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# Learning Outcomes of Flipped Classroom Approaches in Pharmacy Education: Evidence from a Meta-Analysis

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## Abstract

In recent years, the flipped classroom has emerged as an alternative pedagogical model in pharmacy education, combining digital pre-class learning with in-person, student-centered classroom activities. Despite its growing adoption, uncertainty remains regarding whether this instructional approach offers clear advantages over conventional lecture-based teaching. This meta-analysis was undertaken to critically assess and quantify the comparative effectiveness of flipped classroom instruction versus traditional lectures, aiming to provide a more definitive evaluation of its educational impact within pharmacy curricula.A systematic search strategy was applied to seven electronic databases, including the Cochrane Library, PubMed, Embase, ScienceDirect, Web of Science, China National Knowledge Infrastructure (CNKI), and the Chinese Biomedical Literature Service System (SinoMed). Studies were considered eligible if they reported objective measures of academic performance and directly compared flipped classroom formats with traditional instructional methods. Effect sizes were synthesized using standardized mean differences (SMDs) and corresponding 95% confidence intervals (95% CIs).The analysis incorporated 22 eligible studies, representing 28 independent comparisons and a total sample size of 4,379 students. Overall methodological quality was variable, with many studies demonstrating an elevated risk of bias. Meta-analytic findings indicated that students exposed to flipped classroom instruction achieved significantly higher academic performance than those receiving traditional lectures, and no significant publication bias was detected. Further subgroup analyses confirmed the superiority of the flipped classroom across different outcome measures and educational levels.The findings of this meta-analysis indicate that flipped classroom pedagogy is associated with meaningful improvements in learning outcomes in pharmacy education compared with conventional teaching approaches. To maximize these benefits, future instructional designs should prioritize the strategic use of educational technologies and foster active, interactive learning environments.

**Keywords:** Learning performance, Meta-analysis, Flipped classroom, Flipped learning, Pharmacy education

## Introduction

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The flipped classroom represents a blended instructional approach that combines self-paced, asynchronous learning before class with interactive, application-focused activities during scheduled class time. Under this model, students are introduced to core learning materials outside the classroom, while face-to-face sessions are reserved for higher-order cognitive tasks such as problem solving, guided discussion, and debate, allowing instructors to support deeper knowledge integration [1].

A key strength of the flipped classroom lies in its emphasis on learner-centered education, which encourages active student participation and increased interaction between students and instructors [2]. Prior to attending class, learners review assigned materials to establish foundational understanding. Classroom time is then structured around activities designed to stimulate engagement and motivation, including student presentations, clinical case analyses, and interactive learning exercises. This instructional shift moves students away from passive reception of information toward active knowledge construction, thereby fostering critical thinking skills and creativity [2]. Furthermore, collaborative learning strategies, such as group discussion and cooperative problem solving, enable students to benefit from peer-to-peer learning, which can be more effective than instructor-led instruction alone [3, 4].

In recent years, the flipped classroom approach has been increasingly adopted across multiple disciplines within health professions education, including pharmacy programs [5–7]. Several systematic reviews have attempted to evaluate its educational effectiveness in this context. Chen *et al*. conducted a meta-analysis examining the impact of flipped classrooms across health professions education using outcomes such as examination scores, course grades, and objective structured clinical examinations (OSCEs) [5]. Their analysis incorporated both controlled comparisons and pre-post study designs. Subgroup analysis specific to pharmacy education demonstrated favorable effects of flipped classrooms on examination performance (n = 7, 95% confidence interval SMD 0.53 [0.12, 0.93]) and course grades (n = 3, 95% confidence interval SMD 0.53 [0.35, 0.71]), although substantial statistical heterogeneity was observed. Similarly, Hew and Lo evaluated flipped classroom interventions across health education disciplines and included a pharmacy education subgroup [7]. Their findings also supported the flipped classroom model (n = 10, 95% confidence interval SMD 0.45 [0.24, 0.65]), but again with considerable heterogeneity. Gillette *et al*. compared traditional and flipped instructional formats specifically within pharmacy schools (n = 6, 95% confidence interval WMD 2.90 [−0.02, 5.81]); however, due to the limited number of included studies, subgroup analyses were not performed, and variations in instructional contact hours between intervention and control groups were present [6].

Although these reviews provide preliminary evidence supporting flipped classroom instruction, they differ in study selection and offer limited subgroup analyses focused specifically on pharmacy education. To address these gaps, the present meta-analysis was conducted to systematically assess the effectiveness of flipped classroom pedagogy within pharmacy education. By incorporating a broader range of eligible studies and performing subgroup analyses, this study aimed to deliver a more comprehensive and conclusive evaluation of the educational value of the flipped classroom for pharmacy students.

## Materials and Methods

This meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The study protocol was prospectively registered with the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY; registration number: INPLASY202380130), and the full protocol is publicly accessible at https://inplasy.com/inplasy-2023-8-0130/.

### *Literature search strategy*

A comprehensive literature search was conducted across seven electronic databases, including the Cochrane Library, PubMed, Embase, ScienceDirect, Web of Science, China National Knowledge Infrastructure (CNKI), and the Chinese Biomedical Literature Service System (SinoMed). The search covered all available studies published up to October 10, 2022. A predefined search string was applied consistently across all databases using combinations of the following terms: ((flipped classroom) OR (flipped education) OR (flipped learning) OR (reverse classroom) OR (backward classroom) OR (inverted classroom) OR (inverse classroom)) AND (pharmac*). Searches were performed independently in each database using the same keyword strategy.

### *Eligibility criteria*

#### *Study design*

Studies were eligible if they examined the effectiveness of flipped classroom instruction in pharmacy education compared with traditional lecture-based or face-to-face teaching methods and included objective measures of student academic performance, such as course grades or grade point averages. The following study designs were included: randomized controlled trials (RCTs), quasi-experimental studies, and historical (retrospective) cohort studies. In RCTs, participants were randomly assigned to either flipped classroom or traditional instruction groups. Quasi-experimental studies included non-random group allocation, such as assigning different instructional formats to separate classes. Historical cohort studies compared outcomes from flipped classroom implementations with previously collected academic data from traditional teaching cohorts. Studies employing a before-and-after design without a parallel control group were excluded, as these designs only compared outcomes before and after implementation of flipped classroom instruction.

**Participants:** The target population comprised pharmacy students enrolled in higher education institutions and participating in courses within formal pharmacy curricula.

**Interventions and Comparators:** In the experimental groups, flipped classroom instruction involved instructor-prepared pre-class materials, independent student learning prior to class sessions, and interactive in-class activities facilitating engagement between students and instructors. Control groups received conventional lecture-centered instruction. To ensure comparability, studies were required to maintain equivalent credit hours, class duration, and course content between intervention and control groups.

**Outcome Measures:** Primary outcomes included course grades or examination scores used to assess academic performance. Assessment methods and content were required to be comparable or identical between flipped classroom and traditional teaching groups to ensure valid comparisons.

**Exclusion Criteria:** Studies were excluded if they lacked an appropriate control group, did not provide sufficient data for effect size calculation, or involved participants from primary or secondary (K–12) education. Additional exclusion criteria included publication in languages other than English or Chinese and studies published prior to the year 2000.

*Data extraction*

Two reviewers independently screened all eligible articles and extracted relevant data, including author information, year of publication, country of origin, sample size, type of pharmacy course, academic level of students, characteristics of the flipped classroom intervention, instructional approach used in the control group, and outcome measures. Any disagreements between the two reviewers were resolved through discussion, and unresolved discrepancies were settled by consultation with a third reviewer.

*Methodological quality assessment*

The methodological rigor of the included studies was evaluated using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool, which is appropriate for assessing both experimental and observational research designs [8]. The assessment covered six domains: selection bias, study design, control of confounders, blinding, data collection methods, and participant withdrawals or dropouts. Each study was assigned a rating of Strong, Moderate, or Weak for individual domains. An overall quality rating was then determined based on the number of domains rated as weak: studies with no weak ratings were classified as Strong, those with one weak rating as Moderate, and those with two or more weak ratings as Weak.

*Statistical analysis*

Statistical analyses were conducted using Stata/SE version 16 (StataCorp LLC, College Station, TX). Effect sizes were calculated using standardized mean differences (SMDs) with a random-effects model, based on reported means and standard deviations (SDs). Given that educational studies frequently report multiple outcome measures, data were extracted and analyzed separately according to the specific type of academic performance assessed. When multiple similar outcomes were available within a single study, the most representative measure was selected for inclusion in the meta-analysis. In cases where a study reported separate performance outcomes for different course modules or components, each independent comparison was treated as a distinct dataset and analyzed separately.

For studies in which essential statistical information (such as means or SDs) was missing, corresponding authors were contacted to obtain the necessary data. Studies were excluded if the required information could not be retrieved. Statistical heterogeneity was evaluated using the $I^2$ statistic, with values below 25% indicating low heterogeneity, values between 25% and 50% indicating moderate heterogeneity, and values exceeding 50% indicating substantial heterogeneity. When high heterogeneity was detected, subgroup analyses were conducted to explore potential sources, including differences in outcome measures, study design, degree programs, geographic regions, and assessment formats. Publication bias was assessed quantitatively using Begg's test and Egger's regression test, alongside qualitative inspection of funnel plot symmetry.

## Results and Discussion

*Literature search results*

The study selection process is summarized in a PRISMA flow diagram **(Figure. 1).** A total of 933 records were initially identified through the literature search. Of these, 914 records were retrieved from the seven electronic databases, while an additional 19 studies were identified by screening reference lists. During the screening and eligibility assessment stages, 911 records were excluded. Specifically, 186 records were removed as duplicates, 654 studies were excluded after review of titles and abstracts, and 71 articles were eliminated following full-text evaluation.

Ultimately, 22 studies encompassing 28 independent comparison groups and involving a total of 4,379 participants met the inclusion criteria and were incorporated into the meta-analysis [2, 9–29]. Within these studies, Prescott *et al*. contributed two comparison groups, Wong *et al*. reported three comparison groups, and Sumanasekera *et al.* provided four comparison groups.

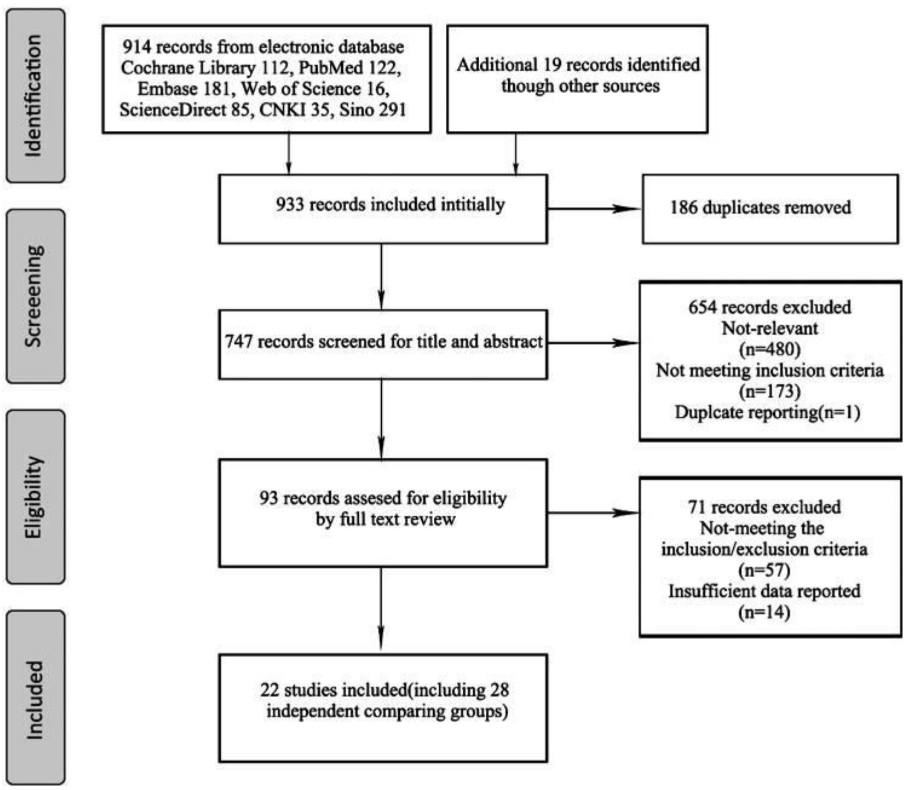


**Figure 1.** PRISMA flowchart illustrating the process of study identification, screening, and inclusion. CNKI refers to China National Knowledge Infrastructure; SinoMed denotes the Chinese Biomedical Literature Service System.

*Characteristics of included studies*

The 22 studies included in this meta-analysis were published between 2014 and 2022. Sample sizes across studies varied considerably, ranging from 35 to 588 pharmacy students (**Table 1**). Among the included publications, 21 were full-text journal articles, while one was reported as a conference abstract.

Regarding study design, the dataset comprised one randomized controlled trial, three quasi-experimental studies, and 18 studies employing historical control designs. Geographically, the majority of studies were conducted in the United States (n = 16), with additional contributions from China (n = 3), Thailand (n = 1), Malaysia (n = 1), and Qatar (n = 1).

With respect to outcome assessment, two studies evaluated student performance using overall course grades, while 18 studies relied on examination scores. One study assessed outcomes using an objective structured clinical examination (OSCE), and another study incorporated both final examination results and OSCE scores. Among the studies that utilized examination-based outcomes, 11 employed multiple-choice question (MCQ) formats, one used calculation-based questions, one included fill-in-the-blank and short-answer items, and six adopted mixed or hybrid examination formats.

In terms of academic level, eight studies involved Doctor of Pharmacy (PharmD) students, two focused on undergraduate programs, one included graduate-level students, and one examined students enrolled in an associate degree program.

**Table 1.** Characteristics of the included studies.

| No. | Study (Year) | Study Design | Sample Size (CG / IG) | Country | Publication Type | Participants / Course | Outcome Measure |
|---|---|---|---|---|---|---|---|
| 1 | Prescott *et al.* (2016) | Historical control | 108 / 123 | USA | Journal | 1st-year PharmD – Patient Assessment I | Overall course grade |
| | | Historical control | 97 / 129 | USA | Journal | 2nd-year PharmD – Patient Assessment II | Overall course grade |
| 2 | He *et al*. (2019) | Randomized controlled trial | 56 / 81 | China | Journal | Undergraduate – Pharmaceutical Marketing & Management | Examination score (short answers, MCQs, essays) |
| 3 | Kangwantas *et al.* (2017) | Historical control | 21 / 29 | Thailand | Journal | 2nd-year PharmD – Fundamental Nutrition | Final examination score (MCQs) |
| 4 | Gloudeman *et al.* (2018) | Historical control | 104 / 102 | USA | Journal | 1st-year pharmacy – Pharmaceutical Calculations | Calculation exam score |
| 5 | Goh *et al.* (2019) | Historical control | 74 / 63 | Malaysia | Journal | 2nd-year pharmacy – Dosage Forms | Examination score (MCQs and essays) |
| 6 | Taglieri *et al.* (2017) | Historical control | 283 / 305 | USA | Journal | 3rd-year PharmD – OTC & Self-Care Products | Final course grade |
| 7 | Lockman *et al.* (2017) | Historical control | 156 / 162 | USA | Journal | 1st-year PharmD – Pharmacology & Therapeutics | OSCE and final exam scores |
| 8 | Koo *et al.* (2016) | Historical control | 89 / 89 | USA | Journal | 2nd-year PharmD – Integrated Pharmacotherapy | Final exam score (MCQs) |
| 9 | Munson *et al.* (2015) | Historical control | 125 / 113 | USA | Journal | 1st professional year – Pharmacogenomics | Final exam score |
| 10 | Wong *et al.* (2014) | Historical control | 105 / 101 | USA | Journal | 1st-year pharmacy – Cardiac Arrhythmias (Basic Sciences) | Final exam score (MCQs) |
| | | Historical control | 105 / 101 | USA | Journal | 1st-year pharmacy – Cardiac Arrhythmias (Pharmacology) | Final exam score (MCQs) |
| | | Historical control | 105 / 101 | USA | Journal | 1st-year pharmacy – Cardiac Arrhythmias (Therapeutics) | Final exam score (MCQs) |
| 11 | Bossaer *et al.* (2016) | Historical control | 72 / 76 | USA | Journal | 3rd professional year – Pharmacotherapy | Final exam score (matching & MCQs) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 | Cotta *et al.* (2016) | Historical control | 165 / 151 | USA | Journal | 1st-year pharmacy – Pharmaceutical Calculations | Final exam score (short answer/fill-in) |
| 13 | McLaughlin *et al.* (2014) | Historical control | 153 / 162 | USA | Journal | 1st-year PharmD – Basic Pharmaceutics | Final exam score (MCQs) |
| 14 | McLaughlin *et al.* (2013) | Historical control | 13 / 22 | USA | Journal | 1st-year pharmacy – Basic Pharmaceutics II | Final exam score (MCQs) |
| 15 | Pierce *et al.* (2012) | Historical control | 68 / 71 | USA | Journal | Undergraduate & Graduate – Renal Pharmacotherapy | Final exam score (MCQs) |
| 16 | Stewart *et al.* (2013) | Historical control | 65 / 71 | USA | Journal | PharmD – Pharmacotherapy module | Final exam score (MCQs) |
| 17 | Donihi *et al.* (2014) | Historical control | 123 / 133 | USA | Conference | 2nd-year PharmD – Gastroenterology & Nutrition | Final exam score (MCQs) |
| 18 | Sumanasekera *et al.* (2020) | Historical control | 91 / 73 | USA | Journal | 2nd-year pharmacy – Hypertension | Final exam score (MCQs) |
| | | Historical control | 91 / 73 | USA | Journal | 2nd-year pharmacy – Kidney & Diuretics | Final exam score (MCQs) |
| | | Historical control | 91 / 73 | USA | Journal | 2nd-year pharmacy – Diabetes | Final exam score (MCQs) |
| | | Historical control | 91 / 73 | USA | Journal | 2nd-year pharmacy – Cardiovascular | Final exam score (MCQs) |
| 19 | Nazar *et al.* (2019) | Historical control | 63 / 69 | Qatar | Journal | Master of Pharmacy – Pharmacy Law | Final exam score (MCQs) |
| 20 | Anderson *et al.* (2017) | Quasi-experimental | 32 / 38 | USA | Journal | 1st-year pharmacy – Pharmaceutical Calculations | OSCE performance |
| 21 | Chen *et al.* (2020) | Quasi-experimental | 44 / 49 | China | Journal | Associate degree – Medicinal Botany | Final exam score |
| 22 | Wang *et al.* (2019) | Quasi-experimental | 30 / 30 | China | Journal | Undergraduate – Individualized Cardiovascular Pharmacotherapy | Final exam score |

OSCE: Objective Structured Clinical Examination; IG, Intervention groups; CG, Controlled groups; MCQ, Multiple choice questions; CN, China

*Quality assessment*

An evaluation of methodological rigor was conducted for the 22 studies included in this review. The assessment showed that 19 studies were classified as having a high risk of bias, whereas only 3 studies demonstrated a moderate risk of bias **(Table 2)**. The high risk ratings were predominantly attributed to weaknesses in blinding procedures, inadequate data collection practices, insufficient control of confounding variables, and incomplete reporting of participant attrition.

In general, the included studies lacked comprehensive methodological reporting, which limited the ability to judge their internal validity. Critical details were frequently omitted, such as clear definitions of the target population, information on participant loss to follow-up, baseline participant characteristics, identification of key confounders across study groups, and evidence supporting the reliability or validity of the measurement instruments used.

**Table 2.** Methodological quality and risk of bias of included studies.

| NO. | Study ID | Study Design | Selection Bias | Blinding | Confounders | Withdrawals and Dropouts | Overall Rating | Data Collection Methods |
|---|---|---|---|---|---|---|---|---|
| 1 | Prescott, *et al.* 2016 | 2 | 2 | 3 | 3 | 3 | 2 | 2 |
| 2 | He, *et al.* 2019 | 1 | 1 | 3 | 1 | 1 | 1 | 2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | Kangwantas, *et al.* 2017 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 4 | Gloudeman, *et al.* 2018 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 5 | Goh, *et al*. 2019 | 2 | 2 | 3 | 2 | 2 | 3 | 3 |
| 6 | Taglieri, *et al.* 2017 | 2 | 2 | 3 | 3 | 3 | 3 | 2 |
| 7 | Lockman, *et al*. 2017 | 2 | 2 | 3 | 1 | 1 | 2 | 2 |
| 8 | Koo, *et al*. 2016 | 2 | 2 | 3 | 3 | 1 | 2 | 3 |
| 9 | Munson, *et al*. 2015 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 10 | Wong, *et al*. 2014 | 2 | 2 | 3 | 1 | 1 | 2 | 3 |
| 11 | Bossaer, *et al*. 2016 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 12 | Cotta, *et al*. 2016 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 13 | McLaughlin, *et al.* 2014 | 2 | 2 | 3 | 1 | 3 | 2 | 2 |
| 14 | McLaughlin, *et al.* 2013 | 2 | 2 | 3 | 3 | 1 | 3 | 3 |
| 15 | Pierce, *et al*. 2012 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 16 | Stewart, *et al*. 2013 | 2 | 2 | 3 | 2 | 3 | 2 | 2 |
| 17 | Donihi, *et al*. 2014 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 18 | Sumanasekera, *et al*. 2020 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 19 | Nazar, *et al*. 2019 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 20 | Anderson, *et al.* 2017 | 1 | 1 | 3 | 1 | 1 | 1 | 2 |
| 21 | Chen, *et al*. 2020 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 22 | Wang, *et al*. 2019 | 1 | 2 | 3 | 3 | 1 | 3 | 3 |

1 = Strong methodological quality; 2 = Moderate methodological quality;3 = Poor methodological quality; EPHPP, The Effective Public Health Practice Project Quality Assessment Tool

*Data synthesis*

Twenty-two studies encompassing 28 comparison groups were included in the quantitative synthesis to examine differences in pharmacy students' academic performance between flipped classroom and traditional instructional methods. Given the substantial between-study variability ($I^2$ = 98.3%**)**, a random-effects model was employed for the meta-analysis. The pooled analysis demonstrated that the flipped classroom approach was associated with a significantly greater improvement in student performance compared with lecture-based learning (SMD = 1.30; 95% CI: 0.84–1.76; $P < 0.001$), as illustrated in **Figure 2.**

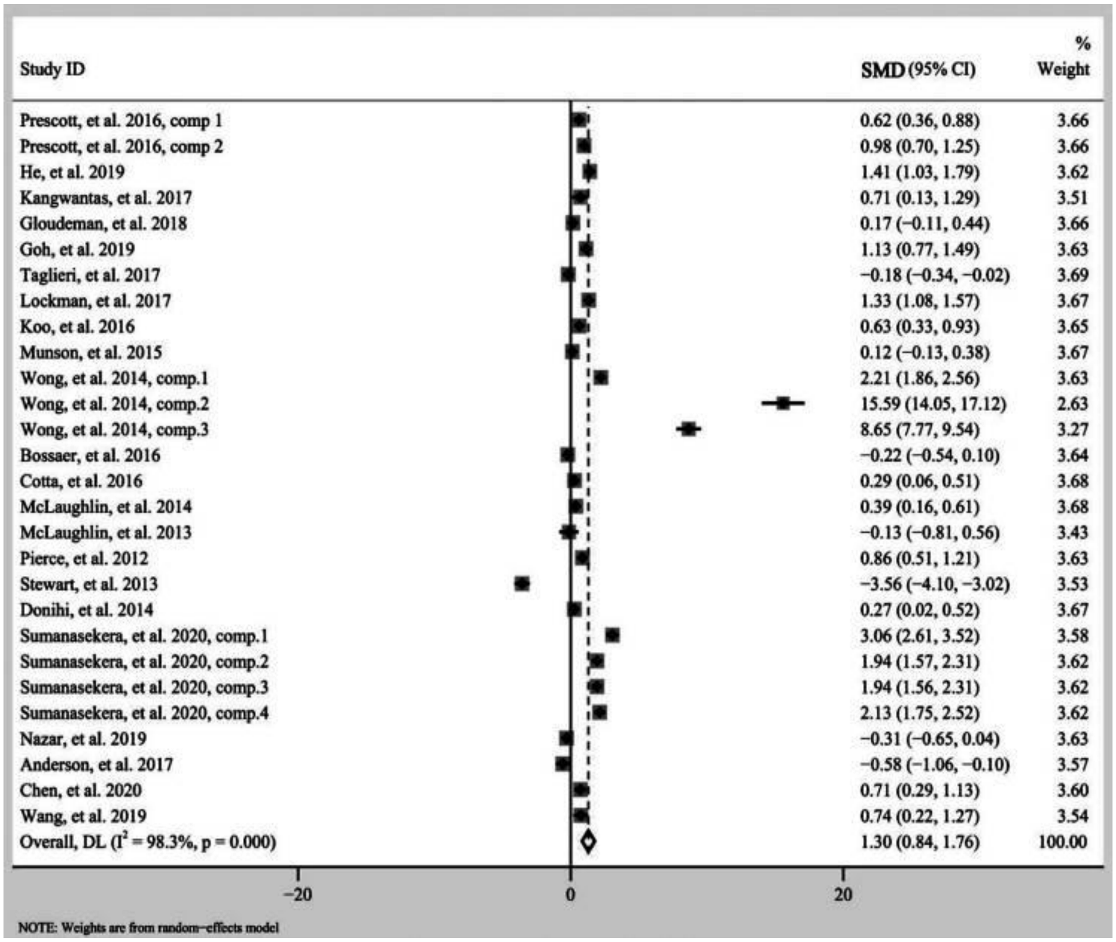

**Figure 2.** Forest plot illustrating the comparative effectiveness of flipped classroom instruction versus conventional lecture-based teaching. *SMD* denotes standardized mean difference; *CI* indicates confidence interval; *comp* refers to comparison groups.

*Subgroup meta-analysis*

Subgroup analyses were performed to explore the impact of flipped classroom approaches relative to traditional instructional strategies from multiple analytical perspectives. Only subgroups containing more than two comparison groups were included in these analyses. The findings indicated that considerable heterogeneity persisted across all examined subgroups, as summarized in **Table 3.**

**Table 3.** Results of subgroup analyses.

| Subgroup / Domain | n | Effects (SMD, 95% CI) | I² (%) | p-value | Heterogeneity p-value |
|---|---|---|---|---|---|
| **Research Design** | | | | | |
| Quasi-experiment | 24 | 0.31 (0.04, 0.58) | 89.60 | 0.023 | < 0.001 |
| RCT | 1 | 1.41 (1.03, 1.79) | | | |
| Historical control | 3 | 1.58 (1.49, 1.68) | 99.00 | < 0.001 | < 0.001 |
| **Outcome Measures** | | | | | |
| Exam scores | 24 | 1.82 (1.71, 1.93) | 99.00 | < 0.001 | < 0.001 |
| OSCE | 2 | 0.98 (0.77, 1.20) | 97.90 | < 0.001 | < 0.001 |
| Course grade | 3 | 0.25 (0.13, 0.38) | 96.70 | < 0.001 | < 0.001 |
| **Country** | | | | | |
| Non-US | 6 | 0.74 (0.58, 0.91) | 90.40 | < 0.001 | < 0.001 |

| | | | | | |
|---|---|---|---|---|---|
| US | 22 | 1.63 (1.53, 1.72) | 99.10 | < 0.001 | < 0.001 |
| **Degree Programs** | | | | | |
| Associate | 1 | 0.71 (0.29, 1.13) | | | |
| Doctor of Pharmacy | 9 | 0.24 (0.15, 0.32) | 97.60 | < 0.001 | < 0.001 |
| Graduate | 1 | -0.31 (-0.65, 0.04) | | | |
| Undergraduate | 2 | 1.2 (0.9, 1.51) | 75.30 | < 0.001 | 0.044 |
| **Course Type** | | | | | |
| Interdisciplinary course | 2 | 0.57 (0.31, 0.82) | 97.70 | < 0.001 | < 0.001 |
| Pharmacy course | 26 | 1.58 (1.48, 1.67) | 99.00 | < 0.001 | < 0.001 |
| **Format of Test** | | | | | |
| Blend | 6 | 0.62 (0.49, 0.75) | 88.50 | < 0.001 | < 0.001 |
| MCQ | 16 | 2.57 (2.41, 2.73) | 99.40 | < 0.001 | < 0.001 |
| Calculation questions | 1 | 0.17 (-0.11, 0.44) | | | |
| Short answer and fill-in-blanks | 1 | 0.29 (0.06, 0.51) | | | |
| **Flipped Classroom Design** | | | | | |
| Incorporating patient case discussion in-class | 18 | 2.14 (2.02, 2.27) | 99.30 | < 0.001 | < 0.001 |
| Quiz at start of in-class | 9 | 3.91 (3.66, 4.16) | 99.70 | < 0.001 | < 0.001 |
| Short recorded video pre-class (average duration < 18 min) | 6 | 0.63 (0.37, 0.88) | 70.8 | 0.004 | < 0.001 |

CI, Confidence Interval; MCQ, Multiple Choice Questions; SMD, Standardized Mean Difference; RCT, Randomized Controlled Trial; OCSE, Objective Structured Clinical Examination

With respect to outcome measures, the flipped classroom approach demonstrated statistically significant benefits across multiple indicators, including examination performance, overall course grades, and Objective Structured Clinical Examinations (OSCEs). Notably, the study by Lockman et al. assessed both final examination scores and OSCE outcomes, further supporting the instructional effectiveness of the flipped classroom model [21]. Given variations in assessment formats, a subgroup analysis was conducted focusing specifically on final examination outcomes. The results indicated that students exposed to flipped classrooms achieved significantly higher scores under both multiple-choice question (MCQ) formats and mixed (blended) examination formats.

When studies were categorized by research design, both historical control studies and quasi-experimental designs consistently showed superior student performance associated with flipped classroom instruction compared with traditional lecture-based teaching.

Subgroup analyses based on geographic location revealed that the positive effects of the flipped classroom were evident in both U.S. and non-U.S. contexts. All non-U.S. studies originated from Asian countries, including China, Qatar, Thailand, and Malaysia.

Analysis by degree program indicated that flipped classroom instruction was advantageous in both Doctor of Pharmacy (PharmD) and undergraduate pharmacy programs. Studies involving PharmD programs were conducted in the United States and Thailand, whereas all undergraduate-level studies were carried out in China.

To further examine the influence of instructional design features within flipped classrooms, four pedagogical components were evaluated through subgroup meta-analyses: incorporation of patient case scenarios, delivery of interdisciplinary courses, use of pre-class videos shorter than 18 minutes, and the inclusion of quizzes at the beginning of class sessions.

Given prior evidence suggesting that flipped classrooms enhance problem-solving skills, studies incorporating patient case scenarios were analyzed separately. This subgroup included 18 comparison groups and demonstrated a substantially greater effect favoring the flipped classroom model (SMD = 2.14, 95% CI: 2.02–2.27).

Two studies examined interdisciplinary course designs: one integrating pharmacy and marketing education by He *et al*., and another combining pharmacy and law by Nazar *et al*. Both studies contributed to a pooled analysis that showed improved outcomes associated with the flipped classroom approach (SMD = 0.57, 95% CI: 0.31–0.82).

Seven comparison groups were included in the analysis of flipped classrooms utilizing pre-class videos of less than 20 minutes in duration. This subgroup analysis indicated a modest but significant advantage of the flipped classroom over traditional instruction (SMD = 0.32, 95% CI: 0.22–0.42).

Similarly, the subgroup examining the availability of quizzes at the start of class comprised nine comparison groups and demonstrated a pronounced benefit for flipped classroom instruction (SMD = 3.91, 95% CI: 3.66–4.16).

*Publication bias*

Assessment of publication bias using a funnel plot revealed marked asymmetry, suggesting the presence of significant publication bias. This observation was further supported by statistical testing, as both Egger's regression test ($P = 0.007$) and Begg's test ($P = 0.028$) yielded P values below the 0.05 threshold.

The findings of this meta-analysis indicate that the application of the flipped classroom model in pharmacy education is more effective than traditional lecture-based instruction in enhancing students' academic performance.

One key advantage of the flipped classroom is its emphasis on in-class practical activities, which are often insufficiently addressed in pharmacy higher education [30, 31]. By integrating online learning resources with active, task-oriented classroom sessions, the flipped classroom helps pharmacy education adapt to the demands of the digital era and promotes student engagement in applied learning activities [32]. Moreover, the use of interactive instructional strategies—such as problem-based discussions—supports the development of students' practical and operational competencies, better preparing them for the evolving responsibilities of the pharmacy profession.

The flipped classroom also employs short instructional videos that enhance learner engagement and sustain attention. Previous research has shown that medical students are typically able to maintain concentration for only 15–20 minutes at the start of a lecture [2]. Attention tends to decline thereafter due to cognitive limitations, particularly in pharmacy education, which often requires extensive memorization [33]. A comparable example can be found in TED Talks, which are limited to 18 minutes—long enough to convey essential concepts while remaining concise enough to maintain audience focus [33]. Accordingly, instructors implementing flipped classrooms often design brief videos or divide full lectures into shorter segments. Drawing on this rationale, videos shorter than 18 minutes were selected for subgroup analysis. The evaluation of six pharmacy education trials demonstrated that flipped classrooms using short pre-class videos produced superior outcomes compared with traditional teaching approaches.

Another strength of the flipped classroom lies in its suitability for interdisciplinary learning. When implemented in courses involving multiple academic disciplines, the flipped classroom facilitates peer learning through collaborative tasks and group-based discussions [25, 26]. Such experiences enable pharmacy students to develop teamwork and communication skills, easing their transition into interdisciplinary professional environments after graduation [34]. Given the interactive and team-based structure of flipped classrooms, we hypothesized that this model would be particularly effective in interdisciplinary contexts. However, only two comparison groups were available for this subgroup analysis, which showed favorable outcomes but also substantial heterogeneity. Consequently, additional studies are required to draw more definitive conclusions.

The flipped classroom model may also promote long-term knowledge retention, a particularly important outcome for pharmacy students, who must master large volumes of factual information [35, 36]. This approach incorporates repeated retrieval practices: students first review content through pre-class videos, then answer recall-based questions, complete quizzes at the beginning of class, and subsequently participate in periodic assessments such as monthly and final examinations. Repeated retrieval strengthens memory consolidation and contributes to improved academic performance. Hew and Lo emphasized that flipped classrooms are especially effective when quizzes are administered at the start of class sessions [7]. Consistent with this observation, our meta-analysis demonstrated that the inclusion of in-class quizzes was associated with improved learning outcomes in flipped classrooms.

*Strengths and limitations*

Several limitations should be considered when interpreting the findings of this meta-analysis. First, a high level of statistical heterogeneity was observed, which limits the strength of the conclusions. This heterogeneity likely stems from substantial variation in flipped classroom designs, as instructors may interpret and implement the model differently, resulting in diverse educational practices and learning effects. Second, evidence of publication bias was detected. In an effort to minimize this bias, conference papers and studies from multiple countries were included; however, this may have contributed to variability in methodological quality. Third, only studies published in English or Chinese were included, potentially excluding relevant trials in other languages and further contributing to heterogeneity.

Despite these limitations, the present study has notable strengths. Our conclusions build upon and extend the findings of three previously published meta-analyses. After comparing their included studies with ours, several studies were excluded due to failure to meet inclusion criteria or insufficient data availability, even after attempts to contact original authors. Ultimately, this meta-analysis incorporated 22 studies comprising 28 comparison groups and a total of 4,379 participants. To our knowledge, this represents the largest meta-analysis examining the effectiveness of flipped versus traditional classrooms in pharmacy education, providing a relatively high level of evidence. Additionally, subgroup analyses were conducted based on multiple factors—including study design, degree program, and instructional format—allowing for a more nuanced understanding of how different flipped classroom components influence learning outcomes.

*Future research directions*

Flipped classrooms, as a form of blended learning, combine the strengths of online instruction with face-to-face teaching while promoting active learning rather than passive information transfer [37]. To maximize their effectiveness, instructors should incorporate diverse interactive activities that reinforce retrieval-based learning. For instance, Sumanasekera *et al*. implemented crossword puzzles and Kahoot-based games, while Wong *et al.* designed active learning exercises tailored to different course modules, such as electrocardiogram interpretation, pharmacological calculations, and patient case discussions in therapeutics courses [13, 29]. Continuous pedagogical innovation and the inclusion of varied retrieval practices may further enhance learning outcomes by improving long-term knowledge retention.

In addition, flipped classrooms should be leveraged to strengthen students' practical and clinical skills. As the role of pharmacists evolves from medication dispensing toward patient-centered and outcomes-driven care [30], educational approaches must reflect these changes. Several included studies adopted patient-based scenarios and encouraged real-world case discussions. For example, Pierce *et al*. engaged students in patient case problem-solving tasks involving clinical interventions, patient assessment, dosage calculations, and pharmacokinetic analyses [38]. By incorporating well-designed patient cases and guided discussions, flipped classrooms can better align pharmacy education with professional practice and prepare students for real-world clinical responsibilities.

Furthermore, student feedback frequently indicates that flipped classrooms require greater time investment, particularly during pre-class preparation. Gloudeman *et al*. reported that some pharmacy students spent more than three hours preparing for flipped classroom sessions [23]. Similarly, He *et al*. found that students devoted more time before class but less time afterward when learning through flipped classrooms compared with traditional methods [25]. While increased time commitment may contribute to improved learning outcomes, detailed data on total learning time were not consistently available in the included studies. Future research should therefore document learning time more precisely and examine its relationship with academic performance.

More comprehensive reporting is also needed to support future meta-analyses. During data extraction, essential details—such as assessment formats, video duration, and measures of variability—were often inadequately reported, resulting in the exclusion of several studies or subgroup analyses. Given that only 22 studies were included, and even fewer contributed to subgroup analyses, the resulting heterogeneity remains high. Future trials should provide more detailed methodological information and expand the evidence base, thereby reducing bias and enabling more robust conclusions.

## Conclusion

This meta-analysis demonstrates that the flipped classroom approach in pharmacy education leads to statistically significant improvements in student performance compared with traditional teaching methods. Accordingly, the flipped classroom represents a promising instructional strategy worthy of broader adoption in pharmacy education. Future research should further explore the integration of online and in-person learning, while educators should fully utilize digital technologies alongside creative, interactive face-to-face teaching environments to optimize student learning outcomes.

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