Asia-Pacific Edu Res
https://doi.org/10.1007/s40299-022-00661-6

REGULAR ARTICLE

A Meta-analysis of Studies on the Effects of Active Learning on Asian Students' Performance in Science, Technology, Engineering and Mathematics (STEM) Subjects

Fridolin S. T. Ting[4] · Ronnie H. Shroff[1] · Wai Hung Lam[2] · Raycelle C. C. Garcia[1] · Chi Lok Chan[5] · Wing Ki Tsang[1] · Ndudi O. Ezeamuzie[3]

Accepted: 10 April 2022

Abstract The objective of this study is to perform a meta-analysis of published data on the effects of active learning on Asian students' performance in science, technology, engineering, and mathematics (STEM) subjects. This comprehensive meta-analysis study includes a systematic review of papers related to various active learning approaches and instructional methods such as collaborative learning, experiential learning, discovery-based, group-inquiry-based, problem-based and activity-based learning, specifically the effects these approaches have on Asian students' performance in STEM-related subjects. The Scopus electronic bibliographic database was searched with search terms and dates to identify and extract the relevant studies that met pre-stated inclusion criteria. A main criterion for inclusion of studies in this meta-analysis were Asian students' exposure to any active learning intervention in STEM-related subjects. Studies that fulfilled the inclusion criteria were processed for data extraction. A total of 2810 full-text peer reviewed papers published from 2000 to 2020 were analyzed and 38 papers met the inclusion criteria established for the meta-analysis. Effect sizes between experimental ($n = 2230$) and control groups ($n = 2510$) were calculated using means and standard deviations which were collected and summarized for a comprehensive and systematic review based on the compiled data. Using means and standard deviations from the studies, a moderately large effect size (ES = 0.6596) was detected. Analysis of the pre-post effect sizes demonstrated a significantly higher mean effect size thereby indicating a positive effect of active learning on Asian students' performance in STEM subjects. Findings from the meta-analysis in this study provide a comprehensive understanding of the effects of active learning on Asian students' performance in STEM subjects. Finally, the significance and relevance of these findings for future research directions are discussed.

✉ Ronnie H. Shroff
ronnie.shroff@polyu.edu.hk

Fridolin S. T. Ting
fridolin@eduhk.hk

Wai Hung Lam
carterlam@ln.edu.hk

Raycelle C. C. Garcia
raycelle.garcia@polyu.edu.hk

Chi Lok Chan
cchilok@eduhk.hk

Wing Ki Tsang
winky.tsang@polyu.edu.hk

Ndudi O. Ezeamuzie
amuzie@connect.hku.hk

[1] Department of Applied Mathematics, The Hong Kong Polytechnic University, TU823, 8/F, Yip Kit Chuen Building, Hung Hom, Hong Kong

[2] Teaching and Learning Centre, Lingnan University, 2/F, B. Y. Lam Building, 8 Castle Peak Road, Tuen Mun, New Territories, Hong Kong

[3] Faculty of Education, The University of Hong Kong, Room 401, Runme Shaw Building, Pokfulam, Hong Kong

[4] Department of Mathematics and Information Technology, The Education University of Hong Kong, 10 Lo Ping Road, Tai Po, Hong Kong

[5] Department of Psychology, The Education University of Hong Kong, 10 Lo Ping Road, Tai Po, Hong Kong

Published online: 09 May 2022

Keywords Active learning · Control group · Effect-size · Experimental group · Lecture-based · Meta-analysis · STEM · Student performance

Introduction

Over the past decade, the higher education field has highlighted the importance and potential significance of student-centered active learning contexts, in which learners are actively engaged in the learning process by applying higher-order thinking skills, conceptual knowledge and subsequently developing the capacity to assume responsibility for their own learning (Ting et al., 2019; Trinidad, 2019). The underlying principle of active learning is based upon the reinforcement of higher-order thinking skills (for example, critical analysis, synthesis and evaluation) that require learners to actively engage in their learning rather than just being passive recipients of instruction (Machemer & Crawford, 2007; Ng et al., 2020; Ní Raghallaigh & Cunniffe, 2013). The active learning method has been applied in various fields within the educational realm, with the objective of increasing learner engagement and interaction by changing students' learning styles from passive learning to active learning (Bonwell & Sutherland, 1996; Kim et al., 2013; Love et al., 2014). However, it should be stressed that the nature and characteristics of active learning approaches, which originate from and comply with a western background and culture, may be received differently in other cultures, especially within an Asian context. For example, key elements of an active learning method of instruction involve active participation, engagement and interaction, which conflicts with the reticent culture traditionally found in Asian classrooms.

More specifically, a number of studies have been devoted to understanding the effects of active learning on student performance in different disciplines (Armbruster et al., 2009; Ballen et al., 2017; Freeman et al., 2007; Yoder & Hochevar, 2005). More notably, a meta-analysis of 225 studies conducted by Freeman et al. (2014), analysed and reviewed data on examination scores and failure rates using a comparative approach to study student performance in undergraduate science, technology, engineering and mathematics (STEM) courses between traditional lecture-based and active learning approaches. The overall mean effect size demonstrated that, on average, student examination and concept-test performance increased by 0.47 standard deviations when employing active learning approaches, while the traditional lecture-based approach led to a higher risk of failing (Freeman et al., 2014). Their study findings subsequently revealed that mean examination scores improved by approximately 6% in the active learning scenarios (Freeman et al., 2014). Not only do these results justify the current implementations of active learning in STEM disciplines, it also serves as a call to STEM instructors to increase active learning in STEM-related courses.

Overall, the results of the meta-analysis performed by Freeman et al. (2014) provided satisfactory data and valid findings to indicate active learning increases student performance irrespective of discipline, that is, active learning results in objective gains in undergraduate STEM students' academic performance, when compared to a traditional lecture-based format. However, it should be noted that these findings were obtained in Western settings, which may not be applicable to other cultural contexts—the results demonstrated a positive impact of active learning on performance, but questions remain unanswered and warrant further investigation on the effect and significance of active learning specifically on Asian students' performance in STEM-related subjects. Therefore, the goal of this study is to explore this gap in the extant literature and perform a meta-analysis of published data on the effects of active learning on Asian students' performance in STEM subjects across all Asian studies in active learning is STEM subjects that meet our criteria for inclusion. It should be noted, that while there are numerous studies published on the effect of specific active learning techniques on student academic performance in STEM disciplines across Asia, there is no consolidated meta-analysis to evaluate the effectiveness of active learning instruction overall in an Asian context.

In this study, we propose to apply meta-analytic procedures to address the following research question: is there a significant increase in Asian students' performance in undergraduate STEM courses when active learning instructional approaches are applied compared to the traditional lecture-based pedagogy? For the purpose of this study, performance is defined by a learning gain, that is the actual difference between two measures (objective or subjective) of actual student performance (for example, a positive difference in students' posttest and pretest examination scores (objective) or learning satisfaction (subjective).

Theoretical Background

Active Learning

The active learning model of instruction is a pedagogical approach that typically focuses on the reinforcement of higher-order cognitive skills that support deep learning and understanding, enabling learners to actively engage in the learning process (Shroff et al., 2021). Active learning is an umbrella term that encapsulates a multitude of different and distinct learning approaches and instructional methods of teaching and learning (Nicol et al., 2018). To this end, various attempts have been made to change traditional lecture class pedagogy by applying active learning pedagogies, strategies or instructional methods such as collaborative learning, experiential learning, discovery-based, group-inquiry-based, problem-based and activity-based learner-centered approaches that focus on engagement and the application of skill such as real world problem solving, critical and analytical thinking and knowledge construction (Herreid & Schiller, 2013; Wright et al., 2019).

For the purpose of this study, active learning is operationally defined as any instructional method or pedagogical approach that engages learners in their own learning process through their active involvement in class, as opposed to a passive learning and traditional instructor-centered, lecture-based pedagogy (Shroff et al., 2021; Ting et al., 2019).

Active Learning on Student Performance

A review of the literature on active learning indicates that active learning has been shown to increase student performance quantitatively, for example in grades, and qualitatively, such as being able to apply higher-order thinking skills (Burt, 2004; Eichler & Peeples, 2016; Freeman et al., 2007; Yuretich et al., 2001). Freeman et al.'s (2014) work remains one of the most widely cited scholarly articles and the first and most comprehensive meta-analysis to date with the most included articles regarding the effects of active learning variants on student performance measures. Freeman's (2014) study demonstrates a well-designed meta-analysis on active learning, revealing that active learning increased student performance in STEM areas, indicating that the odds ratio for failing in a traditional setting was 1.95, with students in traditional lecture-based classrooms being 1.5 times more likely to fail compared to students in an active learning setting. Moreover, in the same study, active learning was also found to improve academic performance particularly in small classes of less than 50 students (Freeman et al., 2014).

Furthermore, a study conducted by Armbruster et al. (2009) demonstrated a significant improvement in student attitudes as well as an increase in performance by incorporating active learning into the instructional design of a course. Furthermore, results of a study conducted by Burt (2004) showed that active learning has the potential to significantly improve students' academic performance and achievement when transitioning from the traditional lecture-based pedagogy to an active learning pedagogy. While there are numerous studies published on the effect of specific active learning techniques on student academic performance in STEM disciplines across Asia, there is no consolidated meta-analysis to evaluate the effectiveness of active learning instruction overall in an Asian context. By calculating and analyzing the effect sizes across these studies, this study will attempt to determine how active learning affects Asian students and indicate to educators and policy makers whether active learning achieves the goals of effective instruction in an Asian context.

Active Learning Within an Asian Context

As active learning modes of instruction become more widely accepted in STEM-related subjects and disciplines, it is also imperative to evaluate whether culture plays a role in the effectiveness and types of outcomes that can be expected, specifically in the context of Asian classroom settings (Cambaliza et al., 2004). Traditionally, in an Asian context and often regardless of subject or discipline, common instructional teaching methods have typically included a didactic lecture-based pedagogy with highly structured learning activities that require strong instructor-centered control, comprising of drill-and-practice exercises with a high dependence upon facts, rote learning and other passive forms of learning (Carr et al., 2015; Tuyết, 2013a, b; Wong, 2004). However, we are now beginning to see a clear shift away from the traditional instructor-centered and passive learning delivery models that characterises Asian classrooms to more active learning student-centered approaches that foster deeper learning and allow students to engage, interact and collaborate with their peers (Cambaliza et al., 2004; Sivan et al., 2000). Moreover, recent research has shown that group-based and collaborative instructional activities fit with an Asian culture with emphasis on collectivistic orientation and cooperation over competition and a strong emphasis on achievement and mastery of skills (Frambach et al., 2014; Lee & Yang, 2020; Wahono et al., 2020). Furthermore, numerous studies of various types have examined the impact of active learning within Asian contexts (Cambaliza et al., 2004; Ng et al., 2020; Park & Choi, 2014; Ting et al., 2019).

Rationale for a Meta-analysis

A meta-analysis methodology was chosen for this study for several reasons. First, the key basis for this study is inspired by the existing meta-analytic study conducted by Freeman et al. (2014) that examined student performance in active-learning versus the traditional lecture-based pedagogy in a North American context. We feel a meta-analysis is warranted, as it would allow us to comprehensively examine the landscape of research in the area of active learning, particularly in respect to Asian students' performance in STEM-related subjects. Secondly, conducting a systematic review of existing studies would not only allow us to focus on the effect size across studies, but also provide a more accurate summary and depiction of the nature of the effects of active learning on Asian students' performance in STEM subjects. Third, by extracting and analysing all available published data from a systematic review (i.e., quantifying and combining results of individual studies) and then calculating the effect size of each study, we would subsequently be able to compute a summary effect size from these studies. Finally, a meta-analysis would provide us with a more quantitative and statistically based conclusion by taking into consideration the strength of effect size in each empirical study evaluated as well as an aggregated and more accurate view of these studies.

Methodology

Criteria for Inclusion and Exclusion

Explicit criteria for inclusion and exclusion were established before reviewing the literature to ensure the relevance of the selected full text published research papers extracted from the bibliometric database. For the present study, the following inclusion criteria were applied to the studies extracted by the literature search: (1) research subjects were primary, secondary, tertiary or vocational students at the time of the study; (2) studies that explicitly investigated the effects of active learning interventions on student performance in a STEM-related discipline; (3) studies from Asian countries; (4) studies that implemented an intervention that involved an active learning pedagogy, strategy or treatment; (5) studies that included at least two treatment groups: an experimental group that were treated with the active learning pedagogy and a control group that either experienced a traditional lecture-based treatment or an active learning approach treatment; (6) the research recorded a quantitative measure of academic student performance, including average mean, standard deviation and sample size for both groups; (7) the research provided the necessary statistical information for the calculation of effect sizes; and (8) Searches were restricted to English research articles. Criteria for exclusion included: (1) studies published that are not available electronically; (2) studies providing qualitative analysis and evaluation only; (3) non-English studies; (4) abstracts and review papers; (5) studies with methodological shortcomings and deficiencies such as non-randomized controlled trials; (6) studies with incomplete data; and (7) studies that did not calculate or present data on means, standard deviations, sample sizes, etc.

Data Collection

The data collection procedure comprised of rigorously and systematically locating all relevant empirical Asian studies related to active leaning interventions on student performance in STEM-related disciplines. The inclusion of all possible studies, which met the criteria, constituted a more comprehensive and representative sample of all studies published. For this study, a computer-based literature search of the Scopus bibliometric database was used for bibliometric analysis, allowing for enhanced literature search capability. Scopus was chosen as a bibliometric source because of its extensive coverage of peer reviewed education literature including a more expanded variety of academic journals in the science, technology, medicine, natural science and social sciences field. Moreover, Scopus was selected for this study because of its unique functionalities that allowed us to perform a more comprehensive search using specific keywords in order to generate a more defined query for obtaining the relevant bibliometric data. This included searching and identifying main keywords in the Publication Date, Title, Abstract, Document Title, Type of Document, Journal Name and References fields. The selection of keywords in the Scopus database was critical to our meta-analytic analysis since the keywords directly influenced the amount of data that was retrieved. Different active learning pedagogies and treatments were extracted from those included in Freeman's meta-analysis, and keywords were used in a comprehensive search for titles and abstracts in Scopus to narrow down literature related to active learning.

For our meta-analysis, a search in Scopus was performed using a combination of search terms, search queries and exclusion criteria with a combination of "AND"-, "OR"- and "'NOT" Boolean search operations to ensure the retrievals or outputs were precise. Since active learning is an umbrella term that encompasses a range of different pedagogical methods, our search strategy comprised of a keyword search of "active learning" as well as numerous search terms relevant to active learning, both in the title and abstract fields on the Scopus database. A literature search using Scopus was performed for journal articles published from 2000 through 2020, which included broad and narrow variations of instructional approaches related to active learning (for example, collaborative learning, experiential learning, discovery-based, group-inquiry-based, problem-based, activity-based learning, etc.) were searched (see Table 1).

Moreover, search terms were combined with "Asia" and each individual country (for example, "Afghanistan", China", "India", "Mongolia", etc.) in the title, abstract, or list of subject heading terms, limited to English. For example, the search criteria in Scopus was performed by searching for terms or term combinations and/or by generating the filtered keywords out of papers and articles. For example, the search criteria in Scopus was performed by searching for terms or term combinations and/or by generating the following filtered keywords out of papers and articles:

(TITLE-ABS-KEY ("active learning" OR "active engagement" OR "problem-based learning" OR "interactive learning") AND DOCTYPE (ar) AND PUBYEAR>-2000 AND PUBYEAR<-2020) AND (LIMIT-TO (DOCTYPE, "ar") AND (LIMIT-TO (SUBJAREA, "MATH") AND

Table 1 Search terminology of instructional approaches related to active learning

Active learning	Flipped learning/flipped approach	Project oriented learning
Action learning	Generative learning	Question-based learning
Action-oriented learning	Goal-based learning	Reflective learning
Anchored instruction	Group learning	Resource-based learning
Authentic learning	Group-inquiry-based learning	Role-play-based learning
Active engagement	Inquiry learning	Scenario-based learning
Activity-based learning	Inquiry-based learning	Self-directed learning
Case method	Inquiry-guided learning	Self-regulated learning
Case-based learning	Interactive learning	Service learning
Collaborative learning	Interprofessional learning	Simulated learning/simulation-based learning
Cooperative learning	Learner-centered learning	Situated learning/situational learning
Competency based learning	Mastery learning	Social learning
Computer-assisted learning	Mobile learning	Student-centered learning
Concept-based learning	Peer-assisted learning	Task-based learning
Context-aware learning	Peer-assessed learning	Task-oriented learning
Context based learning	Peer-to-peer learning	Task-based interaction
Discovery learning	Performance-based learning	Team-based learning
Discovery-based learning	Peer instruction	Think-pair-share
Expansive learning	Practice-based learning	Transformative learning
Experiential learning	Problem-based learning	Transformational learning
Experimental learning	Problem-orientated learning	Work-based learning
Evidence based learning	Project-based learning	

(LIMIT-TO (EXACTKEYWORD, "ACTIVE LEARNING", "MEAN" "STANDARD DEVIATION") AND (LIMIT-TO (AFFILCOUNTRY, "China") AND SRCTYPE(j) AND (LIMIT-TO (LANGUAGE,"English")).

Search criteria in Scopus were also limited to subject areas under the following STEM and STEM-related disciplines.

"COMP" (COMPUTER SCIENCE) "ENGI" (ENGINEERING) "MEDI" (MEDICINE) "PHYS" (PHYSICS AND ASTRONOMY) "MATH" (MATHEMATICS) "DECI" (DECISION SCIENCES) "BIOC" (BIOCHEMISTRY, GENETICS AND MOLECULAR BIOLOGY) "ENVI" (ENVIRONMENTAL SCIENCE) "MATE" (MATERIALS SCIENCE) "AGRI" (AGRICULTURAL AND BIOLOGICAL SCIENCES) "NURS" (NURSING) "ENER" (ENERGY) "EART" (EARTH AND PLANETARY SCIENCES) "MULT" (MULTIDISCIPLINARY) "PHAR" (PHARMACOLOGY, TOXICOLOGY AND PHARMACEUTICS) "HEAL" (HEALTH PROFESSIONS) "CENG" (CHEMICAL ENGINEERING) "DENT" (DENTISTRY) "IMMU" (IMMUNOLOGY AND MICROBIOLOGY) "VETE" (VETERINARY)

The initial computer search using a combination of search terms and Boolean operators, as shown above, resulted in a list of 12,187 titles. Further filtering was performed after assessing the relevance of each study based on the title and abstract, reducing the list to 2810 reports. In accordance with the inclusion criteria (6) mentioned above, which required studies to report both mean and standard deviation on student academic performance, these papers could be filtered by these two words. Consequently, an algorithm was written using a JavaScript programming language and a set of JavaScript commands were subsequently executed to automatically scan documents and return the number of instances a keyword appeared in each document. Results of the electronic search are shown in the flow diagram (Fig. 1), comprising of four steps which provide a summary of the selection process.

The 2810 papers available to be downloaded were extracted and uploaded to a server where the algorithm was implemented for the key words "mean" and "standard deviation." Moreover, the algorithm was programmed to eliminate all papers that did not include either word or did not have the quantitative analysis required to calculate effect size, which subsequently reduced the total relevant research papers to 585. For the remaining 585 studies, each paper was reviewed by a member of the study team and each author received a set of approximately 116 articles to review. The abstract was read to check for relevance to the necessary criteria. Numerous studies were eliminated, including studies that did not pertain to pedagogy, STEM, the Asian continent, no control group comparison or results on perception rather than academic performance. This narrowed down the list of papers to 38 papers with a total of 44 separate studies. It should be

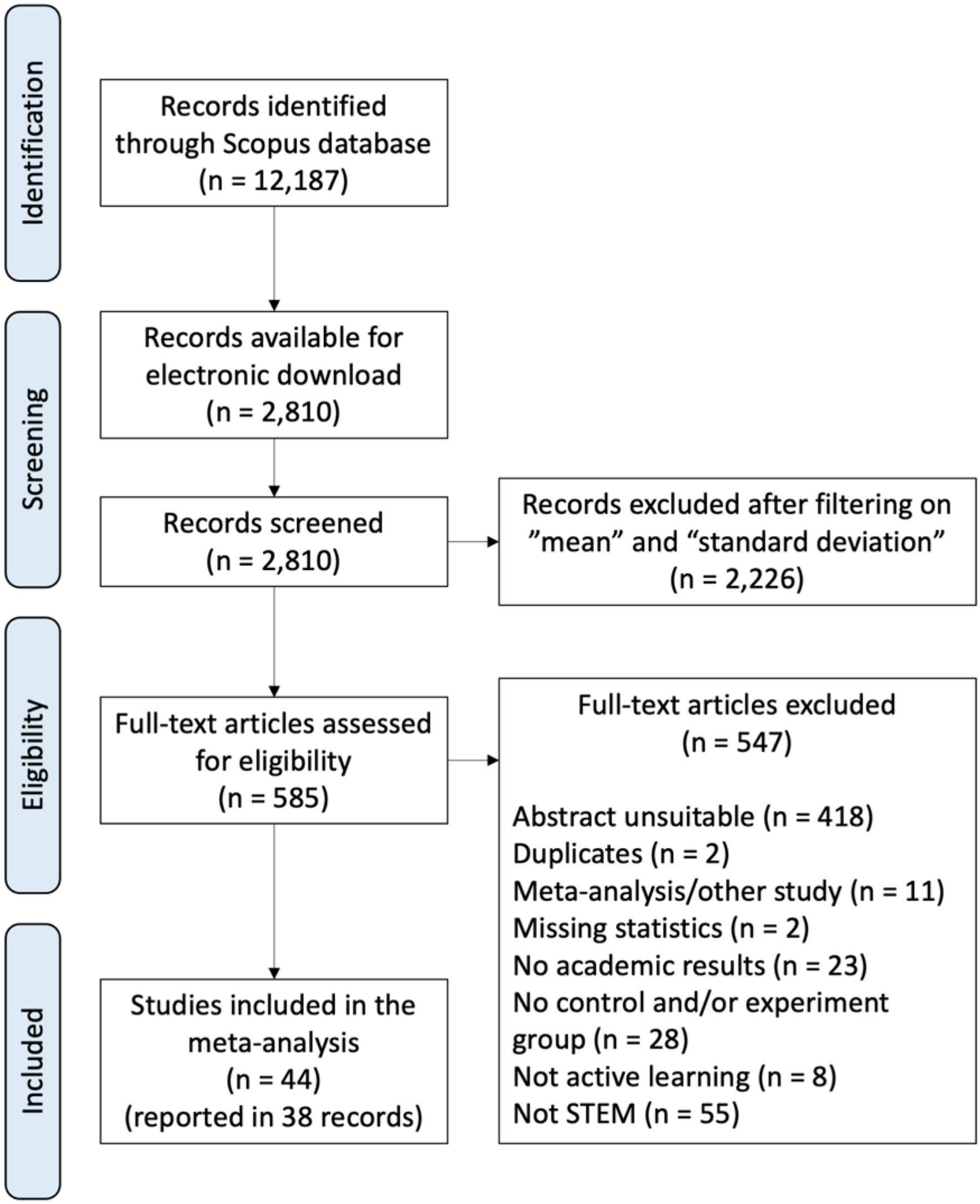

Fig. 1 Flow diagram of the selection process

noted that for this study, some articles were counted as two studies and were reviewed independently when they reported separate results, for example, when one experimental group was compared with two different comparison groups. Of the studies that did fit the necessary criteria, a member of the team extracted the relevant data, including mean, standard deviation and sample sizes for further analysis to calculate the effect size. In summary, after reviewing and applying the inclusion criteria to each of the 585 studies, we were able further narrow down the list to 44 studies which contained sufficient data for calculating the effect size and consequently, deemed suitable to be meta-analyzed.

Coding of Studies

For this study, a systematic and reliable coding procedure was developed for extracting data from the targeted studies. The objective of the formalized coding process was to allow for the capturing of all key information that could then be formatted for easy extraction of data. First, all qualifying articles were identified and then reviewed to establish if they had sufficient data for analysis. The selected papers were then individually examined to ensure they met the inclusion criteria. This was done by constructing a coding spreadsheet comprised of the following variables: name/title of study, year of publication, level of schooling ("primary", "secondary", "tertiary" or "vocational" drop-down fields), experimental design ("experimental", "quasi-experimental" or "non-experiment" drop-down fields), country of study, the type of treatment, intervention, discipline and sample size and means (*M*) and standard deviations (SD) of the experimental group and control group. A total of 44 studies were identified that met the criteria to be included in the meta-analysis (see "Appendix" for a complete list of included studies). An example of relevant variables (i.e., pertinent extracted information from the studies) were coded according to the coding schema reported in Table 2.

Accordingly, the methodological appropriateness and quality of each study was assessed on the basis of a predefined scale, according to suitability of the paper defined as "Yes", "No" or "Not applicable" drop-down fields. Furthermore, all qualifying papers were title reviewed to ensure their titles were suitable or relevant to the inclusion criteria. Furthermore, abstracts of the selected papers were also reviewed against the inclusion criteria.

All retrieved studies were rated independently by five raters who applied the inclusion criteria by extracting data on to the code sheet. To check the accuracy of the coding and to ensure reliability of the coding schema and the coding itself, inter-rater agreement was assessed by comparing ratings between raters and any disagreements or discrepancies were noted and resolved by discussion and consensus, yielding 100% agreement. The extent of agreement between the raters regarding the selection of articles was over 98%, indicating a high interrater reliability.

Results

Computation of Effect Sizes

For this study, effect sizes (i.e., standardized mean difference) were calculated for experimental and quasi-experimental studies using Cohen's *d* formula, a frequent metric used in meta-analysis to calculate the differences in gain scores, that is, the standardized mean difference between

Table 2 Example of coding schema with relevant variables to be coded

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
9	Exploring problem solving patterns and their impact on learning achievement in a blended learning environment	2011	T	E	Taiwan	COM	17	12	43.2	1.48	38.88	3.12	1.883

School Level (*P* Primary, *S* Secondary, *T* Tertiary, *V* Vocational), Design (*E* Experimental, *Q* Quasi-experimental), Discipline (*COM* computing); *EG* experimental group, *CG* control group, *SD* standard deviation the experimental and control conditions (Wilson & Lipsey, 2001). In this study, the following three statistics were required to calculate the effect size: mean of the experimental group ($n = 2230$), mean of the control group ($n = 2510$) and standard deviation (SD) of the experimental and control group. Effect sizes (standardized mean differences) were computed using group means and SDs. The standardized mean differences were reported with accompanying 95% confidence intervals (CIs). Pre–post gain scores were then computed and analyzed to determine if there were any differences between the two groups (i.e., experimental and control groups). Moreover, effect sizes were calculated for each comparison of an experimental group with the control group, including calculating the means and SDs of the active learning before and after treatment. Effect size using Cohen's *d* (1977) formula was calculated for all studies that provided sufficient data. The method of calculating *d* is shown below where *d* is Cohen's effect size, M_2 denotes the mean of the experimental group and M_1 denotes the mean of the control group.

$$d = \frac{M_2 - M_1}{\sqrt{\frac{(n_1 - 1)SD_1^2 + (n_2 - 1)SD_2^2}{n_1 + n_2 - 2}}}.$$

Hence, the *d* statistic is the difference between the means (M_2–M_1) divided by the pooled standard deviation of the treatment group and the control group, respectively (Cohen, 1977). To interpret the strength of the effect sizes in this study, the following classification introduced by Cohen et al. (2007) was used (Table 3).

As shown in the Table 3, effect sizes were classified into four levels: small, medium, large and very large, each corresponding to a Cohen's *d* value of 0.2, 0.5, 0.8 and 1.3 respectively. For this study, a statistical test of heterogeneity

Table 3 Cohen's *d* (1977) classification of effect size

Effect size	Relative size	% of control group below the mean of experimental group
0.2	Small	58
0.5	Medium	69
0.8	Large	79
1.3	Very Large	92

ESV effect size value

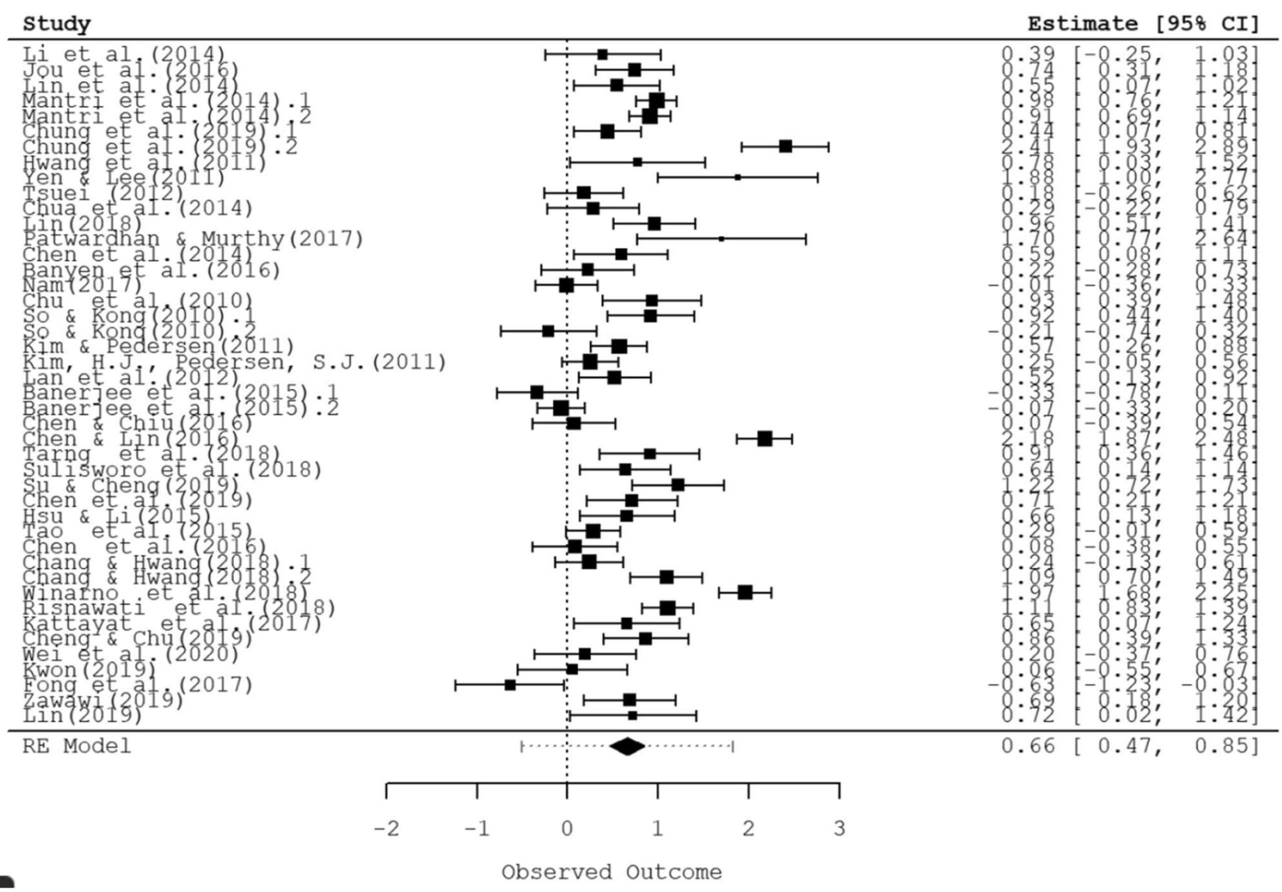

Fig. 2 Forest plot and summary effect

was undertaken to determine whether there was a difference across the included studies. As proposed by Higgins and Thompson (2002), statistical heterogeneity was evaluated using the I^2 statistic and interpreted as the percentage of between-study variance. Heterogeneity was assessed graphically using a forest plot (see Fig. 2), showing the effect size (Cohen' d) of 0.6596 (95% CI ~ 0.47 to 0.85), thereby providing strong evidence that active learning is a significant predictor of performance. Each study in the forest plot is represented by a filled black square (denoting its effect size estimate) together with solid horizontal lines indicating 95% CIs and associated black diamond indicating the summary effect with 95% CI for the 44 studies.

In this study, the test for heterogeneity was significant, indicating high variation among the studies ($p < 0.0001$; $I^2 = 88.80\%$). High heterogeneity is particularly common in educational research studies and a possible explanation for this finding may be due to a combination of variability (i.e., variable sample sizes and variations in populations among studies) as well as small effect sizes found in some of the studies included in the present meta-analysis. Based on the Q-test, the true outcomes appear to be heterogeneous [$Q(43) = 413.1214$, $p < 0.0001$, $\tau_2 = 0.3464$, $I^2 = 88.80\%$].

Data Analysis and Interpretation

Meta-analytic methods were used in this study to aggregate effect sizes. A total of 44 effect sizes ($k = 44$) were computed from 44 studies included in the study. All 44 studies were peer-reviewed. 23 studies were conducted in the Taiwan, 6 in India, 4 in Korea, 2 in Malaysia, 3 in Hong Kong and Indonesia, 1 in China, Singapore and Thailand. Mean weighted effect size for the 44 studies was 0.6596 (95% CI 1/4 0.4710–0.8482). Based on Cohen's d calculation to determine the effect size, the result corresponds to an above medium effect size of $d = 0.6596$, demonstrating that these findings show that the effects of active learning on student performance is approaching to large. Moreover, the effect size indicated a significant main effect of treatment across the studies, that is, the difference in scores between treatment and non-treatment (control) groups.

As shown in Table 4, active learning general effect size on student performance is 0.6596 with an error of 0.0962. Significance was set at $p < 0.05$. Moreover, the average effect size indicated the presence of a significant main effect of treatment across the 44 studies ($p < .05$). This is a high effect based on the classification (Table 3) by Cohen et al. (2007). Furthermore, our results indicate that the effect size is significantly higher in Asian students' performance in undergraduate STEM courses when active learning instructional approaches are applied. Another metric used for calculating the effect size of the comparisons between the treatment and control groups was Hedges and Olkin' g (1985) standardized mean difference. Analyses yielded large mean effect sizes for the pre-post comparison (Cohen's $d = 0.6596$, 95% CI) [0.4710, 0.8482]). Results indicate that active learning interventions had a higher effect on student performance than the traditional lecture-based format. Hence, from the data we can conclude the overall effect size from the meta-analysis is significant.

To investigate any publication bias, funnel plot symmetry was tested and publication bias was assessed using Begg and Mazumdar's (1994) rank correlation test and Egger et al.'s (1997) regression symmetry test (with p value < 0.05 as significance level). There was no evidence of publication bias by Begg's test ($p = 0.7294$) or Egger's test ($p = 0.8021$). Furthermore, visual examination of the symmetrical funnel plot (Fig. 3) carried out by Begg's test, suggested no obvious publication bias among the included studies.

In addition to the funnel plot, a sensitivity analysis was also performed to evaluate whether the pooled effect size was influenced by individual studies, that is, to assess the influence of the individual studies on the overall results by omitting one study at a time. For the sensitivity analysis, a summary of the effect sizes was compared together with their 95% CIs and the results confirmed the robustness to all ($n = 44$) one-by-one study removals, implying that omitting each study did not change the significance of results.

Finally, due to the rich variety of studies found in this meta-analysis, we conducted two separate moderator analyses to explore potential variations due to other present factors. The two potential moderators considered were: (1) country/region; and (2) discipline category, shown in Tables 5 and 6 respectively. The results yielded no significant degree of variation in the effect size for either moderator.

The results indicate that the effect size of active learning pedagogies in these different regions and STEM disciplines are similar, as no significant difference can be clearly defined between different countries/regions in Asia, and between the

Table 4 Findings of studies' effect sizes

General effect size (g)	k	Standard error (SE)	Variance	Z	p	Mean confidence level for effect size	
						Lower limit	Upper limit
0.6596	44	0.0962	0.0093	1.96	0.05	0.4710	0.8482

$^{*}p < 0.05$

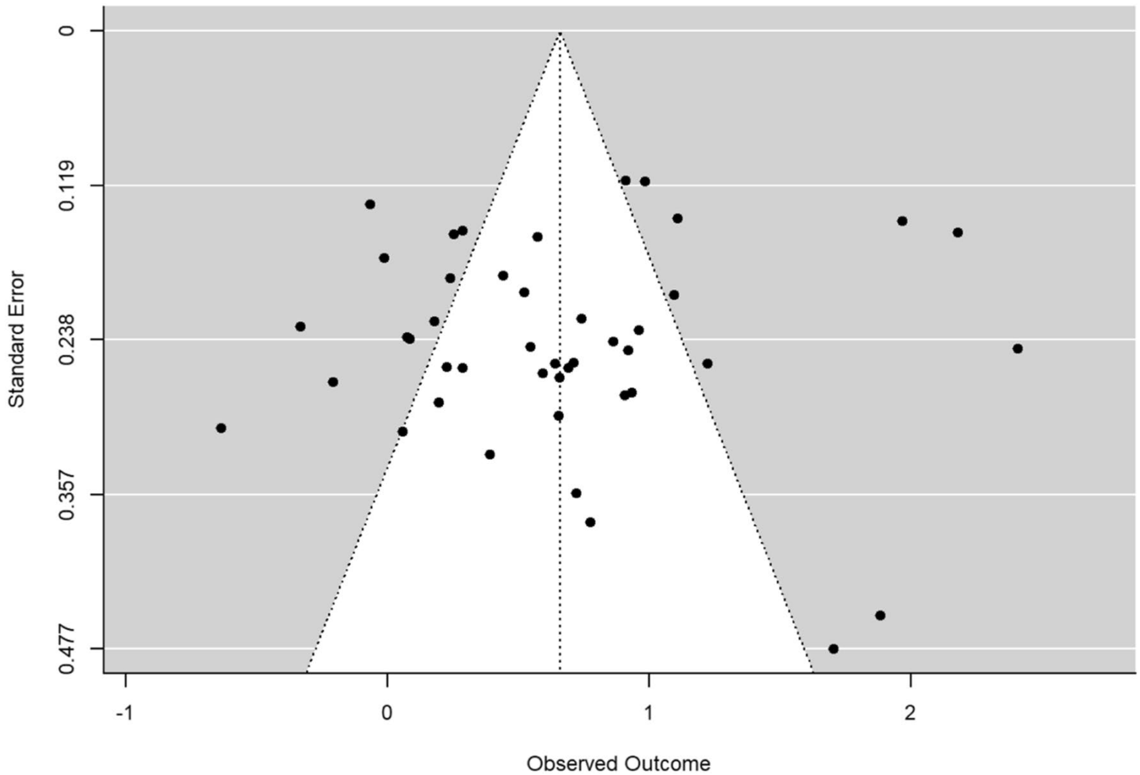

Fig. 3 Funnel plot demonstrating no publication bias

Table 5 Moderator analysis: country/region

Country/region	Effect size	SE	*Z*-value	*p*-value	Confidence interval	*Q*	df	*p*
Intercept (China as base)	0.287	0.593	0.484	0.628	(− 0.875, 1.449)	11.034	9	0.273
Hong Kong	− 0.24	0.697	− 0.344	0.73	(− 1.606, 1.126)			
India	0.298	0.645	0.462	0.644	(− 0.965, 1.561)			
Indonesia	0.975	0.687	1.419	0.156	(− 0.372, 2.322)			
Korea	0.126	0.726	0.173	0.863	(− 1.298, 1.549)			
Malaysia	0.261	0.747	0.349	0.727	(− 1.204, 1.725)			
Singapore	− 0.002	0.864	− 0.002	0.998	(− 1.695, 1.692)			
South Korea	− 0.267	0.739	− 0.362	0.718	(− 1.715, 1.18)			
Taiwan	0.528	0.607	0.869	0.385	(− 0.662, 1.718)			
Thailand	− 0.062	0.864	− 0.072	0.942	(− 1.755, 1.631)			

Table 6 Moderator analysis: discipline category

Discipline category	Effect size	SE	*Z*-value	*p*-value	Confidence interval	*Q*	df	*p*
Intercept (Engineering as base)	0.872	0.206	4.234	< .001	(0.468, 1.275)*	2.972	4	0.563
IT and Computer Science	− 0.189	0.291	− 0.649	0.517	(− 0.76, 0.382)			
Life Sciences	− 0.244	0.337	− 0.725	0.468	(− 0.904, 0.416)			
Mathematics	− 0.652	0.382	− 1.705	0.088	(− 1.401, 0.098)			
Sciences	− 0.237	0.269	− 0.881	0.378	(− 0.765, 0.29)			

different STEM discipline categories present in the studies yielded in the meta-analysis.

Discussion and Conclusion

The present meta-analysis is a quantitative synthesis and systematic review of experimental studies that attempts to summarise the findings of studies in peer-reviewed academic journals from 2000 to 2020 on the effects of active learning on Asian students' performance in STEM subjects. While the academic benefits of active learning pedagogies has been increasingly proven in Western contexts, due to substantial cultural differences in different geographical areas, it is important to analyse if other cultures are compatible with or positively impacted by similar pedagogies (Frambach et al., 2014). The effect size found in this study reflects a significant positive impact of active learning in Asian contexts, which implies that active learning pedagogies are able to cross the cultural barrier from Western to Asian cultures successfully, further justifying the introduction of educational policies towards active learning in Asian countries. Interestingly, not only is the effect size of our study highly compatible to that reported by Freeman's (2014) meta-analysis, but our results reflect a higher impact in Asian contexts. Freeman's results reflected a high preference for active learning with a medium effect size of 0.47. It is also notable that Freeman's results were comparable with previous meta-analysis on alternative pedagogies to traditional lecturing, which had effect sizes of 0.5 and 0.51 (Ruiz-Primo et al., 2011; Springer et al., 1999). These results reflect how changes in pedagogies in Western contexts increase student performance by about half a standard deviation. The results of our analysis reflects an effect size of 0.6596, which is over the classified medium effect size, and an increase from the previous medium classifications found in the previous studies in Western contexts. This significant effect size shows that, in Asian contexts, student performance increased by two thirds of a standard deviation, up from half a standard deviation in Western contexts. Hence, if we assume a comparable or higher SD of assessment marks as in Freeman's (2014) meta-analysis, then Asian student assessment performance scores, on average, increase more than 10%, relative to a class that does not implement active teaching pedagogies.

Next, we enumerate some of the plausible reasons which may help to explain why Asian students perform better in contrast to their 'Western' counterparts. First, in Asian contexts, the structured nature of the formal traditional lecture delivery is typically instructor-centred and highly content-oriented, whereby learners are passive recipients of information instead of active and engaged participants in the learning process (Carr et al., 2015; Tuyết, 2013a, b; Wong, 2004). By changing this static, didactic and almost repressed traditional lecture format into one that is active, learner-centred, inquiry-based and collaborative in nature, Asian students subsequently become fully engaged and find learning meaningful by fully participating in a novel learning activity. They begin to manifest an intrinsic desire and curiosity to engage in learning activities by interacting with their peers and instructors in learning tasks and activities that motivate them to learn and this in turn, is directly linked to their performance and overall achievement. Secondly, as active learning interventions signify a major adjustment and novel alternative for Asian students as compared to their Western counterparts, the application of this active learning approach may have a larger and more significant effect on Asian students as opposed to Western contexts. Finally, the deep learning process that results from this active learning instructional approach as opposed to the passive and rote learning approach, ultimately leads to higher-order learning, meaningful learning outcomes and enhanced academic performance.

Despite the encouraging findings found in the present meta-analytic review, the analysis presented here is not without limitations and thus, warrants discussion. One possible confounding factor is the potential for publication bias in meta-analysis of published studies, meaning those studies that demonstrate statistical significance (i.e., reported data that demonstrates a desired effect) are more likely to be published. Although the presence of publication bias was visually examined by a funnel plot and asymmetry test, the results should be interpreted cautiously. Moreover, since all the selected studies were from Asia, another limitation is related to heterogeneity between studies, that is, any variability (i.e., differences in study designs, subjects, populations and outcomes) seen across the included studies. Improvements and innovations in active learning pedagogies could lead to further gain in student performance (Freeman et al., 2014).

Bearing in mind the limitation of the heterogeneity of the studies analyzed, we can discuss further the results of the moderator analysis to start to examine possible differences on the effect of active learning within the defined constraints of: (1) the geographical region of Asia; and (2) disciplines categories within STEM. First, it is observed that country/region did not demonstrate a statistically significant degree of variation in the effect size. Previous studies have shown that active learning across cultures from geographically close regions, in both developing and developed Asian nations, have yielded positive results (Cambaliza et al., 2004; Ng et al., 2020; Park & Choi, 2014; Ting et al., 2019). This indicates that the current landscape of education and pedagogy drawn from varying cultures and traditions within Asia, are similar enough that the introduction and implementation of active learning strategies produces similar positive effects. However, it is noted that due to known limitations of this analysis, is a worthwhile topic of further research to see whether significant differences do emerge with larger sample sizes. If so, this could help further identify the possible aspects that result in higher effects of active learning, and help indicate to local educators and policymakers which populations can have significant benefits from active learning strategies.

Similarly, no variation is observed when active learning strategies are implemented in different STEM disciplines. As such, the positive and significant improvement of active learning within STEM that this meta-analysis observes is applicable to the wide range of subject matter within STEM. However, noting that STEM, broadly defined, includes a wide range of strong theoretical reasoning and practical application skills, as well as the limitations of this study, further research within the specific STEM subjects may still yield interesting results on the effect of active learning pedagogies.

Returning back to the current scope of this meta-analysis, several directions could be pursued. For instance, future research work could expand on the current study by examining learner engagement as well as learners' motivational and active learning strategies in relation to specific learning contexts such as face-to-face and blended learning environments. Another future study could be a meta-analytic review of studies on active learning in more specific contexts such as the use of technology-based learning activities and, for example, the relationship between technology-enabled active learning contexts, learner performance and higher-order skill development. Finally, the findings from this study have significant practical, research and application implications for instructors and teachers' instructional approaches to learning in university-level STEM courses, specifically how various active learning approaches and instructional methods could be used to improve student performance.

To conclude, this study is a first step toward a systematic and meta-analytic review of the effects of active learning on Asian students' performance in STEM subjects. The landscape of education in Asia, both in short term and long-term contexts, are being shaped by numerous factors, including access to technological advances, the prevalence of online and distance learning, as well as educational policy changes. These developments indicate that a change away from traditional lecturing and passive learning models is paramount and necessary. The results of this meta-analytic study indicate that the shift to active learning strategies can produce significant gains in academic achievement for Asian students, both encouraging calls to transform educational strategies in STEM classrooms, as well as warranting future study on its application in further learning contexts and how these strategies can be applied for an optimal effect on student performance and advancement.

Acknowledgments The authors would like to thank the University Grants Committee of the Hong Kong Special Administrative Region and the Hong Kong Polytechnic University (PolyU) for funding this project.

Funding This paper is part of a project funded by the University Grants Committee of the Hong Kong Special Administrative Region, entitled "Developing Active Learning Pedagogies and Mobile Applications in University STEM Education" (PolyU2/T&L/16-19) with additional support from the Hong Kong Polytechnic University.

Appendix 1

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
1	Impact of learner-centred teaching environment with the use of multimedia-mediated learning modules in improving learning experience	2014	T	E	Malaysia	IT	30	14	12.8	3.25	11.64	2.21	0.391
2	Mobile APP for motivation to learning: an engineering case	2016	T	Q	Taiwan	MS	45	42	70.66	12.86	62.97	6.72	0.742
3	A cloud-based learning environment for developing student reflection abilities	2014	T	Q	Taiwan	IE	35	35	35.42	5.73	32.14	6.281	0.546
4	Working towards a scalable model of problem-based learning instruction in undergraduate engineering education	2014	T	E	India	ECE	121	256	65.26	9.09	53.05	13.70	0.984
5	Working towards a scalable model of problem-based learning instruction in undergraduate engineering education	2014	T	E	India	ECE	121	256	40.84	4.37	36.46	5.00	0.911
6	Research on the learning effect of the positive emotions of "Ship Fuel-Saving Project" APP for engineering students	2019	T	E	Taiwan	ENG	56	59	6.78	1.56	5.92	2.25	0.442

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
7	Research on the learning effect of the positive emotions of "Ship Fuel-Saving Project" APP for engineering students	2019	T	E	Taiwan	ENG	56	59	56.64	3.7	34.27	12.45	2.409
8	An interactive concept map approach to supporting mobile learning activities for natural science courses	2011	P	E	Taiwan	NS	15	15	76	9.92	66.8	13.51	0.776
9	Exploring problem solving patterns and their impact on learning achievement in a blended learning environment	2011	T	E	Taiwan	COM	17	12	43.2	1.48	38.88	3.12	1.883
10	Using synchronous peer tutoring system to promote elementary students' learning in mathematics	2012	P	Q	Taiwan	MATH	57	31	30.53	11.88	28.29	13.67	0.179
11	Enhanced and conventional project-based learning in an engineering design module	2014	T	E	Singapore	ENG	30	30	64.43	8.48	62.18	7.24	0.285
12	Effects of an online team project-based learning environment with group awareness and peer evaluation on socially shared regulation of learning and self-regulated learning	2018	T	E	Taiwan	MIS	43	41	30.53	5.10	26.02	4.22	0.961

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Disci-pline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
13	Designing Reciprocative Dynamic Linking to improve learners' Representational Competence in interactive learning environments	2017	T	E	India	ENG	12	12	21.75	3.09	16.02	3.62	1.705
14	A progressive prompting approach to conducting context-aware learning activities for natural science courses	2014	P	E	Taiwan	NS	31	29	4.00	1.39	3.19	1.33	0.595
15	A blended learning model for learning achievement enhancement of Thai undergraduate students	2016	T	E	Thailand	TIE	30	30	16.93	3.31	16.13	3.76	0.225
16	The effects of digital storytelling on student achievement, social presence, and attitude in online collaborative learning environments	2017	S	E	Korea	CHEM	68	63	62.07	25.38	62.41	26.34	−0.013
17	A two-tier test approach to developing location-aware mobile learning systems for natural science courses	2010	P	E	Taiwan	NS	28	29	56.21	11.74	44.31	13.68	0.932
18	Interaction ofstudents' academic background and support levels in a resource-based learning environment on Earth's movement	2010	P	Q	Hong Kong	SCI	37	36	14.94	2.23	12.86	2.29	0.921

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
19	Interaction of students' academic background and support levels in a resource-based learning environment on Earth's movement	2010	P	Q	Hong Kong	SCI	27	28	10.40	2.18	10.89	2.499	−0.207
20	Advancing young adolescents' hypothesis-development performance in a computer-supported and problem-based learning environment	2011	P	Q	Korea	SCI	100	70	3.39	1.16	2.79	0.86	0.573
21	Advancing young adolescents' hypothesis-development performance in a computer-supported and problem-based learning environment	2011	P	Q	Korea	SCI	100	70	2.64	0.66	2.48	0.59	0.253
22	An approach to encouraging and evaluating learner's knowledge contribution in web-based collaborative learning	2012	T	E	Taiwan	IM	52	50	78.27	11.19	72.56	10.59	0.524
23	Effect of active learning using program visualization in technology-constrained college classrooms	2015	T	Q	India	CS	39	39	4.54	1.99	5.28	2.42	−0.334
24	Effect of active learning using program visualization in technology-constrained college classrooms	2015	T	Q	India	CS	136	95	6.18	2.55	6.35	2.52	−0.067

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Disci-pline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
25	Collaboration scripts for enhancing metacognitive self-regulation and mathematics literacy	2016	S	Q	Taiwan	MATH	35	37	40.23	11.9	39.3	13.43	0.073
26	Development and evaluation of a context-aware ubiquitous learning environment for astronomy education	2016	S	E	Taiwan	AST	132	132	83.53	5.52	72.75	4.3	2.179
27	A sun path observation system based on augment reality and mobile learning	2018	P	Q	Taiwan	AST	28	28	46.97	10.54	38.57	7.77	0.907
28	The impact of using LINE@ on the cooperative learning to improve the critical thinking skills of high school students	2018	S	E	Indonesia	PHY	33	31	66.90	6.87	59.87	14.10	0.641
29	A sustainability innovation experiential learning model for virtual reality chemistry laboratory: an empirical study with PLS-SEM and IPMA	2019	S	E	Taiwan	CHEM	36	36	87.17	7.47	77.82	7.82	1.223
30	Effects of augmented reality-based multidimensional concept maps on students' learning achievement, motivation and acceptance	2019	S	Q	Taiwan	NS	31	34	81.87	10.31	72.11	16.2	0.711

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
31	A competency-based guided-learning algorithm applied on adaptively guiding e-learning	2015	V	Q	Taiwan	CS	29	30	49.07	23.84	35.67	16.43	0.657
32	Extending engineering specialty course concepts in electrical engineering education	2015	T	E	China	EE	54	199	81.72	9.28	78.26	12.69	0.287
33	The effect of metacognitive scaffolds on low achievers' laboratory learning	2016	S	E	Taiwan	SCI	35	36	24.54	4.13	24.11	5.93	0.084
34	Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions	2018	P	E	Taiwan	NS	56	55	86.89	8.84	84.62	10.1	0.239
35	Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions	2018	P	E	Taiwan	NS	56	55	93.95	5.61	85.1	9.99	1.094
36	Impacts of m-DPBL approach towards computer networks teaching and learning process	2018	T	Q	Indonesia	CS	136	140	43.28	2.28	32.06	7.69	1.966

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Disci-pline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
37	The effect of problem-based learning model (PBL) towards creative thinking ability and self-efficacy of junior high school students in Pekanbaru	2018	S	Q	Indonesia	MATH	111	110	83.94	8.71	75.85	5.49	1.110
38	Mobile learning apps in instruction and students achievement	2017	T	E	India	PHY	24	24	70.66	14.06	62.43	10.88	0.655
39	An innovative consensus map-embedded collaborative learning system for ER diagram learning: sequential analysis of students' learning achievements	2019	T	Q	Taiwan	CS	35	42	85.71	13.61	70.24	20.84	0.863
40	Students' guided inquiry with simulation and its relation to school science achievement and scientific literacy	2020	S	Q	Taiwan	SCI	24	25	14.92	6.23	13.73	5.94	0.196
41	Verification of the possibility and effectiveness of experiential learning using HMD-based immersive VR technologies	2019	P	Q	Korea	SCI	20	22	43	6.68	42.55	8.32	0.059

Study ID#	Paper title	Year	School level	Design	Country of study/region of study	Discipline	Sample size		EG		CG		Effect size
							EG	CG	Mean	SD	Mean	SD	
42	Incorporating Wiki technology in a traditional biostatistics course: effects on university students' collaborative learning, approaches to learning and course performance	2017	T	Q	Hong Kong	BS	21	24	66.05	13.49	72.36	5.17	− 0.634
43	Implication of active learning techniques in learning thermodynamics energy conversion using BLOSSOMS thermodynamics energy conversion video towards engineering undergraduates performance	2019	T	Q	Malaysia	ENG	29	34	9.52	1.66	8.04	2.48	0.691
44	Impacts of a flipped classroom with a smart learning diagnosis system on students' learning performance, perception, and problem-solving ability in a software engineering course	2019	T	Q	Taiwan	SE	19	15	83.68	8.95	73.33	19.15	0.722

School level (*P* Primary, *S* Secondary, *T* Tertiary, *V* Vocational), Design (*E* Experimental, *Q* Quasi-experimental), Discipline (*AST* Astronomy, *BS* Biostatistics, *CHEM* Chemistry, *COM* Computing, *CS* Computer Science, *ECE* Electronics and Communication Engineering, *EE* Electrical Engineering, *ENG* Engineering, *IE* Industrial Engineering, *IM* Information Management, *IT* Information Technology, *MIS* Management Information Systems, *MS* Material Science, *MATH* Mathematics, *NS* Natural Science, *PHY* Physics, *SCI* Science, *SE* Software Engineering, *TIE* Technology in Education), *EG* experimental group, *CG* control group, *SD* standard deviation

References

Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE: Life Sciences Education, 8*(3), 203–213.

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE: Life Sciences Education, 16*(4), ar56.

Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics, 50*, 1088–1101.

Bonwell, C., & Sutherland, T. E. (1996). The active learning continuum: Choosing activities to engage students in the classroom. *New Directions for Teaching and Learning, 1996*(67), 3–16.

Burt, J. A. (2004). Impact of active learning on performance and motivation in female Emirati students. *Learning and Teaching in Higher Education: Gulf Perspectives, 1*(4), 1–15.

Cambaliza, O., Mazzolini, A., & Alarcon, M. (2004). Adapting active learning approaches in physics education to local Asian environments. In *Teaching and learning of physics in cultural contexts* (pp. 89–97). World Scientific.

Carr, R., Palmer, S., & Hagel, P. (2015). Active learning: The importance of developing a comprehensive measure. *Active Learning in Higher Education, 16*(3), 173–186.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences*. Academic.

Egger, M., Smith, G. D., & Phillips, A. N. (1997). Meta-analysis: Principles and procedures. *British Medical Journal, 315*(7121), 1533–1537.

Eichler, J. F., & Peeples, J. (2016). Flipped classroom modules for large enrollment general chemistry courses: A low barrier approach to increase active learning and improve student grades. *Chemistry Education Research and Practice, 17*(1), 197–208.

Frambach, J. M., Driessen, E. W., Beh, P., & van der Vleuten, C. P. M. (2014). Quiet or questioning? Students' discussion behaviors in student-centered education across cultures. *Studies in Higher Education, 39*(6), 1001–1021.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of USA, 111*(23), 8410–8415.

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., . . ., Wenderoth, M. P. (2007). Prescribed active learning increases performance in introductory biology. *CBE: Life Sciences Education, 6*(2), 132–139.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Academic.

Herreid, C. F., & Schiller, N. A. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching, 42*(5), 62–66.

Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine, 21*(11), 1539–1558.

Kim, K., Sharma, P., Land, S. M., & Furlong, K. P. (2013). Effects of active learning on enhancing student critical thinking in an undergraduate general science course. *Innovative Higher Education, 38*(3), 223–235.

Lee, W. W. S., & Yang, M. (2020). Effective collaborative learning from Chinese students' perspective: A qualitative study in a teacher-training course. *Teaching in Higher Education*. https://doi.org/10.1080/13562517.2020.1790517

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology, 45*(3), 317–324.

Machemer, P. L., & Crawford, P. (2007). Student perceptions of active learning in a large cross-disciplinary classroom. *Active Learning in Higher Education, 8*(1), 9–30.

Ng, O.-L., Ting, F., Lam, W. H., & Liu, M. (2020). Active learning in undergraduate mathematics tutorials via cooperative problem-based learning and peer assessment with interactive online whiteboards. *The Asia–Pacific Education Researcher, 29*(3), 285–294.

Ní Raghallaigh, M., & Cunniffe, R. (2013). Creating a safe climate for active learning and student engagement: An example from an introductory social work module. *Teaching in Higher Education, 18*(1), 93–105.

Nicol, A. A., Owens, S. M., Le Coze, S. S., MacIntyre, A., & Eastwood, C. (2018). Comparison of high-technology active learning and low-technology active learning classrooms. *Active Learning in Higher Education, 19*(3), 253–265.

Park, E. L., & Choi, B. K. (2014). Transformation of classroom spaces: Traditional versus active learning classroom in colleges. *Higher Education, 68*(5), 749–771.

Ruiz-Primo, M. A., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. A. (2011). Impact of undergraduate science course innovations on learning. *Science, 331*(6022), 1269–1270.

Shroff, R. H., Ting, F. S. T., Lam, W. H., Cecot, T., Yang, J., & Chan, L. K. (2021). Conceptualization, development and validation of an instrument to measure learners' perceptions of their active learning strategies within an active learning context. *International Journal of Educational Methodology, 7*(1), 201–223.

Sivan, A., Leung, R. W., Woon, C.-C., & Kember, D. (2000). An implementation of active learning and its effect on the quality of student learning. *Innovations in Education and Teaching International, 37*(4), 381–389.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69*(1), 21–51.

Ting, F. S. T., Lam, W. H., & Shroff, R. H. (2019). Active learning via problem-based collaborative games in a large mathematics university course in Hong Kong. *Education Sciences, 9*(3), 1–22.

Trinidad, J. E. (2019). Understanding student-centred learning in higher education: Students' and teachers' perceptions, challenges, and cognitive gaps. *Journal of Further and Higher Education, 44*(2), 1–11.

Tuyết, T. T. (2013a). The causes of passiveness in learning of Vietnamese students. *VNU Journal of Science: Education Research, 29*(2).

Tuyết, T. T. (2013b). Is the learning approach of students from the Confucian heritage culture problematic? *Educational Research for Policy and Practice, 12*(1), 57–65.

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education, 7*(1), 1–18.

Wilson, D. B., & Lipsey, M. W. (2001). The role of method in treatment effectiveness research: Evidence from meta-analysis. *Psychological Methods, 6*(4), 413.

Wong, J.K.-K. (2004). Are the learning styles of Asian international students culturally or contextually based? *International Education Journal, 4*(4), 154–166.

Wright, M. C., Bergom, I., & Bartholomew, T. (2019). Decreased class size, increased active learning? Intended and enacted teaching strategies in smaller classes. *Active Learning in Higher Education, 20*(1), 51–62.

Yoder, J. D., & Hochevar, C. M. (2005). Encouraging active learning can improve students' performance on examinations. *Teaching of Psychology, 32*(2), 91–95.

Yuretich, R. F., Khan, S. A., Leckie, R. M., & Clement, J. J. (2001). Active-learning methods to improve student performance and scientific interest in a large introductory oceanography course. *Journal of Geoscience Education, 49*(2), 111–119.