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Effect of flipped classroom versus traditional didactic lecture on learning outcomes among medical students: A crossover study.

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Abstract

Background

The flipped classroom method is a learner-centric approach that encourages active learning. Even though this method has shown promise in medical education, evidence regarding its effectiveness in undergraduate anatomy teaching remains limited.

Objective: The study compared the flipped classroom teaching method with traditional lecture-based learning among first-year MBBS students.

Materials and methods

A crossover study was conducted among 142 first-year MBBS students of both genders at American International Institute of Medical Sciences, Udaipur, Rajasthan. The average age of the participants was 19.1 ± 0.8. Two anatomy topics were taught using a flipped-classroom and traditional lecture method. Performance was assessed using pre- and post-test MCQs, and student perception was evaluated using a structured Likert-scale questionnaire. Data were analysed using t-tests, with $p<0.05$ considered statistically significant.

Results

FC method exhibited greater learning gains than TDL. More than 85% of students reported improved engagement, understanding, and satisfaction with this approach. The post-test scores were higher with FC teaching than with TDL for both topics. For coronary circulation, the FC group achieved a significantly greater improvement than the TDL group ($t = 9.37$, $p < 0.001$). Similarly, for bronchopulmonary segments, the FC group demonstrated a significantly higher gain score compared with the TDL group ($t = 13.30$, $p < 0.001$). Overall, flipped classroom teaching produced higher knowledge gain.

Conclusion

Flipped classroom teaching was more effective than traditional lectures in improving anatomy learning outcomes. It may be integrated into undergraduate anatomy teaching to promote active learning and student engagement.

Recommendation

The FC technique is an excellent teaching-learning tool for undergraduate programmes since it enhances academic achievement, engagement, and self-directed learning. Medical schools should encourage this approach as well as offer faculty training and relevant digital learning materials to ensure its successful implementation.

Keywords: *Anatomy education, Flipped classroom, Traditional lecture, Medical education, Active learning, MBBS students, Competency-based medical education.*
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Introduction

Educational institutions around the globe are increasingly emphasizing the use of innovative instructional methods such as flipped classroom (FC) learning in the rapidly evolving higher education sector [1,2]. This innovative approach encourages critical thinking and prepares students more effectively to handle the challenges of today's world [1]. Despite its potential, there are still issues with the use of technology, learners' preparation, instructional design, and faculty readiness when implementing the flipped classroom approach [2].

Active learning strategies are increasingly used in medical education to promote student participation and higher-order cognitive processing [3, 4]. Among these alternatives, the flipped classroom has received considerable attention [5, 6]. The flipped classroom (FC) is an advanced learner-centered teaching-learning method in which learning resources are pre-loaded in the form of audio-video and print materials [6,7]. The classroom session emphasizes active learning over passive listening, with students engaging in active discussions and applying knowledge through case-based scenarios [6,7]. It extends learning outside the classroom by allowing students to sample new learning resources and participate in content-related activities and collaborative assignments during class [5, 8]. Educators can provide more personalized attention, instilling a sense of responsibility and creative learning in students [8].

Higher-order learning skills are rarely developed in the traditional didactic lecture (TDL) approach because the majority of class time is devoted to imparting fundamental knowledge [3,9]. Assessments, multimedia tools, and online resources are prioritized in the FC approach to help students to prepare for the class [2,3,4]. Additionally, it improves communication between teachers and students and enables teachers to obtain student feedback during class [3, 4].

Flipped classroom instruction has shown potential in medical education, but there is still little data specifically related to teaching anatomy to undergraduates, necessitating further research [3,10,11]. Therefore, this study aimed to compare the efficacy of flipped classroom instruction with traditional lecture-based instruction among first-year MBBS students studying anatomy and to assess how both teaching approaches were perceived by the students.

Material and methods

A prospective crossover educational intervention study was carried out in the Department of Anatomy, American International Institute of Medical Sciences, Udaipur, Rajasthan. The crossover design was selected as it allowed each group to experience both educational interventions and supported a balanced comparison between the teaching methods [12,13]. Informed consent was obtained from all the participants before enrolment. An available sample of 142 out of 150 first-year MBBS students from the 2025–2026 academic year consented to participate in the study.

Inclusion and exclusion criteria

First-year MBBS students who consented to participate (142/150) were included in the study. Students who were unwilling to participate were excluded from the study.

Assignment of participants

The 142 students were allocated into two equal groups (Group A and Group B; n = 71 each) according to their existing academic batches. A crossover design was employed, with Group A receiving FC and Group B TDL for Coronary Circulation (Topic 1). For Bronchopulmonary Segments (Topic 2), the teaching methods were reversed. No blocking, stratification, or minimization procedures were used.

Educational intervention

Deliverer

Experienced faculty members from the Department of Anatomy, American International Institute of Medical Sciences, Udaipur, conducted the interventions. They had previously received training in both flipped classrooms and conventional lecture teaching techniques.

Setting

The study was carried out among first-year MBBS students during regular teaching hours in the lecture halls and small-group teaching classrooms of the Department of Anatomy at the American International Institute of Medical Sciences, Udaipur, Rajasthan.

Exposure quality and duration

Each teaching session lasted 60 minutes. Students in the flipped classroom (FC) group received pre-class learning materials (recorded video lecture, PowerPoint presentation, and reading material) electronically via WhatsApp three days before the session. The classroom session included interactive discussions, concept clarification, case-based learning, problem-solving, and peer group activities. Students in the traditional didactic lecture (TDL) group

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attended a conventional 60-minute faculty-led lecture on the same topic.

Time span

The intervention was conducted over two consecutive weeks, with one anatomy topic covered each week, and all students experienced both teaching methods through the crossover design. Students were informed of the learning objectives and study schedule before the intervention. Attendance was mandatory, and all participants completed the pre-test and post-test. No financial or academic incentives were provided.

Outcomes

The students' cognitive achievement was assessed by pre-test, post-test, and gain scores following FC and TDL sessions. Perception of students of the FC method was evaluated using a validated 10-item five-point Likert scale questionnaire assessing the usefulness of learning resources, classroom interaction, self-directed learning, communication skills, and preference for future implementation.

Measures to minimize bias

Although the study was non-randomized, several measures were implemented to reduce bias. Both groups had comparable baseline knowledge, as demonstrated by similar pre-test scores. The same faculty member delivered both interventions using identical learning objectives, content, teaching duration, and assessment tools. Classroom environment and evaluation procedures were standardized, and the crossover design ensured that all participants were exposed to both teaching methods, thereby minimizing selection and measurement bias.

Assessment tools

The academic performance of the groups was assessed using identical pre-tests and post-tests comprising multiple-choice questions (MCQs) covering the same curriculum content. MCQs are widely used in medical education as they allow broad sampling of knowledge and objective assessment of learning outcomes [14]. Each test questionnaire was reviewed and validated by subject experts to ensure content relevance and appropriateness [15]. This method of assessment has been widely used in educational research to measure short-term learning outcomes [14,15].

Student engagement and satisfaction

A validated questionnaire was used to measure self-reported engagement, understanding, and satisfaction on a 5-point Likert scale. Likert-type scales are commonly used to quantify attitudes, opinions, and perceptions in educational research [16]. The questionnaire was administered after the intervention.

Informed consent and ethical consideration

The study was approved by the Institutional Ethics Committee of American International Institute of Medical Sciences, Udaipur (AIIMS/ IEC/2026/26); Letter No. AIIMSUDR/2026/796 dated 26th June, 2026. Informed consent was obtained from each participant before intervention.

Statistical analysis

Data were analysed using SPSS version 26. Descriptive statistics were used to summarise demographic characteristics. Paired t-tests compared within-group pre- and post-test scores. Independent t-tests assessed between-group differences. These tests are commonly used in health professions education research to compare continuous and categorical outcomes between groups [17]. A significance threshold of $p<0.05$ was applied.

Results

Baseline demographic characteristics

A total of 142 first-year MBBS students participated in the study and were equally allocated into Group A (n = 71) and Group B (n = 71). Fig 1 demonstrates the flow of participants in each stage of the study. The average age of the participants was 19.1 ± 0.8. Both groups underwent a crossover intervention in which one topic was taught using the FC method and the other using the TDL method. Knowledge acquisition was evaluated using pre-test and post-test evaluations. The difference between the pre-test and post-test results was used to determine gain scores. The pre-test scores for both topics were comparable across the groups, indicating equal baseline knowledge.

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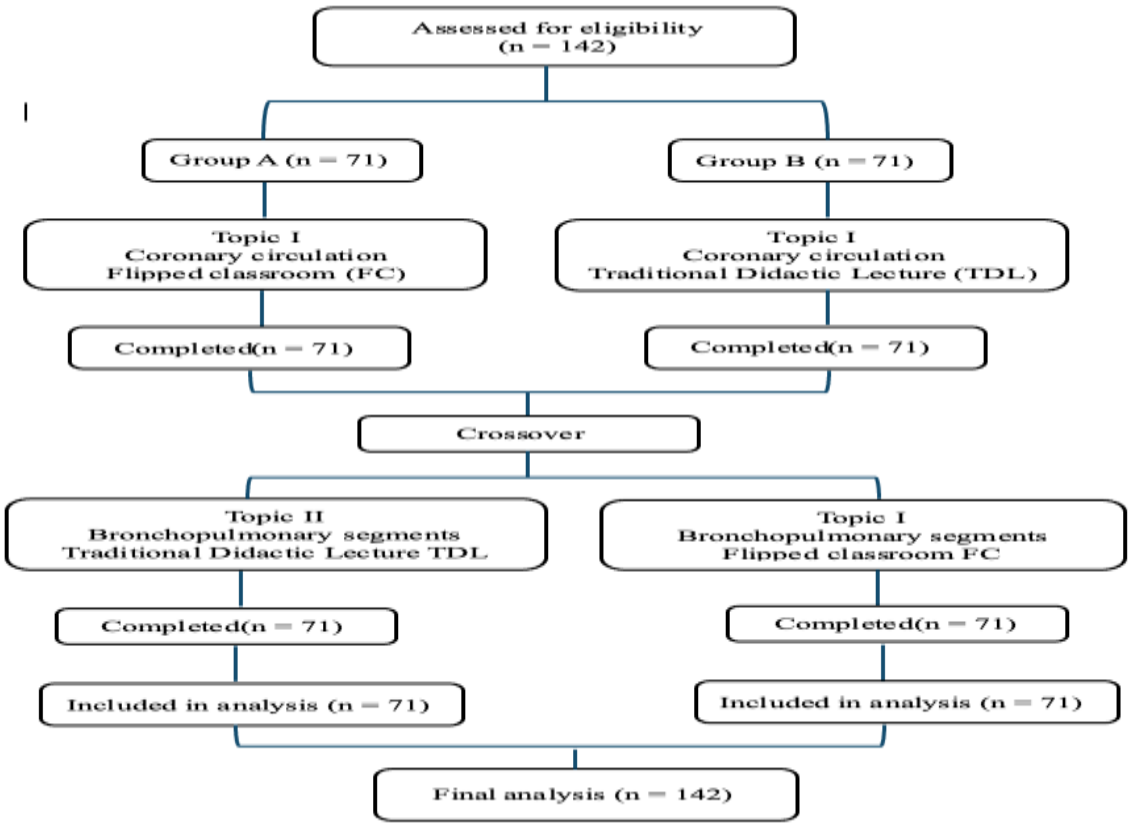

Fig. 1 Flow of participants through each stage of the study

Baseline data

The baseline demographic characteristics of the participants with respect to age, gender distribution, and baseline knowledge were comparable between the two groups before the intervention. No statistically significant differences were observed between groups for any baseline characteristic ($p > 0.05$), confirming that the groups were well balanced before the implementation of the flipped classroom and traditional didactic lecture interventions. (Table 1) An independent samples *t*-test was used to compare continuous variables, and the chi-square test was used to compare categorical variables. For Topic 2, Group A received the traditional didactic lecture and Group B received the flipped classroom intervention according to the crossover design.

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Table 1: Demographic information of participants in each study condition

Characteristic	Group A (n = 71) (%).	Group B (n = 71) (%).	Test statistic	*p* value
Age (years), Mean ± SD	19.3 ± 0.8	19.4 ± 0.7	t = 0.71	0.48
Male, n (%)	37 (52.1)	36 (50.7)	$\chi^2 = 0.03$	0.87
Female, n (%)	34 (47.9)	35 (49.3)		
Baseline pre-test (Topic 1) Mean ± SD (%).	8.87 ± 1.93	9.00 ± 2.27	t = 0.37	0.71
Baseline pre-test (Topic 2) Mean ± SD	10.44 ± 1.95*	10.07 ± 2.13*	t = 1.08	0.28

The students who received FC instruction had a mean pre-test score of 8.87 ± 1.93, which increased significantly to 14.90 ± 2.19 following the intervention. The mean gain score was 6.03 ± 1.19, indicating a marked improvement in knowledge acquisition. The paired *t*-test demonstrated a highly significant increase in scores ($t = 42.51$, $p < 0.001$). (Table 2)

Students taught by the TDL method had a comparable baseline pre-test score (9.00 ± 2.27), which increased to 13.23 ± 2.58 after teaching. The mean gain score was 4.23 ± 1.10, which was lower than that observed in the flipped classroom group. Although the improvement was statistically significant ($t = 32.43$, $p < 0.001$), the magnitude of knowledge gain was considerably smaller than that achieved with the FC approach.

Table2: Descriptive Statistics and Paired t-test of FC and TDL groups

Topic	Group (71)	Pre-test Mean ± SD	Post-test Mean ± SD	Gain Score Mean ± SD	Paired t-value	Independent t test	p-value
Topic 1: Coronary Circulation	FC	8.87 ± 1.93	14.90 ±2.19	6.03 ± 1.19	42.51	9.37	<0.001
	TDL	9.00 ± 2.27	13.23 ±2.58	4.23 ± 1.10	32.43		
Topic 2: Bronchopulmonary Segments	FC	10.07±2.13	16.18±2.17	6.11 ± 1.19	43.72	9.37	<0.001
	TDL	10.44±1.95	13.94 ± 2.61	3.50 ± 1.15	27.36		

Comparison of the gain scores indicates that the FC produced an additional improvement of 1.80 marks compared with the TDL method for coronary circulation, corresponding to an approximately 42.6% greater learning gain. Furthermore, the post-test score in the FC group was 1.67 marks higher than that of the traditional lecture group, suggesting increased knowledge acquisition.

Topic 2: Bronchopulmonary segments

For the topic Bronchopulmonary Segments, students exposed to the FC method achieved a mean pre-test score of 10.07 ± 2.13, which increased significantly to 16.18 ± 2.17 after the classroom session. The mean gain score was 6.11 ± 1.19, with a highly significant paired *t*-value of 43.72 ($p < 0.001$). (Table 2)

In contrast, students receiving TDL demonstrated a mean pre-test score of 10.44 ± 1.95, which increased to 13.94 ± 2.61 following instruction. The mean gain score was 3.50 ± 1.15, with statistically significant improvement ($t = 27.36$, $p < 0.001$). However, the magnitude of improvement was substantially lower than that observed in the flipped classroom group.

The gain score for the flipped classroom group exceeded that of the traditional lecture group by 2.61 marks, representing an approximately 74.6% greater improvement in learning for bronchopulmonary segments. Similarly, the mean post-test score was 2.24 marks higher among students taught using the flipped classroom approach.

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Overall effectiveness of the flipped classroom

The independent samples *t*-test demonstrated that the mean gain scores were significantly higher in the flipped classroom group than in the traditional didactic lecture group for both anatomy topics (Table 2). Across both topics, baseline pre-test scores were comparable between the teaching methods, indicating similar levels of prior knowledge. Both instructional approaches significantly improved students' knowledge, as evidenced by highly significant paired *t*-tests ($p < 0.001$) for all comparisons.

However, the flipped classroom consistently proved to be more effective in teaching. Students taught in a flipped classroom had higher post-test scores, larger gain scores, and higher paired t-values than those taught in standard didactic lectures in both topics. These results show that compared to traditional lecture-based instruction, the flipped classroom delivered a larger amount of information acquisition in addition to improving immediate learning outcomes.

The consistency of these findings across two separate anatomical topics strengthens the argument that the observed improvement was due to the teaching technique rather than differences in topic difficulty. The crossover design, in which each group was exposed to both instructional techniques, reduces selection bias and supports the finding that the flipped classroom is a more effective pedagogical approach for teaching undergraduate anatomy.

The flipped classroom received an extraordinarily positive response from the students. The feedback of the participants is shown in Table 2. More than 80% of the participants agreed or strongly agreed that the resource materials were beneficial, classroom activities were in accordance with pre-class preparation, and the teaching technique improved their grasp of anatomical concepts. Approximately 87% found the classroom sessions entertaining and engaging, and 82% preferred similar teaching-learning strategies in other anatomical topics. Although most of them appreciated the FC method, only 57.7% felt that the pre-class preparation was not time-consuming, indicating that workload management is still an important factor during implementation.

Discussion

The present crossover study demonstrated that the FC teaching significantly improved anatomy learning outcomes compared with TDL-based instruction, as shown in Table 2. Importantly, the superiority of the flipped classroom remained evident irrespective of the topic taught, suggesting that the observed effect was attributable to the teaching method rather than topic difficulty [13]. These findings support previous studies demonstrating improved academic performance among students exposed to flipped classroom methodologies [3]. Recent studies indicate that flipped classrooms promote active engagement, self-directed learning, and improved knowledge retention [3,4,18].

The comparable demographic characteristics and baseline pre-test scores confirmed that both groups possessed similar initial characteristics and knowledge levels, as shown in Tables 1 and 2. Following the intervention, students in the FC group achieved significantly better academic performance, suggesting that active engagement and pre-class preparation contributed to improved learning [3,4,10]. The flipped classroom model promotes higher-order cognitive processes by allowing students to review foundational content independently and utilise classroom time for discussion and application [4,18]. This aligns with Bloom's revised taxonomy, which emphasises analysis, evaluation, and creation as advanced learning objectives [9]. Higher student engagement observed in the FC group may be attributed to increased opportunities for interaction, collaborative learning, and immediate faculty feedback [4,18]. Students often perceive anatomy as content-heavy and difficult to retain. Active learning strategies may facilitate deeper understanding and long-term retention of ideas [3,11,18].

The findings are consistent with previous studies demonstrating improved academic performance among medical students exposed to flipped classroom teaching [3,10,11]. Studies have shown that students appreciate the flexibility of accessing educational materials at their own pace while benefiting from interactive classroom sessions [3,4,18].

The results of the current study are comparable with recent studies on flipped classroom teaching in medical education. Jha et al. reported significantly higher post-test scores and positive learner perceptions among first-phase medical students taught anatomy through the FC method, which closely parallels the present findings in first-year MBBS anatomy teaching [10]. Similarly, Patnaik et al. observed greater improvement in knowledge scores and increased engagement among undergraduate medical students exposed to flipped classroom sessions compared with traditional teaching [5]. A recent large systematic review and meta-analysis also found that flipped classroom instruction produced significantly better knowledge assessment outcomes and higher satisfaction than traditional teaching across medical education settings [3]. However, not all recent evidence is uniformly supportive; a crossover quasi-experimental study in community and family

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medicine reported low student participation and no conclusive difference in score improvement between FC and TDL methods [13]. This contrast suggests that the effectiveness of the flipped classroom method may rely on adequate student preparation, topic suitability, faculty facilitation, and alignment between pre-class resources and in-class activities [13].

The positive perception scores observed in the present study, summarised in Table 3, further support the adoption of learner-centred teaching strategies [3,4]. Most of the students in this study reported increased interest, better understanding, and greater confidence in applying anatomical knowledge. These findings are consistent with earlier reports in anatomy and undergraduate medical education [10,11].

Table 3: Student perception of the flipped classroom method based on Likert-scale responses.

Statement	Responses					Mean ± SD
	Strongly Agree(5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	
Pre-class materials provided were useful and relevant.	68	52	14	6	2	4.26 ± 0.88
Preparation time for the classroom activity was adequate.	54	58	18	9	3	4.06 ± 0.93
Studied all the resource materials provided before the classroom session.	49	56	22	11	4	4.06 ± 0.93
Learning the topic before the classroom session was not time-consuming.	38	44	30	20	10	3.56 ± 1.14
Classroom activities were well aligned with the pre-class learning materials.	72	48	15	5	2	4.29 ± 0.86
Classroom session was interactive and interesting.	79	45	10	6	2	4.36 ± 0.84
Understanding of the topic improved after the classroom activities.	82	43	10	5	2	4.40 ± 0.81
Self-directed learning skills improved after participating in this activity.	66	48	18	7	3	4.18 ± 0.92
Prefer similar teaching-learning methods for other anatomy topics in the future.	74	42	14	8	4	4.23 ± 0.97
Communication and teamwork skills have improved after the classroom activity.	61	50	18	9	4	4.09 ± 0.98

The major advantages of the flipped classroom method include promotion of active learning, better utilisation of classroom time, and greater learner autonomy [3,4,18]. By shifting basic knowledge acquisition to the pre-class phase, classroom sessions can be used for case-based discussion, problem-solving, peer interaction, and clarification of difficult concepts [4]. This is particularly useful in anatomy, where the learners are required not only to memorise

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structural details but also to apply them in clinical and functional contexts [10,11]. The method also allows students to learn at their own pace, revisit difficult topics, and come prepared for interactive sessions, thereby encouraging self-directed learning and lifelong learning habits [3,4]. In the present study, the higher post-test scores and favourable perception responses suggest that these advantages translated into measurable academic and experiential benefits.

However, the flipped classroom also has certain limitations. Its success depends heavily on student compliance with pre-class preparation; those who do not review the learning materials beforehand may find difficulty to participate meaningfully in the classroom activities [13,18]. Preparation of good-quality videos, presentations, reading material, and structured in-class tasks also requires considerable faculty time, planning, and technological support [4,18]. In addition, some students may perceive pre-class learning as an added workload, especially in content-heavy subjects such as anatomy [18]. Unequal access to digital resources, variability in learner motivation, and difficulty in monitoring pre-class preparation may further affect implementation [4,18]. Therefore, flipped classroom teaching should be introduced with clear instructions, concise and focused pre-class resources, formative assessment, and faculty facilitation to ensure that its benefits outweigh its practical challenges [4,1].

The crossover design strengthens the validity of the present study because each group experienced both teaching methods. This design minimised confounding related to baseline student characteristics and learning preferences, thereby supporting a more balanced comparison between flipped classroom and traditional lecture-based teaching [13]. The study has several strengths, including an adequate sample size, direct comparison between two teaching approaches, and use of a crossover design, which helped reduce the influence of baseline differences between student groups.

Limitations

The present study was conducted at a single institution and included only two anatomy topics, which may limit the generalizability of the findings to other medical colleges and broader areas of anatomy. The assessment was based mainly on short-term pre-test and post-test scores; hence, long-term retention of knowledge could not be evaluated. The students' compliance with pre-class preparation was self-reported. This could have differed among participants, which possibly affected the classroom engagement and learning outcomes. Data on Perceptions were collected using a Likert-scale questionnaire, which could be affected by response bias and might not fully reflect detailed qualitative experiences. While the crossover design reduced the baseline group differences, the difficulty of the topic and differences in learner motivation are not eliminated.

Conclusion

The flipped classroom method was far more effective than TDL for anatomy education among first-year MBBS students. The crossover design established dominance of the flipped classroom over two clinically relevant anatomy topics. The academic performance of the participants was significantly superior with the learning process. Incorporation of the FC method into undergraduate anatomy curricula may improve student engagement, active learning, and self-directed learning, thereby improving the educational outcomes in competency-based medical education.

Recommendations

Findings of the study indicate that the flipped classroom approach can be recommended as an effective teaching-learning strategy for undergraduate medical education, as it significantly improved knowledge acquisition, engagement, self-directed learning, and interaction among the students when compared to traditional methods. Medical schools can think about incorporating advanced learning methods like the flipped classroom into their curriculum. Furthermore, multicenter research with bigger sample sizes, various anatomical topics, and terms of assessments of knowledge and clinical application are recommended to reinforce the evidence for the widespread use of this instructional strategy.

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List of abbreviations

FC- Flipped Classroom
TDL- Traditional Didactic Lecture
MCQ- Multiple Choice Questions

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Author contributions
Dr. Sajan Skaria: Conceptualization, methodology, study design, data collection, formal analysis, investigation, manuscript drafting, critical revision and editing of the manuscript, and final approval of the version to be published.

Data availability
Data available upon request.

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