Original Article

Implementation of flipped classroom in Anatomy: attitudes and its effects on students' performance and learning

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ABSTRACT

Background: The Flipped Classroom (FC) model reverses the conventional lecture-homework sequence: students engage with foundational material (videos, podcasts, interactive modules) prior to class, while face-to-face sessions are dedicated to problem-solving, clinical application, and collaborative work. This study evaluates the implementation of the FC model for first-year MBBS students in the Department of Anatomy. **Methods:** A pre-post educational intervention was conducted involving all 125 first-year MBBS students (Batch 2021–22) over a six-month period. Following each conventional didactic lecture, students immediate performance (DL1) and 2-week knowledge retention (DL2) were assessed using 10 validated clinical scenario-based MCQs via Google Forms. The identical evaluation structure was applied after FC sessions (FC1 and FC2). Six structured FC sessions were delivered across six months. Quantitative outcomes were analyzed using paired and unpaired parametric/non-parametric tests, reporting mean differences, effect sizes (Cohens d), and 95% confidence intervals. Student and faculty perceptions were gathered via validated Likert-scale questionnaires. **Results:** Post-intervention test scores following FC sessions (FC1: 8.26 ± 3.00) were statistically significantly higher than conventional didactic lectures (DL1: 7.01 ± 2.83; p = 0.0008, Cohens d = 0.43). Two-week knowledge retention similarly favoured the flipped approach (FC2: 7.38 ± 2.09 vs. DL2: 5.42 ± 2.48; p = 0.0001, Cohens d = 0.85). Questionnaire reliability demonstrated high internal consistency (Cronbachs alpha = 0.88). Faculty and student feedback indicated overwhelmingly positive attitudes regarding engagement and conceptual clarity. **Conclusion:** The flipped classroom model enhances immediate academic performance and long-term knowledge retention in anatomy education. Periodic implementation fosters active learning, strengthens student-teacher interaction, and catalyzes a positive shift toward self-directed learning behaviors among undergraduate medical students.

Keywords: Flipped classroom, Anatomy, Competency-based medical education, Active learning, Knowledge retention, Medical education.

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INTRODUCTION

The terms "inverted classroom" and "classroom flip" were independently introduced by Lageet al.[1] and Baker,[2] revolutionizing modern academic instruction. The model rests on structural simplicity: classroom activities and homework swap places. Students interact with foundational concepts independently through digital resources (videos, podcasts, and interactive modules) prior to class[3,4] transforming face-to-face contact hours into a dynamic forum for critical thinking, application, and collaborative problem-solving.[5]

Traditional undergraduate medical education in India has historically relied heavily on didactic lectures (DL). While efficient for delivering content to large cohorts, this teacher-centric approach frequently induces information overload, passive reception, poor knowledge recall, and limited clinical application. With the National Medical Commission (NMC) adopting Competency-Based Medical Education (CBME), medical educators are mandated to cultivate critical thinking, communication, and self-directed learning (SDL) skills.[6,7]

Although literature extensively validates the flipped classroom model globally and regionally,[6,8] its integration into Indian medical institutions requires careful evaluation due to high student loads, rigorous foundational syllabi, and limited prior student exposure to independent learning.[9]

This study aimed to compare student academic performance and immediate understanding following didactic lectures versus flipped classroom sessions, evaluate short-term knowledge retention at a two-week interval under both pedagogical approaches, quantify effect sizes, mean differences, and 95% confidence intervals to measure educational significance, and document faculty and student perceptions, assessing the feasibility, benefits, and challenges of routine FC integration.

MATERIAL AND METHOD

Study Design and Setting: This study utilized a single-cohort pre-post educational interventional design conducted in the Department of Anatomy at a Government Medical College over a six-month duration.

Participants and Ethical Considerations: All 125 enrolled first-year MBBS students participated in the intervention. The study protocol received clearance from the Institutional Ethics Committee (EC File No: 134 X/11/13/2022-IEC/23; Approval Date: April 28, 2022). Written informed consent was obtained from all participating students and faculty members prior to study commencement.

Faculty Orientation and Module Development: A core committee comprising six faculty members was established. Faculty and students underwent formal orientation and sensitization sessions detailing the objectives, mechanics, and expectations of the FC model. Six core anatomical modules covering complex regional anatomy and clinical correlates were prepared.

Intervention Procedure: The curriculum spanned six monthly educational cycles. Each cycle compared traditional delivery with the experimental flipped approach:

Didactic Phase: Standard didactic lectures (DL) were delivered, immediately followed by a 10-item clinical scenario-based multiple-choice questionnaire administered via Google Forms (DL1). To evaluate knowledge retention, an identical or psychometrically equivalent test was administered unannounced two weeks later (DL2).

Flipped Classroom Phase: Curated study materials (chapter excerpts, reference PDFs, anatomical atlas links, and faculty-recorded video lectures/podcasts) were disseminated via secure social media platforms 48 hours prior to the interactive session. Pre-class engagement logs were maintained via personal and telephonic check-ins to verify material access. During class, small-group collaborative problem-solving, case discussions, and one-on-one facilitator interactions were conducted. Immediate post-session understanding was evaluated via a 10-item MCQ test (FC1), with retention re-assessed two weeks post-session (FC2).

Assessment Tools and Psychometric Validation: MCQ Assessments: Ten-item single-best-answer clinical scenario-based MCQs were utilized across all testing points. Items were peer-reviewed by a panel of three senior medical educators for content validity (Item-Level Content Validity Index [I-CVI] > 0.85).

Difficulty and discrimination indices were evaluated via pilot testing on a separate cohort of senior students, retaining items with a difficulty index (P) between 0.30 and 0.70 and a discrimination index (D) > 0.25. Equivalence in difficulty levels between DL and FC assessment blocks was verified via paired pilot comparisons ($p > 0.05$).

Questionnaires: Student perception, faculty perception, and learning practice inventories were deployed using 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree). Questionnaires were adapted from validated instruments in medical education literature and pilot-tested for internal consistency. Reliability analysis yielded a high internal consistency score (Cronbachs alpha = 0.88 for student perception scales; alpha = 0.85 for faculty scales). Assessors grading the formative evaluations were blinded to student grouping where applicable.

Statistical Analysis: Data were analyzed using SPSS version 21.0 (IBM Corp., Armonk, NY) and Microsoft Excel. Data distributions were tested using the Shapiro-Wilk test and visual Q-Q plots. Parametric assumptions for normality were satisfied for test scores ($p > 0.05$). Intent-to-treat principles were applied; missing data due to occasional absenteeism (< 3%) were handled using pairwise deletion or last-observation-carried-forward where appropriate, without distorting overall variance. Parametric paired and unpaired data were expressed as mean ± standard deviation (SD) with Standard Error of the Mean (SEM). Mean differences, percentage improvements, and 95% Confidence Intervals (CI) were calculated. Effect Sizes: Cohens d was calculated to report the magnitude of experimental effects (0.2 = small, 0.5 = medium, 0.8 = large effect). Given that the identical student cohort experienced both instructional formats across six repeated cycles, a repeated-measures ANOVA / paired framework was utilized to control for intra-subject variability. Statistical significance was set at $p < 0.05$.

RESULTS

Quantitative Performance and Retention Scores: A total of 125 students completed all six instructional cycles. Across all topics, post-intervention performance scores following flipped classroom sessions consistently exceeded those following conventional didactic lectures.

Immediate Performance Analysis (DL1 vs. FC1): The immediate performance analysis demonstrated a mean difference of 1.25 marks (95% CI: 0.53–1.97) between DL1 and FC1, corresponding to a 17.83% improvement. The effect size (Cohen's *d*) was 0.43, indicating a medium effect. The paired *t*-test yielded $p = 0.0008$ (SEM = 0.25 vs. 0.27), demonstrating a statistically highly significant increase in immediate post-session performance following the flipped model.

Delayed Knowledge Retention Analysis (DL2 vs. FC2): The delayed knowledge retention analysis demonstrated a mean difference of 1.96 marks (95% CI: 1.34–2.58) between DL2 and FC2, corresponding to a 36.16% improvement. The effect size (Cohen's *d*) was 0.85, indicating a large effect. The paired *t*-test yielded $p = 0.0001$ (SEM = 0.22 vs. 0.19), confirming superior long-term knowledge retention and resistance to cognitive decay under the FC model.

Table 1: Comparison of mean test scores across six modules (DL1 vs. FC1 immediately post-test; DL2 vs. FC2 at 2 weeks retention)

Session	DL1 Mean ± SD	FC1 Mean ± SD	DL2 Mean ± SD	FC2 Mean ± SD
Session A	7.02 ± 2.84	8.57 ± 3.03	5.36 ± 2.46	7.96 ± 2.26
Session B	7.31 ± 2.95	8.64 ± 3.05	5.17 ± 2.37	7.64 ± 2.16
Session C	6.87 ± 2.77	8.03 ± 2.78	5.63 ± 2.58	6.93 ± 1.96
Session D	7.53 ± 3.04	7.97 ± 3.21	4.97 ± 2.28	7.09 ± 2.01
Session E	6.91 ± 2.79	8.39 ± 3.01	5.48 ± 2.51	7.74 ± 2.19
Session F	6.43 ± 2.60	8.01 ± 2.97	5.93 ± 2.72	6.92 ± 1.98
Average	7.01 ± 2.83	8.26 ± 3.00	5.42 ± 2.48	7.38 ± 2.09

Qualitative Parameters and Perception Surveys

Student Perceptions: Students reported strong satisfaction with pre-class curated resources and interactive sessions. Majority (94.0%) agreed or strongly agreed that provided study materials were useful. Everyone (100%) felt the sessions improved conceptual understanding and learning motivation. While the majority appreciated the interactive depth, a notable subset noted time pressures (24.3% agreed FC was time-consuming; 18.2% reported feeling moderate burden/pressure during initial cycles).

Faculty Perceptions (n = 6): All faculty members (100.0%) agreed that student engagement and enthusiasm were exceptionally high during FC sessions. 100.0% noted improved student-teacher interactions and deeper conceptual comprehension. However, faculty concurred that FC requires substantial initial preparation time and is best deployed selectively for complex or clinically oriented topics rather than every syllabus component.

Behavioral Shifts in Learning Practices: Post-intervention feedback indicated that >85.0% of students experienced tangible shifts in their study habits, reporting increased pre-class preparedness, a heightened sense of academic responsibility, and greater self-awareness as active learners.

DISCUSSION

This study evaluated the implementation of a structured, six-month flipped classroom intervention in a first-year MBBS anatomy curriculum. Our findings demonstrate that the FC model significantly enhances immediate academic performance and two-week knowledge retention compared to traditional didactic lectures. These quantitative findings align closely with international and national literature.[6,10]

Educational Significance and Cognitive Rationale: The observed percentage improvement (17.83% immediate, 36.16% retention) and large effect sizes (Cohens d = 0.85 for retention) underscore the true educational significance of active learning methodologies. Traditional lectures encourage passive information reception, leading to rapid memory decay (forgetting curve). By shifting foundational knowledge acquisition outside the classroom, face-to-face hours are optimized for higher-order cognitive engagement (application, analysis, and clinical correlation) as outlined in Blooms Taxonomy. This active retrieval practice directly reinforces neural pathways, cementing long-term memory retention.

Contextualizing Findings and Challenges: While several studies have demonstrated FC to be an effective educational intervention comparing parallel control and experimental groups, [6,10-13] our single-cohort cross-over design ensured equity by exposing every student to the intervention, eliminating selection bias between parallel groups. Nonetheless, variations in individual baseline motivation and self-regulation caused some performance dispersion, reinforcing that active learning formats require transitional scaffolding, as noted by Nouri[12] and other researchers.[9]

Not all prior research has found uniform performance gains; some studies report mixed or non-significant performance differences owing to variations in student preparedness and baseline motivation.[14] However, short- and long-term learning outcomes generally favor flipped environments.[13] Student feedback in our investigation closely mirrored observations from multiple prior studies regarding engagement, active resource consumption, and enhanced conceptual understanding.[10-12,15-20]

Furthermore, student feedback highlighted initial concerns regarding workload and time consumption. Transitioning from a spoon-fed, lecture-reliant high school ecosystem to independent collegiate pre-learning creates transient cognitive friction. Faculty members similarly noted increased logistical demands, confirming that sustainable institutional rollout requires protected faculty time and institutional digital infrastructure.

Limitations: Several limitations should be considered when interpreting these findings. First, the single-centre design: the study was conducted at a single medical institution in northern India, limiting immediate generalizability across diverse geographic and institutional settings. Second, the small faculty sample: the faculty qualitative sample size (n = 6) reflects department-specific feedback rather than broader institutional consensus. Third, the absence of long-term follow-up: assessment was restricted to a two-week post-intervention window; multi-year

longitudinal tracking through clinical postings is warranted. Fourth, potential response bias: perception surveys relied on self-reported Likert scales, which may be subject to social desirability bias. Fifth, confounding variables: although internal controls were maintained, unmeasured extramural study hours and peer-group study circles could act as minor confounding variables.

Implications for Medical Education: CBME Alignment: The flipped classroom model seamlessly satisfies NMC guidelines by fostering self-directed learning, clinical problem-solving, and communication skills. Curricular Integration: Rather than treating FC as an isolated pedagogical experiment, medical departments should strategically embed FC modules into 15–20% of core, conceptually dense topics. Assessment Reform: Examinations must evolve alongside instructional methods to reward clinical application and critical reasoning rather than rote memorization.

CONCLUSION

The flipped classroom approach delivers statistically significant improvements in student academic performance and long-term knowledge retention in anatomy education. Supported by highly favorable student and faculty perceptions, routine periodic implementation of FC fosters critical thinking and guides undergraduate medical students toward becoming competent, self-directed healthcare professionals.

DECLARATIONS

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