benefits to enhance teaching pedagogies and help learners work at their own pace. With blended learning practices, students can take part in the learning environment from their homes and can share recorded knowledge content without any time or place limitations (Osguthorpe & Graham, 2003). Moreover, it is more effective in its

use of classroom time in which students are more active, more creative, and better prepared (Susan & Chris, 2015).

Evidence on blended learning has been reported through different research studies. Werth and Kellerer (2013) conducted a study involving teachers and found that 53% of them believed that blended learning was effective in increasing students' academic achievement. A search was also conducted using the ERIC database to locate information on students' perceptions about blended learning and resulted to roughly 109 peer-reviewed articles. Only few studies referred to K to 12 student perceptions, majority of the studies referred to higher education. Chandra and Watters (2012) found that high school students were happy and satisfied on their blended learning experience in science and physics classes. Another study concluded that science learning with an Edmodo-based blended learning model can create a pleasant learning environment and motivate junior high school students to actively think scientifically (Wahyuni et al., 2019).

Moreover, blended learning is effective in higher education. The findings of the experimental study revealed that test scores of students enrolled in e-learning environments were significantly higher than the scores of students in the traditional classroom (Zhang, Zhao, & Zhou, 2004). This means that education can be more effective if the advantages of a web environment are blended with face-to-face interaction in courses that contain more visual elements. The study of Lee, Lau, and Yip (2016) on the design and evaluation of an inter-university collaborative project on science-related interdisciplinary subjects reported positive outcomes for certain attributes such as conceptual understanding, eagerness and confidence in learning science, and metacognitive reflection on students' learning.

Meta-analysis studies were also conducted to provide substantial evidence of the significant effect of blended learning approach. In the meta-analytic study of the U.S. Department of Education, 45 studies were synthesized that compared face-to-face with online learning. Although online learning had a modestly higher effect than traditional instruction, nine of the eleven individual studies with significant effects favoring the online condition used a blended learning approach (U.S. Department of Education, 2010).

Most of the educational research conducted are empirical studies and only few are meta-analysis studies. Meta-analysis is still a less explored research territory in Asia (Okwuduba & Okigbo, 2018). There is a need to undertake this study and look into the significant effect of blended learning approach on students' metacognition and academic achievement in science. It is important to examine the type of methods or strategies used and how it effectively fits into the students' needs and characteristics. This in turn will be the basis of the government to appropriate funds to different educational interventions that were empirically tested.

Methodology

Literature Search

This study utilized a meta-analysis research design to systematically investigate and produce statistical syntheses of previous studies related to the effects of blended learning approach on students' metacognition and academic achievement in science. The literature search was systematically done on five electronic databases such as CORE, IOP Science, ERIC, Google Scholar, and Open Access Theses and Dissertations for the period of 2011 to 2021 to include one decade of recent research studies. The final searches were conducted

using the following queries: “metacognition” AND “blended learning”, and “academic achievement” AND “blended learning”.

On the search stage, the electronic databases’ searches resulted in 612,069 hits for journal articles and 19,491 hits for theses and dissertations for both metacognition and academic achievement. However, 561,746 hits were removed upon the incorporation of the set scope of time. The 69,814 unique studies were eventually obtained and used in the screening of the titles, abstracts, and keywords during the first inclusion stage.

Eligibility Criteria

The eligible articles and dissertations for meta-analysis followed a paper selection process that (a) had to focus on blended learning approach. Only peer-reviewed studies that (b) had to deal with the dependent variables such as ‘metacognition’ and ‘academic achievement’ were included. Other papers such as book reviews, book chapters, conference papers, abstracts, editorials, and news were excluded. The scope of the study (c) had to focus on science areas that include General

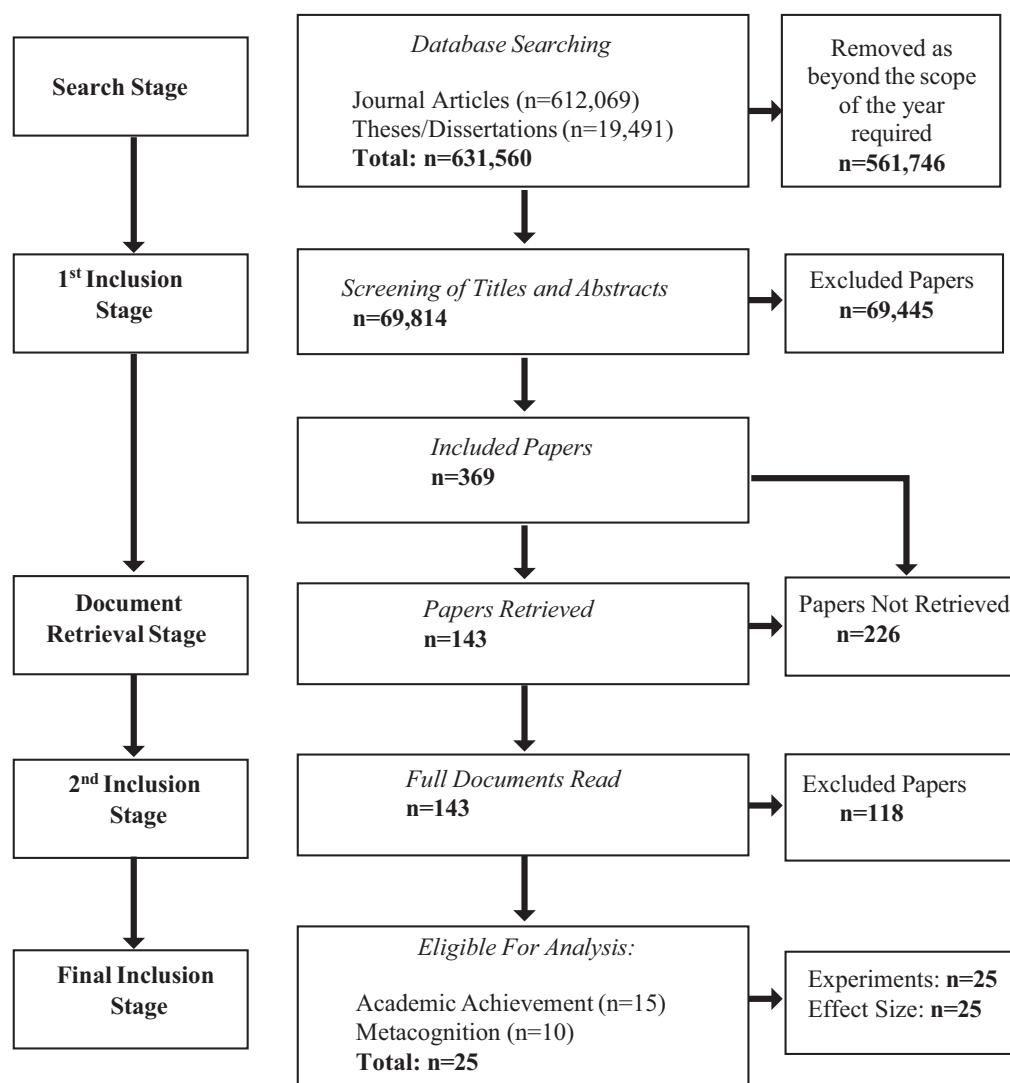


Figure 1. Flowchart for selection of studies

Science, Earth and Space Science, Biology, Chemistry, and Physics to investigate the cumulative effect of blended learning on the said learning outcomes for the past ten years (2011-2021). Moreover, the research (d) had to compare an experimental group that was exposed under the blended learning approach against a control group under the conventional teaching approach. The subjects of the study (e) had to consist primary, secondary, and/or tertiary school students with at least ten students per group to ensure that the effect size Cohen's d would be normally distributed (Hedges & Olkin, 1985; de Boer et al., 2018). Finally, the studies (f) had to provide posttest and/or delayed test measures that include mean and standard deviation/standard error, t -test value, or F -test value.

The first three criteria were used in the first inclusion stage. This selection stage resulted in the provisional inclusion of 369 studies. However, 226 studies were not retrieved during the document retrieval stage. The remaining 143 studies were accessed in full copies during the second inclusion stage and were subjected to full-text reading for the final inclusion stage following the last three criteria. Ten (10) studies met the eligibility criteria under metacognition and 15 under academic achievement. Generally, the eligible studies had employed a total of 25 experiments on blended learning approach and had 25 effect sizes for meta-analysis.

Data Analysis

Meta-Essentials Tools (MET) version 1.4, developed by Suurmond, van Rhee, and Hak (2017), were utilized to perform the meta-analysis. This statistical package was used to calculate the combined and individual effect sizes (Cohen's d /Hedges' g) with the corresponding standards of small (0.2), medium (0.5), and large (0.8); and variances of the interventions based on the statistical data obtained from the 25 eligible studies. Standard mean differences were computed for the students' metacognition and academic achievement in the posttests using a combination of means and standard deviations or means and standard errors. When descriptive statistics data were not reported, effect sizes were generated from inferential statistics such as the F -test and t -test values. Moreover, the significance of the summary effect was determined by z -test values and p -values at .05 level of significance. MET was also used to produce pictorial and graphical representations of the meta-analytic results, estimate the extent of heterogeneity, analyze publication bias, and perform the Rosenthal's (1979) fail-safe N .

Results and Discussion

This section presented the results of the study. The 25 studies included in the meta-analysis synthesized a total of 25 experiments and 25 effect sizes. The results of the empirical studies were discussed to answer these two research questions: (1) What are the post-test effects of Blended Learning Approach on students' metacognition? and (2) What are the post-test effects of Blended Learning Approach on students' academic achievement?

Posttest Effects of Blended Learning Approach on Students' Metacognition

The posttest measures of metacognition were acquired from a total of 10 studies and 10 effect sizes. It was shown in Table 1 that the combined effect size (adjusted) was 0.25 indicating a small effect according to Cohen (1988). However, blended learning approach had a significant overall effect on students' metacognition in

science compared to students under the conventional teaching approach as supported by z -test and p values. In addition, Rosenthal's *fail-safe N* showed that additional 628 studies, with zero mean effect, would be needed to make the combined effect size statistically nonsignificant.

Table 1	Posttest mean effect size for metacognition (n=1359)					
	k	d	SE	95% CI	z-value	p-value
Overall	10	0.25	0.27	[0.38, 1.60]	3.66	0.000

* $p < 0.05$, Fail-safe $N = 628$

Moreover, the overall results in Table 1 can be further explained in the forest plot showing the effect sizes' distribution of 10 studies in Fig. 2. It revealed that the confidence intervals of studies 4 and 5 touched the line of no effect. Thus, these studies had lower values of Hedges' g (0.10 and 0.11) indicating a shorter line of 95% confidence intervals. The control groups and the experimental groups in these studies did not observe a statistical difference. Thus, blended learning approach did not affect the metacognitive knowledge, skills, and experiences of students in science. However, eight studies (1, 2, 3, 6, 7, 8, 9, and 10) showed a statistically significant difference between the groups with a p -value less than the .05 threshold of significance. Study 8 has the largest Hedges' g equal to 2.89. The results of these studies imply that blended learning approach significantly improves the students' metacognition in science better than the conventional teaching approach.

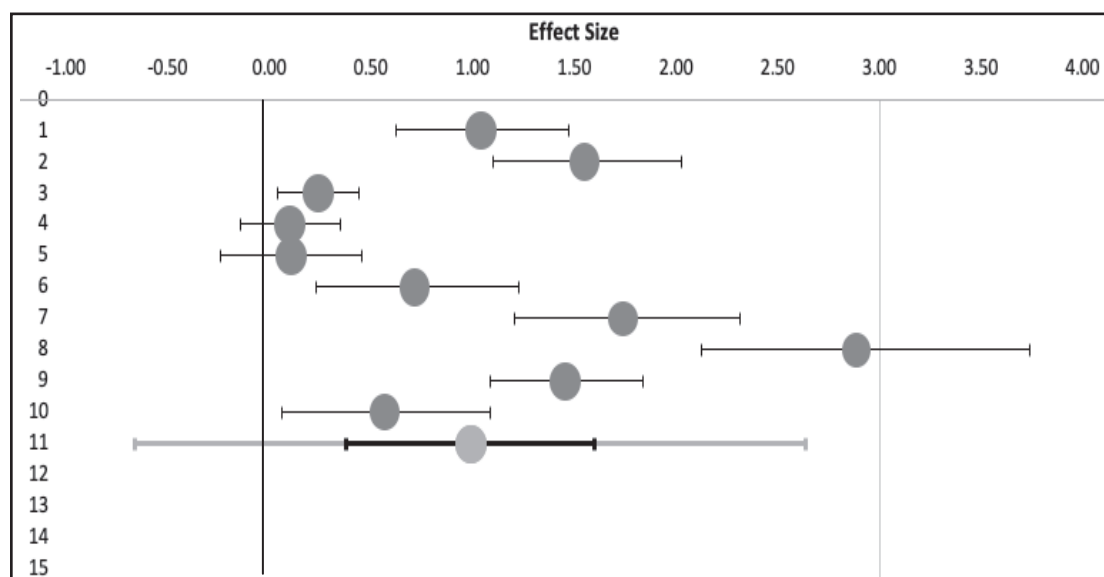


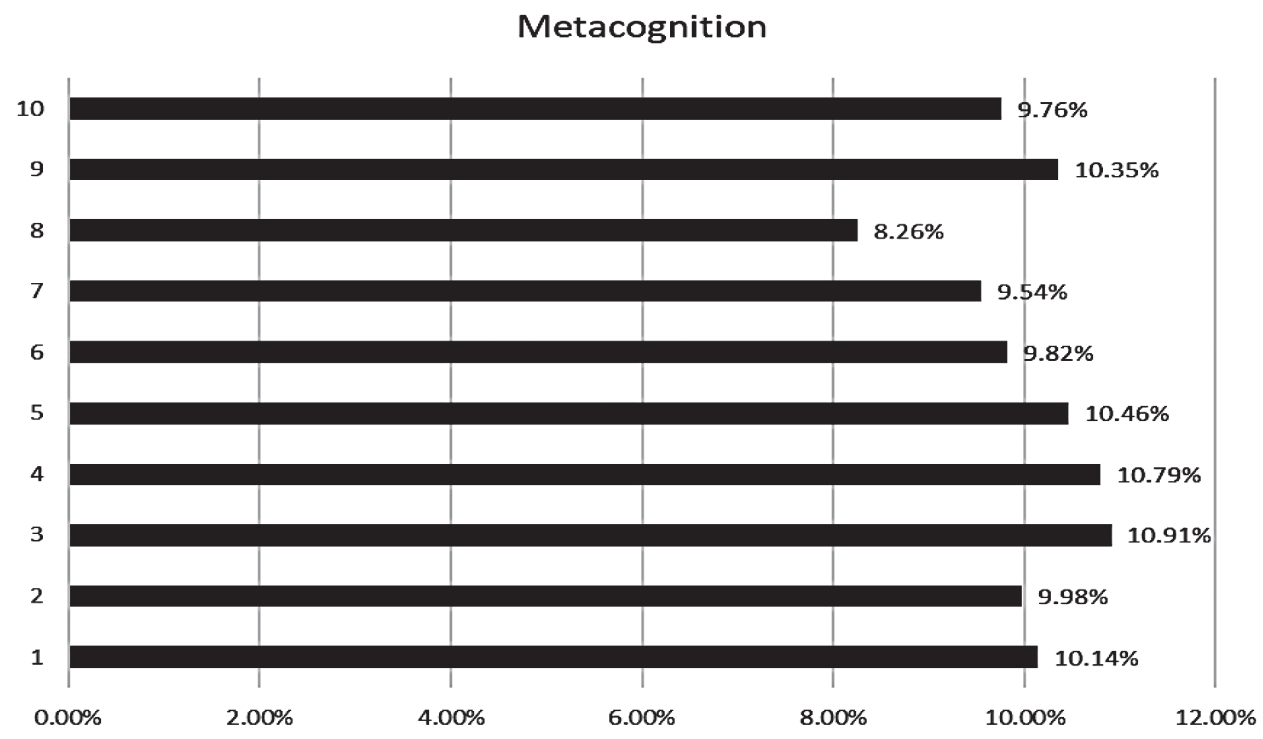
Figure 2. Forest plot of the effect sizes' distribution of 10 studies on metacognition

The ten (10) eligible studies under metacognition that include data on their effect sizes (Hedges' g), confidence intervals (lower limit and upper limit), and weights are specified in Table 2. Based on the data presented, the higher the value of the Hedges' g (2.89) like in study 8 and the wider the values of the 95% confidence interval (2.13, 3.74), the lower the weight of the study (8.26%). This indicates that the study has less precision (Bradburn, 2020). On the other hand, the lower the value of the Hedges' g (0.24) like in study 3 and the narrower the values of the confidence interval (0.04, 0.44), the higher the weight of the study (10.91%). This implies that the study has a high precision (Bradburn, 2020).

Table 2 Summary statistics of each study under metacognition

Study	Author (s)	Hedges' g	CI Lower Limit	CI Upper Limit	Weight (%)
1	Aldalalah et al. (2019)	1.04	0.62	1.47	10.14
2	Husamah (2015)	1.55	1.10	2.03	9.98
3	Gronlien et al. (2021)	0.24	0.04	0.44	10.91
4	Langdon et al. (2019)	0.10	-0.14	0.35	10.79
5	Musyaddad & Suyanto (2019)	0.11	-0.24	0.45	10.46
6	Vallejo, et al. (2019)	0.72	0.23	1.22	9.82
7	Lestari, U., Susanti, S., & Suwono (2017)	1.74	1.20	2.32	9.54
8	Lotfali & Ghanbarpour (2017)	2.89	2.13	3.74	8.26
9	Hajeh & Qarareh (2013)	1.46	1.09	1.84	10.35
10	Hidayatulloh, et al. (2020)	0.57	0.06	1.09	9.76

Furthermore, the weights of the 10 studies under metacognition are shown in Fig. 3. The weight given to each study is chosen to be the inverse of the variance of the effect estimate (Shaneyfelt, 2013).

**Figure 3.** Weights of each study under metacognition

Thus, larger studies, which have narrower 95% confidence intervals, are given higher weights (see studies 3, 4, and 5) than the smaller studies that have wider confidence intervals (see studies 6, 8, and 10). This means that they had the highest influence and made a big difference in the pooled results on metacognition. This choice of weights minimizes the uncertainty of the pooled effect estimate.

Evaluation of Heterogeneity Between Studies

It is also important to examine how heterogeneous the studies are with respect to each other to establish the assumption of heterogeneity. This meta-analytic study had adopted the value ranges of Higgins and Thomas (2003) where 25% - 50% was interpreted as low heterogeneity, 50% - 75% as medium heterogeneity, and 75% - 100% as high heterogeneity. Based on table 3, the total variance of the data set is $Q = 127.34$. It was also shown that the p-value of the chi-squared test is 0.000. Hence, the p-value is less than the .05 level of significance, which implies that the distribution of the populations was not the same and that the assumption of heterogeneity between studies was not violated.

Table 3 Heterogeneity test under metacognition					
	Q	p_Q	I^2	T^2	T
Overall	127.34	0.000	92.93%	0.46	0.68

* $p < 0.05$

Moreover, the I^2 value is 92.93% which means that the distribution of the effect sizes among the studies was highly heterogeneous. This high level of variability further indicated good differences in studies population, methodologies, interventions, or outcomes that can impact the overall results of the meta-analysis.

Analysis of the Publication Bias of the Studies

This analysis was also performed to identify potential bias that might occur after the study is completed. The probability that a statistically significant result will be reported and published is thought to be higher than a statistically nonsignificant finding. As a result, the total effect size of the study may be higher than the reality. Publication bias aims to signal this kind of error and adjust the combined effect size estimates (Hak, van Rhee, & Suurmond, 2016).

The funnel plot below indicates asymmetry in the distribution of effect sizes. This implied that there were missing studies. To impute one or more studies, the study applied a trim-and-fill method to adjust the combined effect size for the potentially missing studies (Hak, van Rhee, & Suurmond, 2016). In Fig. 4, it was shown that there were six (6) imputed data points. Thus, the trim-and-fill method adjusted the combined effect size from .60 to 0.25. In effect, the distribution of the studies was balanced, and the funnel plot turned symmetric. It suggests that the publication of the study sample was not biased in favor of blended learning approach on students' metacognition.

The aforementioned results on blended learning approach and metacognition are supported by the findings from the meta-analysis study of U.S. Department of Education (2010). It included 45 studies that compare face-to-face instruction with online and blended learning. It was reported that 34 studies on online learning

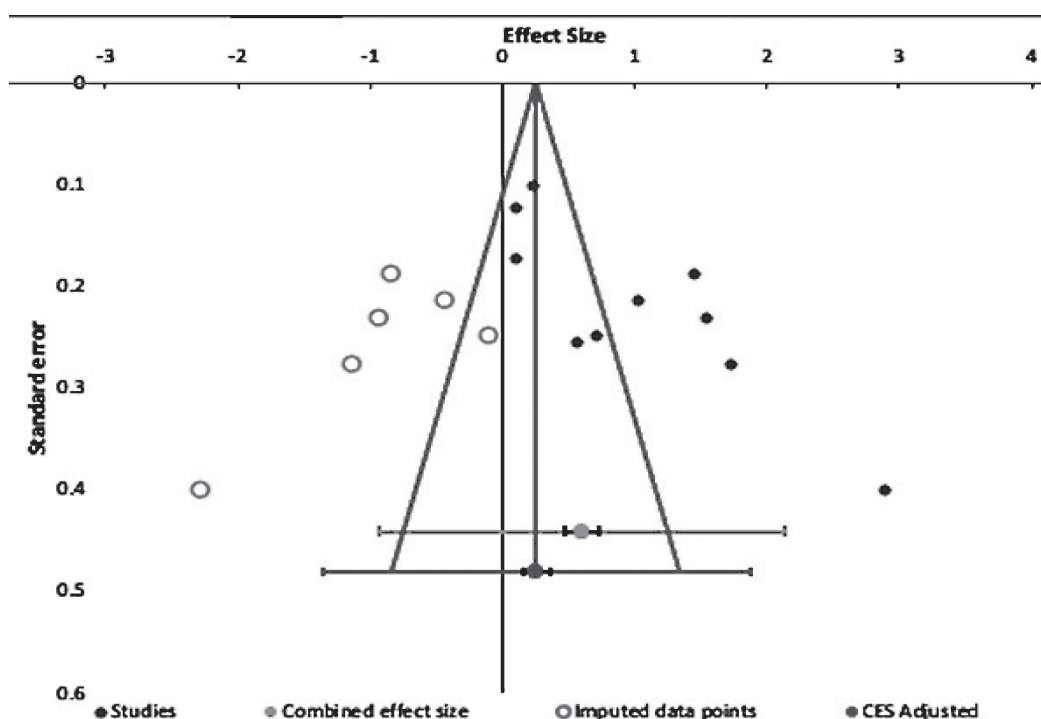


Figure 4. Funnel plot of studies' effect sizes under metacognition

and nine (9) out of the 11 studies on blended learning approach had a significantly higher effect than the traditional instruction. Moreover, a meta-analysis study on metacognition also found that the blended learning approach had a significant effect on students' metacognitive knowledge, skills, and experiences (Zhu et al., 2013) and metacognitive reflection on students' learning (Lee, Lau & Yip, 2016).

Posttest Effects of Blended Learning Approach on Students' Academic Achievement

The academic achievement posttest measures were obtained from 15 eligible studies and 15 effect sizes. The combined effect size (adjusted) was 0.94, manifesting a large effect size according to Cohen (1988). Therefore, blended learning approach had a significant overall effect on students' academic achievement in science higher than the students who were exposed under the conventional teaching approach as supported by z -test and p -values. Rosenthal's *fail-safe N* also showed that additional 2115 null-effect studies would be needed to bring the p -value beyond the 0.05 threshold of significance.

Table 4. Posttest mean effect size for academic achievement (n=1082)						
	k	d	SE	95% CI	z-value	p-value
Overall	15	0.94	0.38	[0.76, 2.38]	4.15	0.000

* $p < 0.05$, *Fail-safe N* = 2115

The overall results are further discussed in Fig. 5 showing the forest plot of the effect sizes' distribution of 15 studies. It was evident that the confidence intervals of studies 5, 8, and 10 hit the line of no effect, which means that they had lower values of Hedges' g (0.23, 0.06, and 0.35). In these three studies, students who

were exposed to blended learning approach and conventional teaching approach have the same academic achievement in science.

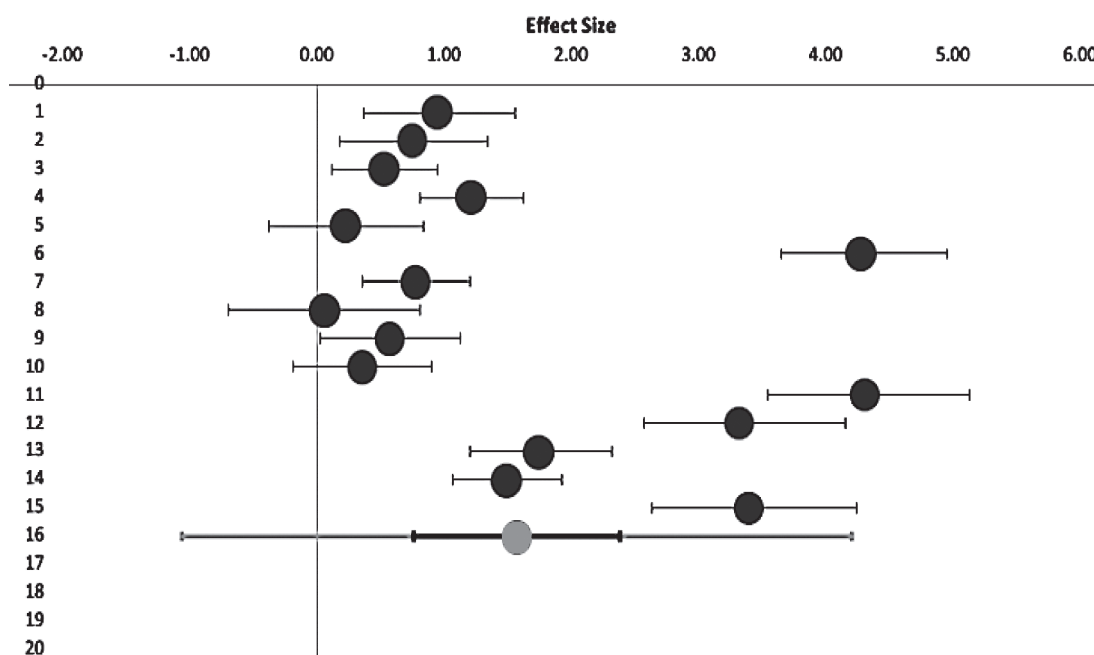


Figure 5. Forest plot of the effect sizes' distribution of 15 studies on academic achievement

Nevertheless, twelve studies such as 1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, and 15 had confidence intervals that did not touch the line of no effect and had greater effect sizes. Thus, students who were exposed under the blended learning approach performed better in terms of academic achievement in science than students under the conventional teaching approach. This result was supported through a p-value that is less than the 0.05 threshold of significance.

Moreover, Table 5 presents the summary statistics of 15 studies under academic achievement. It is important to highlight that study 11 has the highest value of Hedges' g (4.30) with wider 95% confidence intervals (3.55, 5.13) and lower value of weight (6.38%), which indicates that the study has less precision (Bradburn, 2020). On the other hand, Study 3 has a Hedges' g of 0.53, which considered to have a medium effect size with narrower confidence intervals (0.11, 0.95). This in turn produced a higher value of weight (6.89%), which indicates that the study has a high precision (Bradburn, 2020).

Table 5 Summary statistics of each study under academic achievement					
Study	Author (s)	Hedges' g	CI Lower Limit	CI Upper Limit	Weight (%)
1	Akgunduz & Akinoglu (2016)	0.94	0.36	1.56	6.68
2	Akgunduz & Akinoglu (2017)	0.75	0.17	1.35	6.70
3	Almasaeid (2016)	0.53	0.11	0.95	6.89

4	Alsahi, Eltahir & Al-Qatawneh (2019)	1.21	0.81	1.63	6.90
5	Bolley (2013)	0.23	-0.38	0.84	6.67
6	Accra & Chima (2020)	4.27	3.65	4.95	6.59
7	Harahap, Nasution & Marunung (2019)	0.77	0.36	1.20	6.88
8	Hinkhouse (2013)	0.06	-0.70	0.82	6.47
9	Kazu & Demirkol (2014)	0.57	0.03	1.13	6.74
10	Lin, Tseng & Chiang (2016)	0.35	0.18	0.90	6.75
11	Nair & Bindu (2016)	4.30	3.55	5.13	6.38
12	Sanwal (2019)	3.32	2.57	4.15	6.38
13	Lestari, U., Susanti, S., & Suwono (2017)	1.74	1.20	2.32	6.73
14	Yapici & Akbayin (2012)	1.49	1.06	1.93	6.87
15	Daphine, Selvakumar & Sivakumar (2020)	3.40	2.64	4.25	6.36

The results can be further elaborated through the weights of the 15 studies under academic achievement as depicted in Fig. 6. Studies are weighted differently in a meta-analysis and commonly the weight used is the inverse of the variance of the study (Shaneyfelt, 2013). The higher the weight of the study (see study 4), the shorter the line of 95% confidence interval. Whereas the lower the weight of the study (see study 15), the longer the line of 95% confidence interval. Thus, study 4 had the highest influence and made a large difference in the pooled results. It can also be observed that other studies had a greater influence on the results. The uncertainty of the pooled effect estimate was reduced by this weight selection.

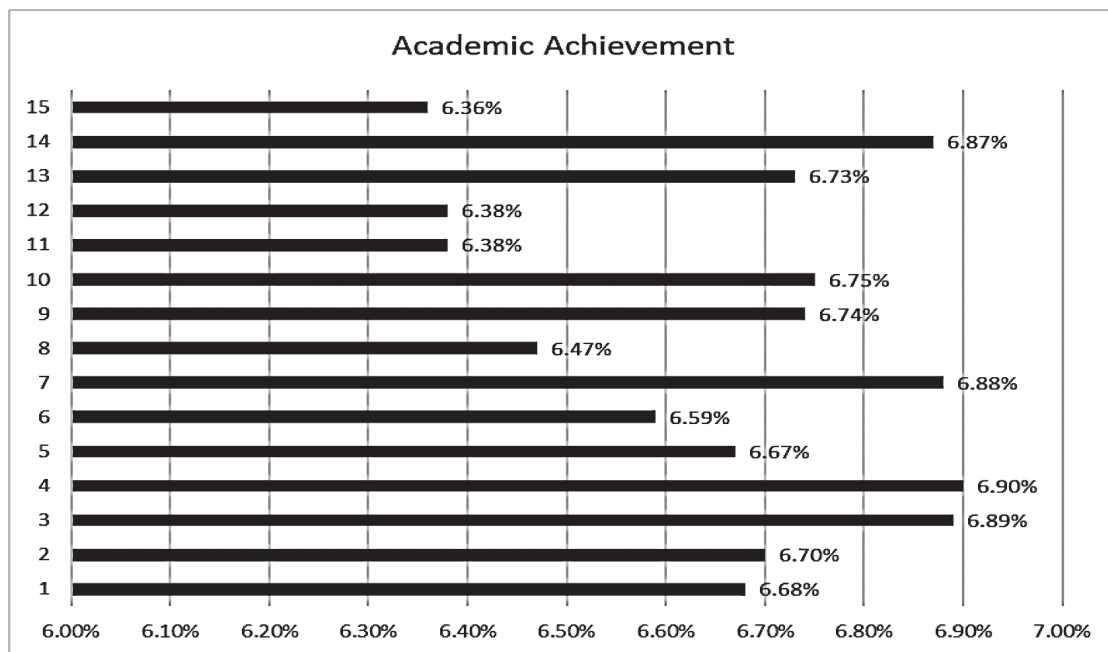


Figure. 6. Weights of each study under academic achievement

Evaluation of Heterogeneity Between Studies

Based on the table, the total variance of the data set is $Q = 264.72$. It was also shown that the p-value of the chi-squared test is 0.000 which is less than the .05 significance level. This indicates that the assumption of heterogeneity between studies was established. Moreover, the I^2 value is 94.71% suggesting a high heterogeneity (Higgins & Thomas, 2003) on the distribution of effect sizes among the studies. This high level of variability implies that some factors other than sampling error accounted for the variance that can impact the overall results of the blended learning approach on the students' academic achievement.

Table 6	Heterogeneity test under academic achievement				
	Q	p_Q	I^2	T^2	T
Overall	264.72	0.000	94.71%	1.37	1.17

* $p < 0.05$

Analysis of the Publication Bias of the Studies

Figure 7 shows the funnel plot of the effect sizes of 15 studies. The distribution of the effect sizes was asymmetric, which denotes that there were missing studies. To impute one or more studies, the meta-analysis study applied a trim-and-fill method to adjust the combined effect size for the potentially missing studies (Hak, van Rhee, & Suurmond, 2016). In Fig. 7, it was shown that there were only three (3) imputed data

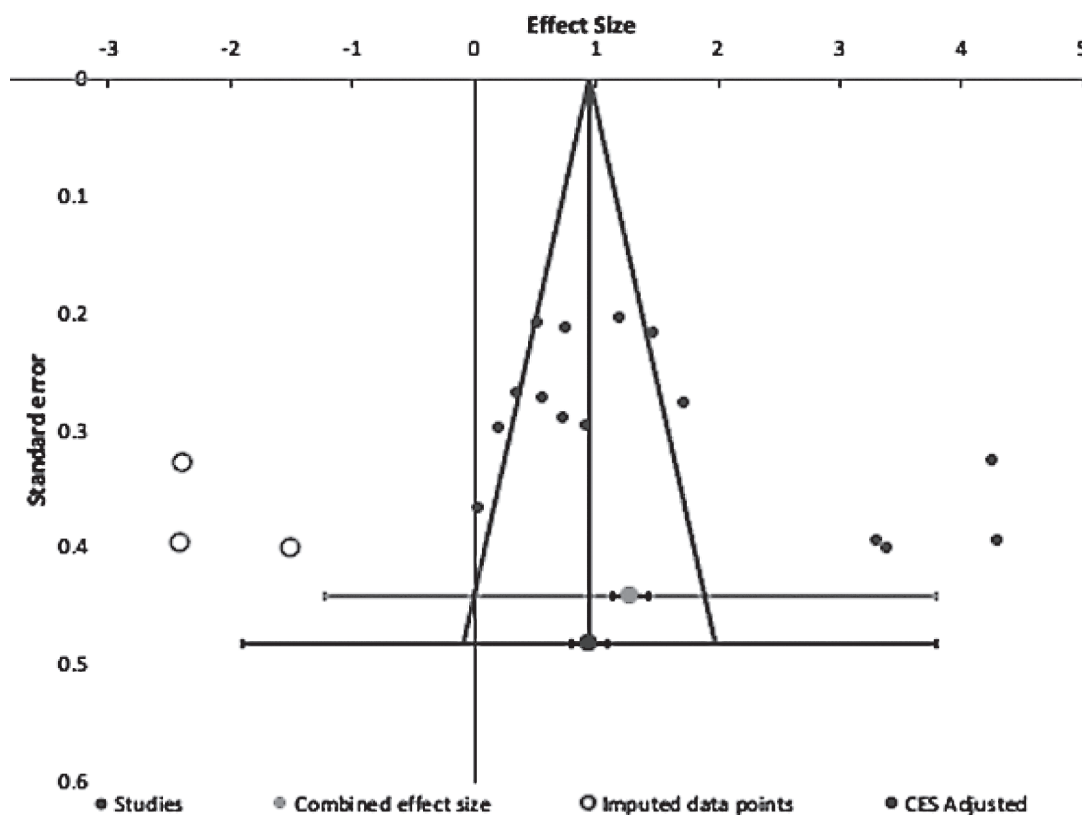


Figure 7. Funnel plot of studies' effect sizes under academic achievement

points. The trim-and-fill method adjusted the combined effect size from 1.28 to 0.94. As a result, there was balance and symmetry on the distribution of the studies. It suggests that the publication of the study sample was not biased in favor of blended learning approach on students' academic achievement.

The results of this meta-analysis study on blended learning approach and academic achievement are consistent with the findings of the study of Migalang (2018) that whenever a student is exposed to a blended learning approach, they exhibit academic excellence. Similarly, Siahaan et al. (2017) found that BLA increased the academic achievement posttest results of students in science. Moreover, Dagaang (2016) reported that students who experienced BLA obtained better scores after the intervention was given compared to students who were exposed to conventional teaching approach. Thus, the blended learning approach is effective in teaching science and in improving the academic achievement of students.

Conclusion

This meta-analysis of 25 studies has provided empirical evidence that blended learning approach has a positive effect on students' metacognition and academic achievement in science compared to the conventional teaching approach. The combined effect of e-learning and traditional classroom learning through this approach helps students to reflect more on their school performance through a positive change in their metacognitive knowledge, skills, and experiences. It also facilitates students to obtain higher test scores in general science, earth and space science, biology, chemistry, and physics. A large number of unpublished studies with a zero mean effect size would also be required to invalidate the significant overall effect of blended learning approach on both learning outcomes. Moreover, possible moderators should be identified to factor in other variables that reduce the unexplained variance. Finally, it is imperative to invest on educational interventions that are responsive to possible global crises.

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Conflict of Interest

The authors of this meta-analysis paper hereby declare that there is no conflict of interest concerning the publication of this paper.

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