Section: Pharmacology

Original Research Article

A CROSS-OVER RANDOMISED CONTROLLED TRIAL ON THE EFFECTIVENESS AND PERCEPTION OF FLIPPED LEARNING IN PHARMACOLOGY AMONG PHASE II MBBS UNDERGRADUATES

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ABSTRACT

Background: Competency-Based Medical Education (CBME) emphasises active learning and clinical application, whereas traditional lectures are predominantly teacher-centred. Flipped learning shifts foundational content acquisition to the pre-class phase and utilises classroom time for higher-order application and interaction. **Aims and Objectives:** To compare the effectiveness of flipped classroom and lecture-based teaching in pharmacology and to assess student perceptions among Phase II MBBS undergraduates. **Materials and Methods:** A cross-over randomised controlled educational trial was conducted from August to November 2024 in the Department of Pharmacology, Government Medical College, Virudhunagar. One hundred and ten consenting Phase II MBBS students were randomised into two groups using an AB/BA crossover design. The intervention comprised lecture-based and flipped classroom sessions across simple and complex pharmacology topics. Knowledge outcomes were assessed using pre-test and post-test multiple-choice questions (MCQs) evaluating factual knowledge and clinical context–based application. Student perceptions were assessed using a validated three-point Likert scale questionnaire. Between-group and within-group comparisons were performed using independent and paired t-tests, with $p \leq 0.05$ considered statistically significant. **Results:** Baseline pre-test scores were comparable between lecture-based and flipped classroom groups across all topics ($p > 0.05$). Flipped learning demonstrated significantly higher post-test–pre-test score gains for clinical context–based MCQs in diuretics (7.17 vs 5.35; $p = 0.003$), dyslipidaemia (6.95 vs 4.75; $p < 0.001$), anticoagulants (7.91 vs 4.74; $p < 0.0001$), and fibrinolytics/antiplatelets (8.27 vs 4.26; $p < 0.0001$). For factual MCQs, significant improvement with flipped learning was observed in complex topics, including diuretics (3.81 vs 2.85; $p = 0.0003$) and anticoagulants (5.07 vs 3.50; $p = 0.001$). Internal assessment scores were higher with flipped learning among both low- and high-performing students. Student perceptions favoured flipped learning, particularly for facilitator interaction (82%), recall (77%), and peer interaction (76%). **Conclusion:** Flipped classroom teaching was more effective than traditional lectures in improving conceptual understanding and clinical application in undergraduate pharmacology, particularly for complex topics, and was positively perceived by students. Flipped learning represents an effective complementary instructional strategy within the CBME framework.

INTRODUCTION

The introduction of the CBME curriculum, medical education has started to move medical education away from purely traditional teaching methods. Competency is understood as the ability to demonstrate appropriate knowledge, skills, and attitudes in real clinical settings.[1] For many years, teaching largely followed a pedagogical model in which didactic lectures formed the backbone of instruction. Lectures were preferred because they allowed large batches of students to be taught within

a limited time and faculty availability.[2] However, this method places the teacher at the centre of the learning process, while students often listen passively, with little opportunity to ask questions or apply what they have learned.

Didactic lectures dominate instruction in many institutions and are associated with fact memorisation and rote learning.[3] The utility of lecture-based teaching across disciplines and its perceived benefits from students' perspectives have been widely reported.[4] Adult learning theory recognises that adults acquire knowledge differently from children, a concept described as andragogy. Adult learners are typically self-directed, internally motivated, and goal-oriented, with a preference for autonomy in identifying learning needs and outcomes. Accordingly, andragogy promotes a shift away from teacher-centred instruction towards more learner responsibility, leading to changes in traditional educator–learner roles in medical education.[5,6]

Self-determination theory further emphasises the role of intrinsic motivation in supporting sustained engagement, deeper understanding, and improved academic performance.[7] In line with these principles, the competency-based medical education (CBME) curriculum for undergraduate medical training in India highlights small group teaching as a key instructional strategy. Small-group learning, typically involving,[8-10] students, facilitates active participation, critical thinking, problem-solving, teamwork, and communication through interaction with peers and faculty.8 Commonly used methods include seminars, tutorials, bedside clinical teaching, and problem-based learning.

The flipped classroom is a learner-centred instructional approach that aligns well with adult learning theory.[9] In this model, foundational content is introduced before class, often through recorded lectures, placing responsibility for initial learning on students. Classroom time is then utilised for discussion, clarification, and application of concepts. The F-L-I-P outline—flexible learning environment, learner-centred culture, intentional content, and the educator as a facilitator-supports deeper classroom engagement and higher cognitive processing, as described in Bloom's taxonomy.[10] Reflective thinking further strengthens flipped learning by encouraging analysis, synthesis, and evaluation during interaction with learning materials, peers, and faculty.[11]

Despite increasing use of flipped learning in medical education, evidence supporting its effectiveness in undergraduate pharmacology remains limited and inconsistent. Many studies focus primarily on learner satisfaction or short-term outcomes, with relatively few well-designed trials assessing deeper learning. Additionally, crossover randomised controlled studies within the Indian context of CBME are rare. Pharmacology, a core Phase II MBBS subject, requires integration of foundational knowledge with conceptual understanding and clinical application. Teaching strategies that promote deeper learning and higher-order cognition are therefore essential.

This study aimed to evaluate the effectiveness and feasibility of flipped classroom teaching in promoting deeper learning in undergraduate pharmacology.

Aim and objectives

Aim

To evaluate the effectiveness and feasibility of flipped classroom teaching in promoting deep learning in pharmacology among Phase II MBBS undergraduates under the CBME curriculum.

Objectives

The primary objective of this study was to compare the effectiveness of flipped classroom teaching versus traditional lecture-based teaching in pharmacology among Phase II MBBS undergraduates, and the secondary objective was to assess learning outcomes across topics of varying complexity and evaluate students' perceptions of flipped classroom teaching under the CBME curriculum.

MATERIALS AND METHODS

This was a cross-over randomised controlled trial, educational intervention study involving Phase II MBBS undergraduates was conducted in the Department of Pharmacology, Government Medical College, Virudhunagar, from August to November 2024.

The study was approved by the Institutional Ethics Committee, Government Medical College, Virudhunagar (IEC approval no.: ___/2024), and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participating students.

Sample size calculation

Based on the pilot study, the lowest post-test mean scores were 6.03 in Group 1 and 7.02 in Group 2, with standard deviations of 1.99 and 1.20, respectively. With a study power of 80%, a 95% confidence level, a 1:1 allocation ratio, and a 10% non-response rate, the required sample size was calculated using Open Epi. The final sample size was 55 students (each group).

Inclusion Criteria

Phase II MBBS students attending Pharmacology classes who gave informed consent were included.

Exclusion Criteria

Students absent during the study sessions > 20% absenteeism in the preceding three months, and participated in the pilot study were excluded.

Methods

Students were contacted in the lecture hall and informed about the study purpose. Participation was voluntary, and students were assured that their decision would have no impact on academic assessment or examination results. Students were assigned to two groups using a computer-generated AB or BA sequence in a crossover format. Group 1

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attended sessions 1–4 as traditional lectures followed by sessions 5–8 as flipped classroom sessions, while Group 2 received the same sessions in the opposite order. Participants were recruited using consecutive sampling, and all eligible consenting students during the study period were enrolled; participant flow is illustrated in Figure 1.

Data collection included pre-test and post-test MCQ scores and student perception responses. Knowledge assessment was performed using 20 MCQs administered before and after each session to assess recall, understanding, and application of knowledge. Part A assessed factual knowledge, while Part B assessed analytical and interpretative skills. Students were stratified into low scorers (previous internal assessment <40%) and high scorers (>60%) for subgroup comparison of learning outcomes. Perceptions of the flipped classroom were assessed after the eighth session by a validated three-point Likert scale questionnaire.

Pre-tests were conducted four days before each session. Flipped learning group students received recorded lectures and presentation slides and were given four days to prepare. Teaching sessions were held on the fifth day according to group allocation, with flipped sessions used mainly for discussion and clarification.

Post-tests identical to the pre-tests were managed after each session, and mean scores were analysed. Outcomes were assessed by group sequence (A/B), MCQ type, and topic difficulty (simple or complex) for both factual and clinically oriented questions. Topic difficulty was defined in advance by faculty agreement based on content scope, concept integration, and cognitive demands. Bias was minimised through standardised teaching content, use of the same facilitators for both methods, blinding of test setters and data analysts, and restriction of material sharing.

The primary outcome was the difference with pre- and post-test MCQ scores between the flipped classroom and the lecture-based teaching. The secondary outcomes included topic- and difficulty-wise performance, subgroup analysis based on prior internal assessment scores, and student perceptions of flipped learning.

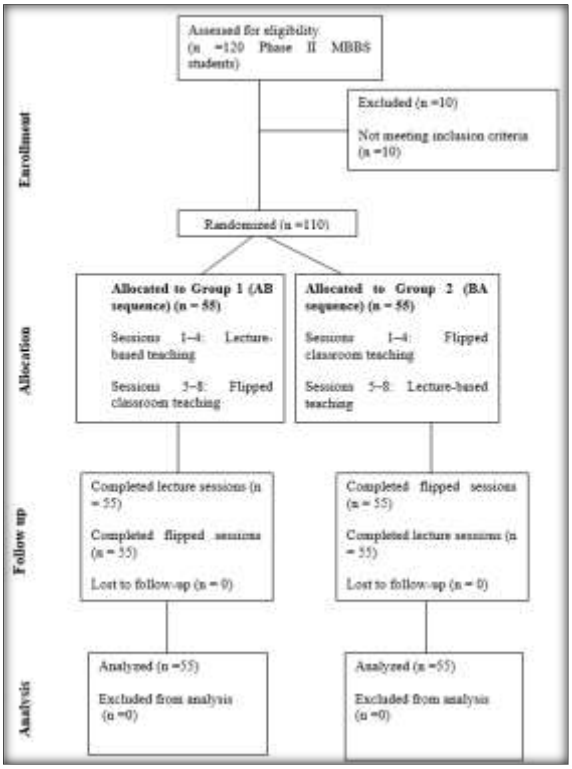

Figure 1: Consort diagram

Statistical Analysis

Learning effectiveness was assessed using post-test–pre-test MCQ score differences as the primary outcome, while student perceptions and internal assessment score differences across performance levels were secondary outcomes. Data were analysed using SPSS version 26. Descriptive statistics were expressed as mean ± SD and percentages. Between-group and within-group comparisons were performed using independent and paired t-tests, respectively, with $p \leq 0.05$ considered statistically significant. Student satisfaction was analysed descriptively, and data normality was assessed before analysis; the crossover design permitted within-group comparisons, with no anticipated carryover effects due to topic-specific interventions.

RESULTS

Baseline pre-test scores were comparable across all topics, with no significant differences observed for diuretics (3.04 ± 0.93 vs 3.02 ± 0.78; p = 0.906), dyslipidaemia (2.54 ± 1.11 vs 2.73 ± 0.95; p = 0.336), anticoagulants (2.71 ± 1.26 vs 2.72 ± 1.11; p = 0.94), and fibrinolytics (2.42 ± 1.23 vs 2.82 ± 1.27; p = 0.084). [Table 1]

Table 1: Comparison of baseline pre-test scores between lecture-based and flipped classroom groups

Parameter	Category (Topic)	Lecture	Flipped class	p value
Pre-test score	Diuretics	3.04 ± 0.93	3.02 ± 0.78	0.906
	Dyslipidaemia	2.54 ± 1.11	2.73 ± 0.95	0.336
	Anticoagulants	2.71 ± 1.26	2.72 ± 1.11	0.94
	Fibrinolytics	2.42 ± 1.23	2.82 ± 1.27	0.084

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Values expressed as Mean ± SD. Groups compared using an independent t-test; $p < 0.05$ considered significant.

All assessed topics showed higher score differences in the flipped class compared to lectures (4/4; 100%). Significant differences were observed for diuretics (5.35 vs 7.17; $p = 0.003$), dyslipidaemia (4.75 vs 6.95; $p < 0.001$), anticoagulants (4.74 vs 7.91; $p < 0.0001$), and fibrinolytics/antiplatelet (4.26 vs 8.27; $p < 0.0001$). [Table 2]

Table 2: Between-group comparison of post-test–pre-test score differences for clinical context-based MCQs across pharmacology topics

Parameter	Category (Topic – difficulty)	Lecture	Flipped class	p value
Score difference	Diuretics (Complex)	5.35 ± 2.3	7.17 ± 1.9	0.003
	Dyslipidaemia (Simple)	4.75 ± 2.4	6.95 ± 2.3	<0.001
	Anticoagulants (Complex)	4.74 ± 1.8	7.91 ± 1.5	<0.0001
	Fibrinolytics/Antiplatelets (Simple)	4.26 ± 2.1	8.27 ± 1.29	<0.0001

Values expressed as Mean ± SD. Between-group score differences were compared using an independent t-test; $p < 0.05$ was considered significant.

Significant differences were observed in two topics (2/4; 50%), with higher score differences in the flipped class for diuretics (3.81 vs 2.85; $p = 0.0003$) and anticoagulants (5.07 vs 3.50; $p = 0.001$). No significant differences were noted for dyslipidaemia (4.33 vs 4.02; $p = 0.63$) or fibrinolytics/antiplatelet (3.38 vs 3.36; $p = 0.95$). [Table 3]

Table 3: Between-group comparison of post-test–pre-test score differences for factual MCQs across pharmacology topics

Parameter	Category (Topic – difficulty)	Lecture	Flipped class	p value
Score difference	Diuretics (Complex)	2.85 ± 1.3	3.81 ± 1.2	0.0003
	Dyslipidaemia (Simple)	4.02 ± 1.8	4.33 ± 1.9	0.63
	Anticoagulants (Complex)	3.50 ± 1.7	5.07 ± 1.8	0.001
	Fibrinolytics/Antiplatelets (Simple)	3.36 ± 1.9	3.38 ± 1.8	0.95

Values expressed as Mean ± SD. Between-group comparisons performed using an independent t-test; $p < 0.05$ considered significant.

Significant differences were observed in six of eight comparisons (6/8; 75%) reflecting within-group crossover comparisons. A higher scores in the flipped class for factual MCQs in Group A (simple: 8.27 vs 4.75, $p < 0.0001$; complex: 7.78 vs 5.35, $p = 0.003$) and Group B (simple: 6.95 vs 4.20, $p < 0.0001$; complex: 7.17 vs 4.74, $p < 0.0001$), and for clinical context-based MCQs in complex topics for Group A (5.16 vs 2.85, $p < 0.001$) and Group B (4.33 vs 3.38, $p = 0.01$). [Table 4]

Table 4: Group-wise comparison of lecture-based and flipped classroom performance across factual and clinical context–based MCQs stratified by topic complexity

Group	Parameter	Category	Lecture	Flipped class	P value
Group A	Factual MCQs	Simple topics	4.75 ± 2.4	8.27 ± 1.2	<0.0001
		Complex topics	5.35 ± 2.3	7.78 ± 1.5	0.003
	Clinical Context-Based MCQs	Simple topics	3.38 ± 1.9	4.01 ± 1.8	0.07
		Complex topics	2.85 ± 1.3	5.16 ± 1.2	<0.001
Group B	Factual MCQs	Simple topics	4.20 ± 2.02	6.95 ± 2.3	<0.0001
		Complex topics	4.74 ± 1.8	7.17 ± 1.9	<0.0001
	Clinical Context-Based MCQs	Simple topics	3.51 ± 1.7	3.82 ± 1.3	0.24
		Complex topics	3.38 ± 1.8	4.33 ± 1.9	0.01

Values expressed as Mean ± SD. Within-group lecture versus flipped comparisons were analysed using a paired t-test; $p < 0.05$ considered significant. MCQs = Multiple Choice Questions.

Higher internal assessment scores were observed with flipped learning in both performance categories, including low scorers (44.00 vs 31.93; $p < 0.022$) and high scorers (57.77 vs 48.64; $p = 0.0049$). [Table 5]

Table 5: Comparison of internal assessment scores between lecture-based and flipped learning methods, stratified by prior academic performance

Parameter	Category	Lecture (Mean ± SD)	Flipped learning (Mean ± SD)	p value
IA score	Low scorers (Avg previous IA <40)	31.93 ± 3.5	44.00 ± 2.8	<0.022
	High scorers (Avg previous IA >60)	48.64 ± 4.6	57.77 ± 1.9	0.0049

Values expressed as Mean ± SD. Between-group comparison using an independent t-test $p < 0.05$ considered significant. IA = Internal Assessment.

Most students agreed that flipped learning improved facilitator interaction (82%), recall (77%), peer interaction (76%), and attention span (68%). [Table 6]

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Table 6: Student perceptions of flipped learning across key domains of engagement and learning effectiveness

Parameter	Category	Agree (%)	Neutral (%)	Disagree (%)
Perception	Improved recall	77	21	2
	Improved facilitator interaction	82	13	5
	Improved attention span	68	24	8
	Improved peer interaction	76	22	2

Values expressed as percentages. Responses were analysed descriptively without inferential statistics. % = Percentage.

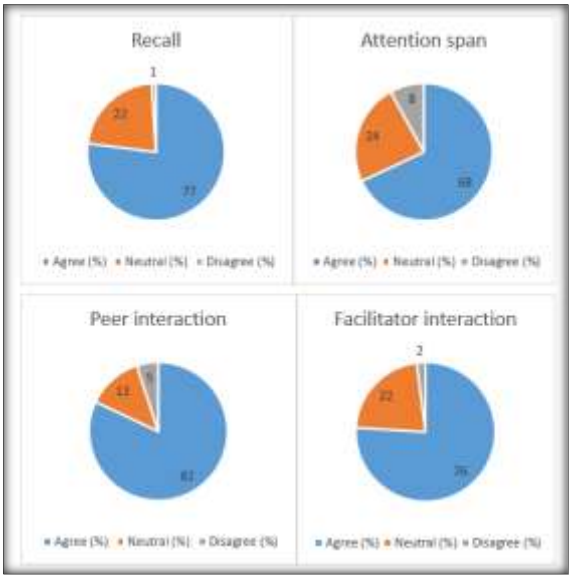

Figure 1: Student perceptions of flipped learning across recall, attention span, peer interaction, and facilitator interaction

DISCUSSION

This study compared flipped classroom teaching with traditional lectures in pharmacology among Phase II MBBS students. Flipped learning was associated with well conceptual understanding and clinical application, particularly for complex topics, while improvements in factual recall were limited. Pre-test scores were similar in the lecture-based and flipped classroom groups across all pharmacology topics, showing similar knowledge and reducing the chances of selection bias. This similarity strengthens the validity of the post-intervention findings and suggests that the observed learning gains were related to the teaching method rather than pre-existing academic differences.

Flipped classroom teaching led to more improvement in clinical context–based MCQs across pharmacology topics, with significant gains in diuretics, dyslipidaemia, anticoagulants, and fibrinolytic/antiplatelet agents. This indicates that flipped learning supports clinical reasoning and application of knowledge. Pharmacology requires students to connect drug mechanisms with indications, contraindications, and adverse effects in clinical settings. The flipped format allowed classroom time for discussion, clarification, and problem-solving, which likely improved performance in oriented assessments. These findings support the use of flipped classroom teaching within the CBME framework. In contrast, gains in factual MCQs with flipped learning were seen in complex topics, while simpler topics showed minor difference between teaching methods. This finding aligns with cognitive load principles, as heavy information delivery during lectures can limit deeper understanding.[12] Complex topics place higher demands on working memory, and the flipped approach helps by shifting initial learning to the pre-class phase and keeping class time for guided application and reinforcement.

The benefits of flipped learning observed in complex topics can be understood using the mastery learning framework proposed by Carroll and later developed by Bloom, which highlights the importance of flexible learning time and repeated practice for achieving mastery.[13] Flipped learning provides more time and multiple exposures to content, helping them reach a uniform level of understanding. This approach is relevant in pharmacology, where clear conceptual understanding is essential for rational prescribing and sound clinical decision-making.

Student feedback showed high agreement that flipped sessions improved interaction with facilitators and peers, as well as attention span and recall. These findings are consistent with Kusurkar R and ten Cate's adult learning theory and self-determination theory, which emphasise autonomy, engagement, and intrinsic motivation as for effective learning.[7] The opportunity for active participation and immediate feedback during flipped sessions contributed to increased confidence in handling case-based questions and improved preparation for subsequent sessions.

Internal assessment scores were more with flipped learning among both low and high-performing students. This shows that flipped classrooms support learners across the academic spectrum. Slow learners benefit from self-paced pre-class preparation, while high achievers gain from deeper discussion and application. Previous studies have reported similar benefits, particularly among lower centile scorers and prevalence in female students.[14,15] In the present study, objective performance did not differ by gender, although perception data indicated that more acceptance of flipped learning was observed among female students based on perception responses.

The findings of this study align with prior reports indicating better examination performance and self-perceived knowledge with flipped learning in medical education.[16,17] These findings support the use of flipped classroom strategies in pharmacology teaching under the CBME framework, which

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supports clinical reasoning, communication, and lifelong learning.

Flipped teaching was more effective in improving conceptual understanding and clinical application, was well acknowledged by students, and benefits across different learner groups. The strengths of this study include the crossover randomised design, comparable baseline performance, standardised teaching methods, and objective outcome assessment.

Limitations

The study was limited by its single-institution setting and reliance on MCQs for assessment. Long-term knowledge retention and clinical performance were not assessed.

CONCLUSION

Flipped classroom teaching improved conceptual understanding and application in pharmacology compared with traditional lectures, mainly for complex topics. The approach helped both low- and high-performing students and was welcomed by learners. Therefore, this supports its use within the CBME framework for undergraduate medical education. Future research should examine long-term retention, clinical performance, and applicability across institutions. Combining flipped learning along with lectures is recommended for pharmacology teaching.

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