Effectiveness of Blended Instructional Approach in Improving Students' Scientific Learning Outcomes: A Meta-Analysis

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This study examined the effectiveness of blended instructional approach in improving students' scientific learning outcomes. This study employed a quantitative research design, where meta-analysis guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol was mainly used to determine the effectiveness of previously done studies on blended instructional approaches. Using Comprehensive Meta-Analysis (CMA) software, the study extracted 53 effect sizes from 49 empirical studies from January 2016 to June 2021. The overall weighted effect size of g=1.349 suggests that the blended instructional approach has a significantly large and positive effect on students' scientific learning outcomes. Moderator analyses showed that the blended instructional approach has the largest effect on students' learning achievement (g=1.499) in comparison to scientific attitudes (g=0.472) and scientific process skills (g=0.277) with both small effects. Overall, the findings establish the effectiveness of blended instructional approaches in developing students' scientific learning outcomes. Hence, science teachers must be equipped with technological and pedagogical knowledge on the effective implementation of the blended instructional approaches in science teaching.

Keywords: blended instructional approach, learning achievement, scientific attitudes, scientific process skills, meta-analysis

INTRODUCTION

Scientific literacy has been the primary goal of science education (American Association for the Advancement of Science, 1993; K to 12 Science Curriculum, 2016). Scientific literacy entails the development of scientific understanding, attitudes, and process skills (Yuenyong & Narjaikaew, 2009), enabling students to cope with the rapid changes in the scientific and technological world (Shishigu et al., 2017). Scientific understanding equips students with essential knowledge that they can later use and apply in their lives (Jain, 2021). Academic performance improves when students exemplify scientific attitudes (Movahedzadeh, 2011). Scientific process skills, on the other hand, are critical in assisting students through experiential learning, which makes science authentic and relevant to students' learning (Pardhan, 2022). However, the pandemic has brought significant changes in the delivery of science education (Daniel, 2020), making the promotion of scientific learning outcomes among students a challenging practice. Hence, blended instruction has become more widely recognized as an emerging instructional approach (Garrison & Kanuka, 2004; Stockwell et al., 2015) as academic institutions have adapted the concept of blended instruction in teaching science (al Darayseh, 2020). As blended instruction becomes more common in

scientific classrooms, teachers have to ensure that students are afforded with learning opportunities that will allow them to develop their conceptual understanding, scientific attitudes, and process skills.

Blended instruction is the integration of face-to-face classroom instruction and online learning, which can be delivered through both synchronous modes and asynchronous modes (Cahapay, 2020; Oh & Park, 2009; Delialiouglu & Yildirim, 2007). Two of the most widely used blended instructional approaches are blended and flipped learning approaches. Flipped learning is a student-centered classroom model, where direct instruction is moved from the class group space to individual students' learning spaces (Jones, 2019; La Marca & Longo, 2017). In a previous study, students exposed to flipped learning exhibited significantly higher academic achievement and attitudes in science than those exposed to conventional instruction (Malto et al., 2018). On the contrary, in the study of Hinampas, Murillo, Tan, and Layosa (2018), students' academic achievement exposed to the blended learning approach did not significantly differ from non-blended learning approaches. On a positive note, students' process skills significantly improved than those non-exposed to the blended learning approach. Taken together, these studies suggest contrasting results about blended instruction; therefore, the current state of the empirical literature on blended instruction in science education has to be revisited as to whether blended instructional approaches positively affect students' scientific learning outcomes.

In the literature, there have been several meta-analyses on the effectiveness of the blended instructional approach; however, most of these studies focused on health education at the tertiary level. For example, Balakrishnan et al., (2021) conducted a meta-analysis on the effectiveness of blended learning in pharmacy education. Using a random effect model, results showed a statistically significant positive effect size on knowledge and skill. A similar result was found by Vallée et al., (2020), who did a meta-analysis of blended learning in medical education. The results demonstrated that it has consistently better effects on knowledge outcomes when compared with traditional learning in health education. This was supported by the meta-analysis conducted by Hew and Lo (2018), providing further evidence that the flipped classroom approach in health professions education significantly improves student learning compared with traditional teaching methods. Additionally, although without significant difference, Li et al., (2019) elucidated that blended learning could effectively improve nursing students' knowledge, skills, and satisfaction compared with traditional teaching.

Furthermore, in higher education, Vo et al., (2017) found a significantly larger mean effect size in STEM disciplines compared to non-STEM disciplines when it comes to academic achievement. Van Alten et al., (2019) conducted a meta-analysis that included 114 studies that compared flipped and non-flipped classrooms in secondary and postsecondary education. Results showed a small positive effect on learning outcomes, but no effect was found on student satisfaction regarding the learning environment. In addition, they found out that students in flipped classrooms achieved higher learning outcomes when the face-to-face class time was not reduced compared to non-flipped classrooms or when quizzes were added in the flipped classrooms. Moreover, Strelan et al., (2020) conducted a meta-analysis on flipped classrooms at all levels of education. Overall, the flipped classroom had a moderate positive effect ($g = .50$).

To the best of the researcher's knowledge, there has been no meta-analytic review of the literature that focuses on blended instructional approach in science education. Accordingly, there is a need to delve into empirical evidence in the literature that may inform educational policies for adapting blended instructional approaches in the delivery of scientific education in the post-COVID-19 pandemic. The results of this meta-analysis may be used as a basis for educators to arrive at research-informed decisions and sound educational policies in the implementation of blended instructional approach. Likewise, it is crucial that science teachers and educators be exposed to a repertoire of effective blended learning approaches previously explored and implemented to guide and support them in their instructional practices. The substantial information generated from this meta-analysis may serve as a significant input to designing a professional development training programs that may empower science teachers and educators' technological and pedagogical knowledge and skills in blended instructional approaches.

Research Questions

The main objective of this study was to examine the effectiveness of blended instructional approaches on students' scientific learning outcomes using a meta-analysis. Specifically, this study aimed to answer the following questions:

1. How effective is the blended instructional approach in maximizing students' scientific learning outcomes in terms of:
    a. learning achievement;
    b. attitudes, and;
    c. scientific process skills?
2. How does the effectiveness of the blended instructional approach differ according to the:
    a. scientific learning outcome;
    b. level of education;
    c. scientific discipline studied, and;
    d. duration of the implementation?
3. What were the blended instructional approaches that have been employed by the existing studies to improve students' scientific learning outcomes?

METHODS

Research Design

A quantitative research design, mainly meta-analysis, was used to examine existing studies on the effectiveness of blended instructional approaches in enhancing students' scientific learning outcomes. Meta-analysis is a comprehensive statistical analysis of the results of previously done studies (Antonio & Prudente, 2022; Cohen, 1988; Shroeder et al., 2007). It aims to draw generalizations on the current state of the literature and suggests new emphasis for future research by exploring the gaps in existing research (Cohen et al., 2007; Creswell, 2013).

Literature Search Procedures

As shown in Figure 1, the selection of relevant studies was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses or PRISMA (Moher et al., 2009). Research articles were obtained from six (6) meta-search engines, mainly Google Scholar, ScienceDirect, Microsoft Academic, ERIC, SCOPUS, and PubMed. The researcher purposely chose to start the search from January 2016 until the end of the second quarter of 2021. Using Harzing's Publish or Perish application, several descriptors were strategically entered in meta-search engines with some variations to account for specific retrieval sources (Bernard et al., 2014): science achievement, biology achievement, chemistry achievement, physics achievement, earth science achievement, science attitudes, biology attitudes, chemistry attitudes, physics attitudes, earth science attitudes, and science process skills. These words were put randomly and interchangeably in the meta-search engines with the constant use of the word "blended learning" or "flipped learning" until studies were exhausted.

In the literature search, there were 1, 194 research articles returned by different databases as relevant at first sight. Using an online removal tool, 585 duplicates were removed. Manual checking of duplicates was also done since the online tool did not detect other duplicates (n=49) due to other differences. After the abstract screening, only 253 articles remained which were assessed using the inclusion and exclusion criteria.

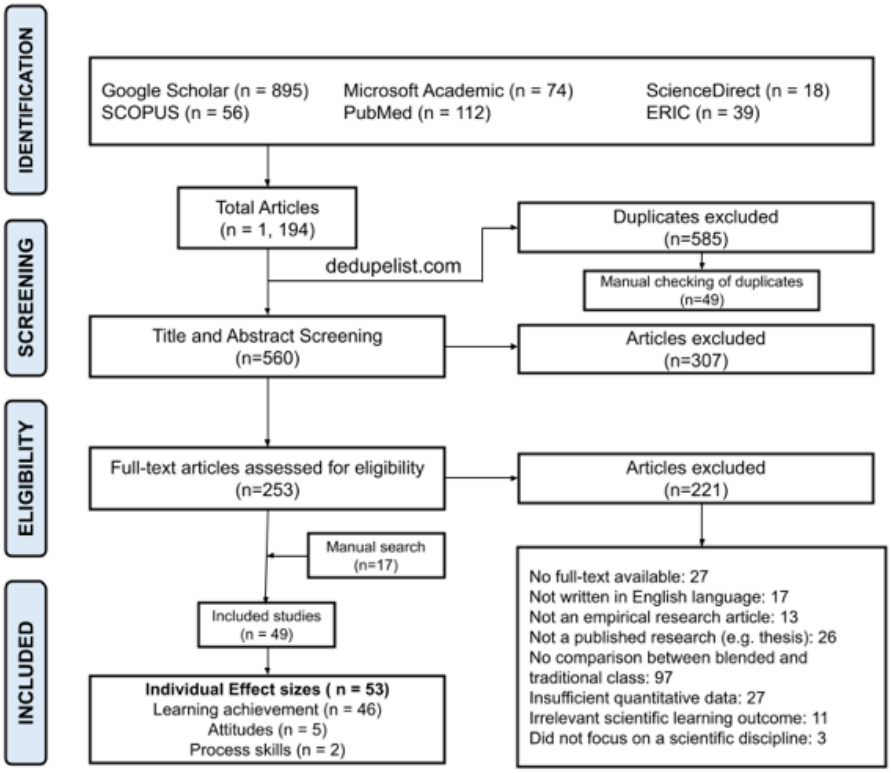
Inclusion and Exclusion Criteria

The literature included and analyzed in this meta-analysis has met the following inclusion criteria: a) has an available full text; b) must be written in the English language; c) must be an empirical study; d) must be a published research from 2016 to June 2021; e) must include an explicit reference to a blended

instructional approach in its title or abstract; f) must use an experimental and/or quasi-experimental design with pretest/post-test control groups, wherein the non-blended instructional approach was used in the control group and the blended instructional approach in the experimental group; g) must provide sufficient statistical or quantitative information; h) must use any of the scientific learning outcomes (achievement, attitudes, and process skills) as the dependent (outcome) variables; i) was conducted in a K-12 or higher education setting, and; j) must focus on any scientific discipline.

From the 253 research articles, 221 studies were removed due to the following reasons: a) no full-text available: 27; b) not written in the English language: 17; c) not an empirical research article: 13; d) not a published research (e.g., thesis): 26; e) no comparison between blended and non-blended group: 97; f) insufficient quantitative data: 27; g) irrelevant scientific learning outcome: 11, and; h) did not focus on a scientific discipline: 3. After excluding the 221 research articles, a manual search was conducted to exhaust the literature, resulting in 17 research articles qualified for inclusion in the meta-analysis. Forty-nine (49) research studies were included with 53 effect sizes that quantified the magnitude of the effect of the blended instructional approach on students' scientific learning outcomes.

FIGURE 1
FLOW CHART OF THE LITERATURE SEARCH USING PRISMA PROTOCOL



Coding Procedures

Relevant information from the research articles were analyzed and coded in a coding sheet. The researcher carefully noted the following characteristics: a) authors and year of publication; b) country; c) scientific learning outcome; d) level of education; e) scientific discipline; f) blended instructional approach; g) duration of the implementation, and; h) comparison of groups with statistical results i.e., means, standard deviations, and sample size.

Effect Size Calculation

Hedges g was mainly used as effect size to measure the magnitude and strength of the effectiveness of the blended learning approaches in improving students' learning outcomes. Hedges g is the standardized mean difference equal to the difference between the mean values of experimental and control groups divided by the standard deviation (Hedges & Olkin, 1985). Using Cohen's (1988) criteria, the magnitude of the effect size was interpreted accordingly: 0.80 and above (large); 0.50 to 0.79 (medium); 0.20 to 0.49 (small), and; less than 0.19 (no effect). A positive and larger effect size means that the group exposed to the blended instructional approach achieved a higher score than the control group exposed to a non-blended approach. The statistical analyses were performed using the software Comprehensive Meta-Analysis (CMA) Version 3. Moderator analyses were also utilized to determine whether the effectiveness of blended learning approaches on students' scientific learning outcomes varied when grouped according to specific scientific learning outcomes, level of education, scientific discipline, and duration of the implementation.

RESULTS

Based on the studies included in this meta-analysis, a total sample size of 4, 537 students was exposed to the blended and non-blended instructional approaches. The descriptive features of these studies, such as the scientific learning outcome investigated, students' level of education, scientific discipline studied, and duration of the implementation, are presented in Appendix A.

Majority of the studies (87%) included in the meta-analysis examined the effectiveness of the blended instructional approach in maximizing students' learning achievement (e.g., Hwang et al., 2019). Nine percent (9%) of the studies were only carried out to investigate the effectiveness of the blended instructional approach in improving students' scientific attitudes (e.g., Çirkinoğlu Şekercioğlu & Yünkül, 2021), while only four percent (4%) focused on developing students' scientific process skills (e.g., Harahap et al., 2019). Meanwhile, as regards students' level of education, it can be gleaned that most of the studies (57%) were conducted at the secondary level (e.g., Ebrahim & Naji, 2021) followed by the tertiary (28%) and primary levels (15%). In addition, the blended instructional approach was noted to be widely used in the teaching and learning of scientific concepts in Biology (45%), (e.g., Elian & Hamaidi, 2018) and Physics (30%), (e.g., Cagande & Jugar, 2018). The other scientific disciplines, where blended instructional approaches were used, with decreasing percentages are as follows: Chemistry (11%), General Science (10%), Earth Science (2%), and Science and Technology (2%). Furthermore, it can be observed that the usual duration of the implementation of the blended instructional approach in the included studies ranged from 5 to 8 weeks (32%), e.g., Seage and Türegün (2020), or 1 to 4 weeks (30%), e.g., Say and Yıldırım (2020). Nineteen percent (19%) of the included studies, however, did not specify the duration of the implementation (e.g., Zawawi et al., 2017). Eighteen percent (18) of the studies implemented the instructional approach from 9 to 16 weeks (e.g., Yapici, 2016).

TABLE 1
OVERALL EFFECT SIZE AND HETEROGENEITY ANALYSIS

	k	ES (*g*)	SE	Variance	95% CI		z	*p*	Q	df (Q)	*p*
					Lower	Upper					
Fixed	53	0.906	0.032	0.001	0.844	0.968	28.473	0.000	991.873	52	0.000
Random	53	1.349	0.142	0.070	1.070	1.628	9.478	0.000			

Note. k=number of effect sizes; Q=Homogeneity Value; df=degrees of freedom; g=Hedges' g; SE=standard error; CI=confidence of interval for the average value of ES.

As reflected in Table 1, results showed that the heterogeneity analysis was significant ($p < .05$), while the Q value was found to be 991.873 with degrees of freedom of 52. Based on the random-effects model, the calculated effect sizes vary between 1.628 (upper limit) to 1.070 (lower limit) at a 95% confidence interval. The overall weighted effect size of 1.349 suggests that the blended instructional approach has a significantly large and positive effect (Cohen, 1988) on students' scientific learning outcomes. Therefore, it can be stated that the blended instructional approach is effective and positively impacts students' holistic scientific learning.

FIGURE 2
FOREST GRAPH SHOWING THE DISTRIBUTION OF EFFECT SIZES OF THE STUDIES INCLUDED IN THE META-ANALYSIS

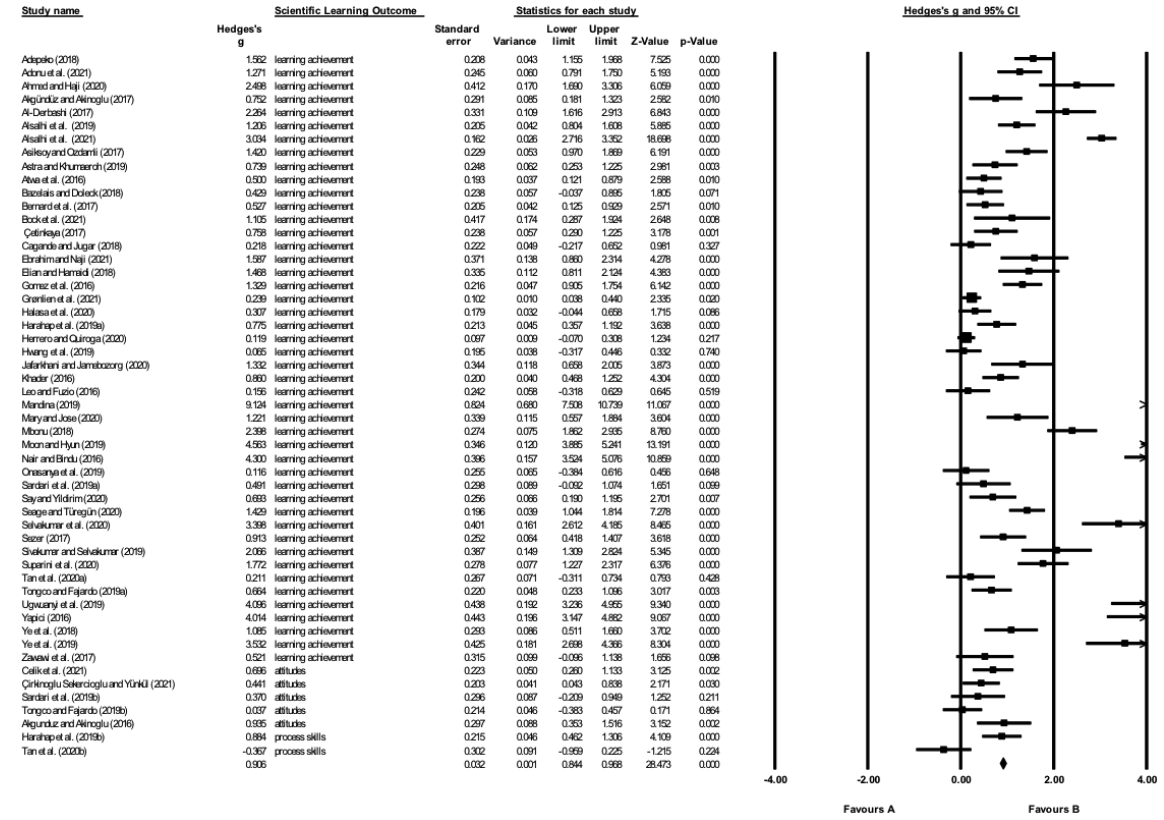


Figure 2 displays the distribution of Hedges g effect sizes of the studies included in the meta-analysis. The forest plot distribution of effect sizes showed that most of the studies favored the experimental (blended instruction) over the control (non-blended) group. This indicates that the blended instructional approach positively affects students' scientific learning outcomes. When the individual studies were examined, the maximum effect size was 4.563 (Moon & Hyun, 2019), while the minimum effect size was -0.367 (Tan et al., 2020b). Also, the lower and upper limits of the effect sizes of the studies were found to range between -0.959 (Harahap et al., 2019b) and 10.739 (Mandina, 2019).

TABLE 2
MODERATOR ANALYSES OF THE INCLUDED STUDIES

Moderator	*k*	*Effect size (g)*	*95% CI*		*Qb*	*p*
			LL	*UL*		
Scientific learning outcome					***23.115***	***0.000****
learning achievement	*46*	*1.499*	*1.186*	*1.813*		
scientific attitudes	*5*	*0.472*	*0.179*	*0.765*		
science process skills	*2*	*0.277*	*-0.949*	*1.502*		
Level of education					***0.474***	***0.789***
Primary	*8*	*1.190*	*0.647*	*1.734*		
Secondary	*30*	*1.417*	*1.044*	*1.790*		
Tertiary	*15*	*1.298*	*0.711*	*1.884*		
Scientific discipline studied					***69.929***	***0.000****
Biology	*24*	*1.157*	*0.782*	*1.533*		
Chemistry	*6*	*2.046*	*0.646*	*3.446*		
Earth Science	*1*	*3.532*	*2.698*	*4.366*		
Physics	*16*	*1.275*	*0.870*	*1.681*		
Science and Technology	*1*	*0.065*	*-0.317*	*0.446*		
General Science	*5*	*1.734*	*1.247*	*2.220*		
Duration of the implementation					***14.206***	***0.007****
1-4 weeks	*16*	*2.151*	*1.535*	*2.766*		
5-8 week	*17*	*1.097*	*0.752*	*1.442*		
9-12 weeks	*5*	*1.477*	*0.215*	*2.738*		
13-16 weeks	*5*	*0.756*	*0.175*	*1.338*		
Not reported	*10*	*0.771*	*0.240*	*1.302*		

*Random-effects model, *p < 0.05*

As can be gleaned in Table 2, moderator analysis was done with respect to the following variables: scientific learning outcome investigated, students' level of education, scientific discipline studied, and duration of the implementation. In terms of the scientific learning outcome, blended instructional approach

had the largest effect size on students' learning achievement (g=1.499), followed by scientific attitudes (g=0.472) and scientific process skills (g=0.277) with both small effects. The heterogeneity analysis implies significant differences among the effect sizes of the included studies (Qb=23.115; p < .05) when grouped according to the scientific learning outcome. As regards the students' level of education, it was revealed that the blended instructional approach had a larger effect size on students at the secondary level (g=1.417) than that on students at the primary (g=1.190) and tertiary levels (g=1.262). No significant difference was found among the effect sizes of the studies (Qb=0.474; p > .05) when grouped according to the students' level of education. In relation to the scientific discipline studied, blended instructional approach had the largest effect on the teaching and learning of Earth Science (g=3.532), followed by Chemistry (g=2.046), General Science (g=1.734), Physics (g=1.275), Biology (g=1.157), and Science and Technology (g=0.065). All of which had large effect sizes except for Science and Technology with no effect. According to the scientific discipline, significant differences were observed among the effect sizes of the included studies (Qb=69.929; p < .05). Finally, as to the duration of the implementation of the blended instructional approach, the largest effect size was recorded in 1-4 weeks (g=2.151). Large effect sizes were also noted in the duration of 5-8 weeks (g=1.097) and the duration of 9-12 weeks (g=1.477). A medium effect size was measured in the duration of 13-16 weeks (g=0.756), while a large effect size was obtained from the studies that did not report the duration of the implementation (g=0.771). Significant differences were also observed among the effect sizes of the studies (Qb=14.206; p < .05).

FIGURE 3
BLENDED INSTRUCTIONAL APPROACHES EMPLOYED IN TEACHING SCIENCE

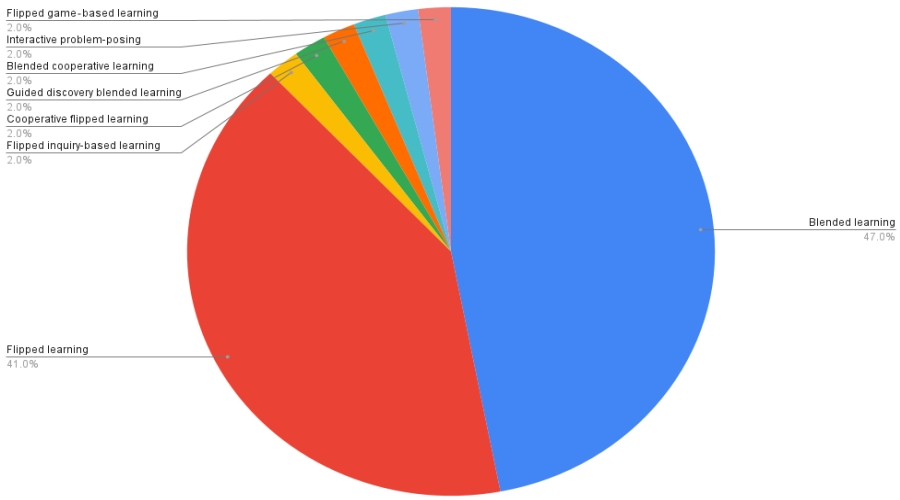


Figure 3 reflects the different blended instructional approaches employed in the teaching and learning of science from various levels of education. From the 49 studies included in the meta-analysis, blended learning has been the most widely used instructional approach (47%), followed by flipped learning (41%). Interestingly, it can be noted that such blended and flipped learning approaches had been integrated into different instructional strategies; some studies utilized inquiry-based learning and cooperative learning in implementing flipped learning environments. A small percentage (2%) of the studies incorporated guided discovery learning, cooperative blended learning, problem-posing strategy, and game-based learning.

Table 3 lists the different blended instructional approaches employed in the included studies with the corresponding effect sizes in decreasing magnitude. Among the nine specific approaches noted from the individual studies, large effect sizes ranging from 4.014 to 1.085 were reflected. More specifically, the largest effect size of g=4.014 was recorded in blended cooperative learning. This was followed by the interactive problem-posing guiding-based flipped learning (g=3.532), guided discovery blended learning

(g=1.772), cooperative flipped learning (g=1.332), blended learning (g=1.159), and flipped game-based learning (g=1.085). From the included studies, flipped learning approach returned a medium effect size of g=0.694. However, small effect sizes were recorded in the combination of blended and flipped learning (g=0.307) and flipped inquiry learning (g=0.211).

TABLE 3
EFFECT SIZES OF THE DIFFERENT BLENDED INSTRUCTIONAL APPROACHES EMPLOYED IN THE INCLUDED STUDIES (N=49)

Blended instructional approaches	n	Hedges g
blended cooperative learning	1	4.014
interactive problem-posing guiding-based flipped learning	1	3.532
guided discovery blended learning	1	1.772
cooperative flipped learning	1	1.332
blended learning	22	1.159
flipped game-based learning	1	1.085
flipped learning	20	0.694
blended and flipped learning	1	0.307
flipped inquiry learning	1	0.211

Publication Bias

The funnel plot analysis through visual inspection revealed that the effect sizes of the studies show an asymmetry. To confirm this finding, Begg-Mazumdar rank correlation and fail-safe N tests were conducted. The Begg-Mazumdar rank correlation yielded Kendall's tau of 0.59 (p=0.001). The classical fail-safe N test results indicate that 6, 263 more studies are needed to be added to the analysis to make the p-value (0.000) non-significant.

DISCUSSION

The meta-analysis of forty-nine (49) empirical studies that involved 4, 537 students across different levels of education indicated that the blended instructional approach had been widely employed in science classrooms to improve students' scientific learning outcomes. The blended instructional approach has been extensively used to facilitate the development of students' learning of scientific concepts. While a large number of studies have been conducted on its impact on students' learning achievement, only a few studies have attempted to investigate its effect on students' attitudes towards science and their process skills. A possible explanation for this is that scientific attitudes and process skills require longer period of time to develop, hence rarely investigated in the literature. When the utilization of the blended instructional approach was examined, it can be noted that it is more widely used in the secondary and tertiary levels of education, where physical and biological concepts have usually been the subject matter. Few studies had been carried out in teaching concepts in Earth Science and Chemistry. As regards the duration of the implementation, it is seen that the usual duration of the implementation of the blended instructional approach in the included studies ranged from 1 to 8 weeks.

Based on the analysis, the overall effect size of 1.349 is interpreted as having a "large and positive effect." This result suggests that the blended instructional approach has a large and positive effect on students' scientific learning outcomes; hence, it is more effective than non-blended instruction in facilitating students' scientific learning. These results were consistent with the findings of other meta-analyses regarding the effectiveness of blended instructional approach (Balakrishnan et al., 2021; Hew & Lo, 2018; Li et al., 2019; Vallée et al., 2020). However, the results of the present meta-analysis are different

from van Alten et al., (2019) who found a positive but a small effect. The effectiveness of the blended instructional approach can be attributed to its potential in creating an active learning environment that promotes individualization, personalization and relevance, greater flexibility, and accessibility (Hancock & Wong, 2012).

Considering that the heterogeneity analysis was significant, it can be implied that the effectiveness of the blended instructional approach varied as to the scientific learning outcomes, levels of education, scientific disciplines, and duration of the implementation. When the effectiveness of the blended instructional approach in enhancing students' scientific learning outcomes was examined, it is seen that it had the largest effect on learning achievement (g=1.499) in comparison to attitudes (g=0.472) and process skills (g=0.277) with both small effects. In terms of learning achievement, the maximum effect size was observed to be g=4.563 (Moon & Hyun, 2019), while the minimum effect size was observed to be g=0.065 (Hwang et al., 2019). The large effect size obtained in the study of Moon and Hyun (2019) can be attributed to the integration of online learning and in-class sessions using videos and printout lectures among nursing students. The study of Hwang et al., (2019), on the other hand, found no effect on the implementation of a blended learning environment among primary students. Although they found out that the blended instructional approach helped improve students' learning achievement in science and technology, not all of the students benefited from it. They argued that there were specific learning profiles that could really progress in the blended learning environment.

As regards the development of students' attitudes, the study of Akgunduz and Akinoglu (2016), who enriched the implementation of blended learning with learning activities aligned with constructivism, recorded the largest effect (g=0.935). On the other hand, no effect (g=0.037) was recorded in the study of Tongco and Fajardo (2019), who compared the effects of the 5E instructional model and 5E in a blended learning approach to secondary students. Results indicated that attitudes towards science did not differ significantly between the 5E model versus the 5E in the blended learning platform. Taken together, the positive and large effect obtained in the study of Akgunduz and Akinoglu (2016) and the no effect result of Tongco and Fajardo (2019) point to the effectiveness of constructivist strategies, as integrated in a blended instructional approach, in enhancing students' attitudes towards science.

In relation to students' process skills, the largest effect (g=0.884) was seen in the study of Harahap et al., (2019b) who implemented a blended learning environment aided with educational websites as learning media in teaching the basic concept of plant tissue culture. On the contrary, Tan et al., (2020), who explored the comparative effectiveness of inquiry-based and flipped inquiry-based classrooms, got a negative effect (g=-0.367). The results of their study showed that the flipped inquiry-based approach did not make students perform better than the non-flipped inquiry-based learning environment in terms of the development of process skills and understanding. Although a flipped learning environment caters students' flexible learning, in-class sessions can provide better social interactivity and learning activities for students (Abate, 2004; Antonio & Prudente, 2021). However, the results for the effectiveness of blended instructional approach on students' attitudes and process skills are inconclusive considering the limited number of studies on these variables included in the meta-analysis.

In connection with the level of education of the students, the meta-analysis showed that the blended instructional approach has the largest effect on students' scientific learning outcomes at the secondary level (g=1.417), followed by the tertiary level (g=1.298) and primary (g=1.190) level. Unlike the heterogeneous results of the individual studies when grouped according to the scientific learning outcome, the meta-analysis revealed that there is no significant difference among the effect sizes when grouped in terms of the level of education. This suggests that the blended instructional approach can be effectively utilized and implemented across different levels of education. Students' scientific learning whether in primary, secondary, and tertiary levels of education can be better facilitated when blended instructional approach is used as compared with conventional instruction.

In relation to the scientific discipline, there is only one (1) study that investigated the effectiveness of a blended instructional approach in learning Earth Science concepts, which recorded the largest effect size (g=3.532). Here, Ye et al., (2018) implemented a flipped learning strategy coupled with interactive problem-posing activities before class and during class among elementary students. Specifically, students

played a commercial video game prior to instruction and participated in group discussions and other classroom activities. Results indicate that the digital games used in flipped learning helped students achieve better learning. For other scientific disciplines, it is interesting to note that most of them obtained large and positive effect sizes as follows: General Science (g=1.734), Physics (g=1.275), and Biology (g=1.157). Significant differences were observed among the effect sizes of the included studies (Qb=69.929; $p < .05$) according to the scientific discipline. This suggests that the effectiveness of the blended instructional approach varied in terms of the scientific discipline. Hence, the appropriateness of the subject matter should be taken into consideration when planning to adapt a blended instructional approach.

As for the duration of the implementation of the blended instructional approach, it is worth mentioning that large and positive effect sizes were calculated albeit varying durations. It can be noted that the largest effect size was recorded in the duration of 1-4 weeks (g=2.151), which tends to decrease as the implementation becomes longer. This may be attributed to the novelty effect, which leads to positive outcomes when a blended instructional approach is introduced, and as the novelty fades, so does the positive effect (Clark, 1983). Significant differences were also observed among the effect sizes of the studies (Qb=14.206; $p < .05$). Although positive effect sizes were obtained, these results imply the importance of taking the implementation period of the blended instructional approach into account. Teachers still need to vary the instructional approaches to sustain students' engagement.

Furthermore, this meta-analysis specifically revealed that the majority of the studies employed blended learning (47%) and flipped learning approaches (41%) in the teaching and learning of scientific concepts. Blended learning occurs when most teaching and learning is done online, but some in-person activities, such as lectures or labs, are required, whereas students in flipped classes watch a short lecture video online and then come into the classroom to complete activities such as group work, projects, or other exercises (Cleveland-Innes & Wilton, 2018). For instance, in a flipped learning environment, Sardari et al., (2019) allowed students to learn through PowerPoint presentations and animations as pre-class learning tasks, while their in-class sessions focused on asking questions and solving problems.

When the individual studies were critically examined in terms of the blended instructional approaches employed, it can be said that all of these studies reported positive effect sizes suggesting the effectiveness of the blended instructional approaches in facilitating students' development of scientific learning outcomes over non-blended approaches. Studies that returned largest effect sizes incorporated elements of constructivism in their implementation, such as cooperative learning (e.g., Yapici, 2016; Jafarkhani & Jamebozorg, 2020) and inquiry-based learning (e.g., Tan et al., 2020, Harahap, et al., 2019). Furthermore, some studies incorporated guided discovery learning (e.g., Suparini et al., 2020), problem-posing strategy (e.g., Ye et al., 2019), and game-based learning (Ye et al., 2018) in blended instructional approaches. These only suggest that integrating student-centered and active learning strategies can better facilitate the implementation of a blended instructional approach towards students' meaningful acquisition of scientific learning outcomes. However, it can be deduced that flipped learning approach returned a medium overall effect size of g=0.694. Although this result implies the potential effectiveness of flipped learning in assisting students to develop positive scientific learning outcomes, it can be stated that blended learning approach, which integrates online learning and face-to-face learning, has a greater effect (g=1.159). Blended learning fosters an active learning environment and facilitates students' autonomous learning and thoughtful reflection (Zhang, 2020). Furthermore, small effect sizes were recorded in the combination of blended and flipped learning (g=0.307) and flipped inquiry learning (g=0.211). Thus, considering that the COVID-19 pandemic has created an atmosphere for technology-enabled learning (Mishra, 2020), the necessity of teaching and learning with asynchronous and synchronous platforms can better lead to significant benefits when these methods are layered into face-to-face instruction (Kim, 2020).

CONCLUSION AND RECOMMENDATIONS

This meta-analysis synthesized the results of forty-nine (49) experimental studies that measured the effectiveness of the blended instructional approach on students' scientific learning outcomes. The total number of samples in the control and experimental group was 4, 537 students from various levels of

education. Based on the meta-analysis result, the overall effect size of 1.349 revealed that the blended instructional approach has a significantly large and positive effect on students' scientific learning outcomes. This result establishes the effectiveness of integrating in-class sessions and online learning to improve students' scientific learning outcomes. Moderator analysis showed significant differences in the effect sizes of the individual studies when grouped according to the scientific learning outcome, scientific disciplines, and duration of the implementation. This implies that teachers have to consider the scientific discipline, where blended instructional approach will be used, and the duration of the implementation of the approach to further assist students in achieving better scientific learning outcomes. However, when it comes to the level of education, the obtained positive and large effect sizes suggest that a blended instructional approach can be effectively utilized and implemented whether students are at the primary, secondary or tertiary level. Furthermore, it was noted that the blended instructional approaches employed by individual studies are mostly blended learning and flipped learning. Blended instructional approaches have also been found to have an incorporation of constructivist learning strategies such as inquiry, cooperative learning, guided discovery, problem-posing strategy, and game-based learning.

Considering that a blended instructional approach has a positive impact on students' scientific learning outcomes, teachers should continuously employ meaningful technology integration in their instructional practices. Teachers should be further capacitated to become adept at effective implementation and integration of technology in classroom instruction with the aim of improving students' scientific learning outcomes. Hence, teachers should be provided with professional development training programs about blended instruction and its impact on student learning. Concerning the limited number of studies on the effectiveness of blended instructional approach in promoting students' attitudes and process skills, it is significant to conduct empirical studies on these aforementioned variables in the future since the impact of the blended instructional approach is underexplored in these areas. Moreover, future meta-analyses might deal with the effects of a blended instructional approach in developing students' higher-order thinking skills and other 21st-century skills.

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APPENDIX: DESCRIPTIVE FEATURES OF THE INCLUDED STUDIES

No.	Author/s	Country	Scientific Learning Outcome	Level of Education	Scientific Discipline	Blended Instructional Approach	Duration of Implementation	COMPARISON					
								CONTROL			EXPERIMENTAL		
								Mean	SD	N	Mean	SD	N
1	Adepeko (2018)	Nigeria	achievement	Secondary	Physics	blended learning	5-8 weeks	17.90	4.48	60	27.80	7.70	60
2	Adonu et al., (2021)	Nigeria	achievement	Secondary	Biology	flipped learning	1-4 weeks	60.79	8.88	39	73.85	11.30	40
3	Ahmed and Haji (2020)	Iraq	achievement	Secondary	General Science	flipped learning	9-12 weeks	13.80	4.94	20	24.00	2.85	21
4	Akgündüz and Akınoğlu (2017)	Turkey	achievement	Primary	Biology	blended learning	5-8 weeks	15.79	6.29	24	20.44	5.87	25
5	Al-Derbashi (2017)	United Arab Emirates	achievement	Secondary	Physics	flipped learning	1-4 weeks	7.48	2.16	29	12.93	2.56	30
6	Alsalhi et al., (2019)	United Arab Emirates	achievement	Secondary	Physics	blended learning	5-8 weeks	14.12	1.60	51	16.11	1.67	61
7	Alsalhi et al., (2021)	United Arab Emirates	achievement	Tertiary	Chemistry	blended learning	9-12 weeks	12.37	1.44	163	17.67	2.00	163
8	Aşıksoy and Ozdamli (2017)	Cyprus	achievement	Tertiary	Physics	flipped learning	9-12 weeks	66.53	8.45	47	81.40	12.02	47
9	Astra and Khumaeroh (2019)	Indonesia	achievement	Secondary	Physics	flipped learning	not specified	70.70	10.22	34	78.47	10.56	34
10	Atwa et al., (2016)	Malaysia	achievement	Secondary	Physics	flipped learning	5-8 weeks	0.36	0.12	56	0.43	0.15	53
11	Bazelais and Doleck (2018)	Canada	achievement	Tertiary	Physics	blended learning	5-8 weeks	54.44	17.98	34	62.14	17.53	37
12	Bernard et al., (2017)	Poland	achievement	Tertiary	Chemistry	flipped learning	not specified	64.40	11.40	54	70.80	12.80	44
13	Bock et al., (2021)	Germany	achievement	Tertiary	Biology	blended learning	1-4 weeks	14.80	2.30	12	17.00	1.50	13

14	Çetinkaya (2017)	Turkey	achievement	Secondary	Biology	flipped learning	1-4 weeks	55.40	17.70	37	66.89	11.70	37
15	Cagande and Jugar (2018)	Philippines	achievement	Secondary	Physics	flipped learning	not specified	5.03	1.89	35	5.53	2.53	47
16	Ebrahim and Naji (2021)	Kuwait	achievement	Secondary	Biology	flipped learning	5-8 weeks	4.89	2.17	18	8.16	1.86	19
17	Elian and Hamaidi (2018)	Jordan	achievement	Primary	Biology	flipped learning	1-4 weeks	16.27	2.47	22	19.09	1.01	22
18	Gomez et al., (2016)	Spain	achievement	Tertiary	General Science	flipped learning	1-4 weeks	3.52	2.22	51	6.23	1.81	52
19	Grønlien et al., (2021)	Norway	achievement	Tertiary	Biology	blended learning	13-16 weeks	2.17	1.55	172	2.55	1.62	216
20	Halasa et al., (2020)	Jordan	achievement	Secondary	Biology	blended and flipped learning	13-16 weeks	2.60	0.54	66	2.77	0.57	59
21	Harahap et al., (2019)	Indonesia	achievement	Secondary	Biology	blended learning	5-8 weeks	80.08	7.81	43	85.75	6.76	51
22	Herrero and Quiroga (2020)	Spain	achievement	Tertiary	Biology	flipped learning	13-16 weeks	45.45	21.35	229	47.95	20.45	201
23	Hwang et al., (2019)	Taiwan	achievement	Primary	Science and Technology	blended learning	13-16 weeks	89.11	12.16	46	89.92	12.67	60
24	Jafarkhani and Jamebozorg (2020)	Iran	achievement	Tertiary	Biology	cooperative flipped learning	5-8 weeks	12.75	1.92	20	15.71	2.41	20
25	Khader (2016)	Jordan	achievement	Primary	Biology	blended learning	5-8 weeks	15.78	3.10	54	18.13	2.26	54
26	Leo and Fuzio (2016)	USA	achievement	Secondary	Biology	flipped learning	not specified	103.25	31.36	29	107.92	28.37	40
27	Mandina (2019)	Zimbabwe	achievement	Secondary	Chemistry	blended learning	1-4 weeks	48.84	2.66	32	74.98	2.98	35
28	Mary and Jose (2020)	India	achievement	Secondary	General Science	blended learning	1-4 weeks	17.50	3.30	20	21.50	3.12	20
29	Mbonu (2018)	Nigeria	achievement	Secondary	General Science	blended learning	5-8 weeks	36.13	11.26	48	64.47	12.21	43

30	Moon and Hyun (2019)	South Korea	achievement	Tertiary	Biology	blended learning	1-4 weeks	6.47	2.63	60	16.40	1.56	60
31	Nair and Bindu (2016)	India	achievement	Secondary	Biology	blended learning	not specified	36.14	3.21	42	46.81	1.35	42
32	Onasanya et al., (2019)	Nigeria	achievement	Tertiary	Chemistry	blended learning	not specified	3.12	1.01	30	3.24	1.02	30
33	Sardari et al. (2019)	Iran	achievement	Secondary	Biology	flipped learning	not specified	16.39	2.61	22	17.56	2.05	23
34	Say and Yıldırım (2020)	Turkey	achievement	Secondary	Physics	flipped learning	1-4 weeks	9.16	3.03	31	11.38	3.27	32
35	Seage and Türegün (2020)	USA	achievement	Primary	General Science	blended learning	5-8 weeks	2.58	0.73	64	3.58	0.66	65
36	Selvakumar et al., (2020)	India	achievement	Secondary	Physics	blended learning	1-4 weeks	50.50	2.25	30	57.67	1.90	30
37	Sezer (2017)	Turkey	achievement	Primary	Biology	flipped learning	1-4 weeks	15.45	2.18	33	18.02	3.25	35
38	Sivakumar and Selvakumar (2019)	India	achievement	Secondary	Physics	blended learning	1-4 weeks	13.85	1.66	20	17.10	1.41	20
39	Suparini et al., (2020)	Indonesia	achievement	Secondary	Biology	guided discovery blended learning	1-4 weeks	80.17	3.54	35	86.00	2.95	36
40	Tan et al., (2020)	Philippines	achievement	Secondary	Biology	flipped inquiry learning	5-8 weeks	24.15	8.28	27	25.86	7.66	28
41	Tongco and Fajardo (2019)	Philippines	achievement	Secondary	Chemistry	blended learning	not specified	28.62	5.69	40	32.43	5.68	46
42	Ugwuanyi et al., (2019)	Nigeria	achievement	Secondary	Physics	flipped learning	5-8 weeks	40.79	8.76	30	69.50	4.76	34
43	Yapici (2016)	Turkey	achievement	Tertiary	Biology	blended cooperative learning	13-16 weeks	13.50	0.98	31	18.33	1.37	30

44	Ye et al., (2018)	Taiwan	achievement	Secondary	Physics	flipped game-based learning	1-4 weeks	41.24	17.13	26	59.55	16.08	26
45	Ye et al., (2019)	Taiwan	achievement	Primary	Earth Science	interactive problem-posing guiding-based flipped learning	1-4 weeks	75.91	1.65	27	81.71	1.59	29
46	Zawawi et al., (2017)	Malaysia	achievement	Tertiary	Physics	blended learning	not specified	8.41	2.76	27	9.75	2.05	16
47	Celik et al., (2021)	Turkey	attitudes	Tertiary	Physics	flipped learning	5-8 weeks	4.00	0.50	42	4.28	0.26	42
48	Çirkinoğlu Şekercioğlu and Yünkül (2021)	Turkey	attitudes	Tertiary	Physics	flipped learning	9-12 weeks	62.08	10.71	50	67.07	11.76	48
49	Sardari et al., (2019)	Iran	attitudes	Secondary	Biology	flipped learning	not specified	11.83	1.45	22	12.38	1.47	23
50	Tongco and Fajardo (2019)	Philippines	attitudes	Secondary	Chemistry	blended learning	9-12 weeks	4.10	0.36	40	4.12	0.66	46
51	Akgunduz and Akinoglu (2016)	Turkey	attitudes	Primary	Biology	blended learning	5-8 weeks	72.67	12.43	24	82.92	8.94	25
52	Harahap et al., (2019)	Indonesia	process skills	Secondary	Biology	blended learning	5-8 weeks	70.15	9.86	43	79.93	11.82	51
53	Tan et al., (2020)	Philippines	process skills	Secondary	Biology	flipped inquiry learning	5-8 weeks	20.55	5.32	22	18.29	6.72	21