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Effectiveness of a Flipped Classroom With Case-Based Discussions in Improving Learning Outcomes in Undergraduate Medical Education: A Quasi-experimental Study at a Tertiary Medical College in Koraput, Odisha

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Abstract

Introduction: Traditional lecture-based teaching often limits student engagement and higher-order cognitive processing in undergraduate medical education. Innovative learner-centered approaches are required to improve conceptual understanding and clinical reasoning. The flipped classroom model shifts foundational learning to the pre-class phase and utilizes classroom time for interactive case-based discussions, thereby promoting active learning.

Objectives: To evaluate the effectiveness of a flipped classroom with case-based discussions compared to traditional lectures in improving learning outcomes among undergraduate medical students.

Methodology: A quasi-experimental study was conducted among 200 undergraduate medical students in a tertiary medical college in Koraput, Odisha, from July to December 2025. Students were allocated to intervention (n = 100) and control (n = 100) arms. The intervention group received pre-class digital learning materials, followed by in-class facilitated case-based discussions, while the control group received conventional lectures. Knowledge was assessed using a validated 20-item multiple-choice questionnaire administered at baseline, immediately post intervention, and at two- and six-week follow-ups. Mean scores were compared using appropriate statistical tests.

Results: Baseline knowledge scores were comparable between the intervention and control groups (50.1 ± 9.8 vs. 49.6 ± 10.2; p = 0.68). Immediately after the intervention, the intervention group achieved significantly higher mean knowledge scores than the control group (72.1 ± 11.0 vs. 60.0 ± 12.1; p < 0.001). This improvement was sustained at the two-week follow-up (70.8 ± 11.5 vs. 58.9 ± 12.8; p < 0.001) and six-week follow-up (70.2 ± 11.8 vs. 58.1 ± 13.2; p < 0.001). The difference-in-differences analysis demonstrated a sustained intervention effect across all assessment periods. Passing rates were also higher in the intervention group than in the control group (87.0% vs. 62.0%; p < 0.001).

Conclusion: The flipped classroom with case-based discussions is an effective and feasible teaching strategy that enhances learning outcomes and knowledge retention in undergraduate medical education.

Categories: Medical Education, Quality Improvement, Preventive Medicine
Keywords: case-based learning, flipped classroom, learning outcomes, medical, medical education, students

Introduction

Undergraduate medical education has traditionally relied on didactic, lecture-based instruction to transmit theoretical knowledge. While this approach allows structured coverage of curricular content, it often promotes passive learning and limits opportunities for critical thinking, clinical reasoning, and learner engagement. With the introduction of competency-based medical education in India, there has been a paradigm shift toward learner-centered pedagogies that emphasize application, analysis, and problem-solving skills over rote memorization. Innovative instructional strategies are therefore essential to align teaching-learning processes with expected graduate competencies [1]. The flipped classroom is an educational approach in which foundational content is delivered outside the classroom using pre-recorded lectures, reading materials, or digital modules, while in-class time is dedicated to interactive learning activities. This model is grounded in adult learning theory and constructivist principles, enabling learners to engage with content at their own pace and use face-to-face sessions for higher-order cognitive tasks. Studies have demonstrated that flipped classrooms enhance student engagement, promote self-directed learning, and improve academic performance in health professions education [2-4]. Case-based discussion is a well-established teaching method in medical education that uses real or simulated clinical scenarios to contextualize theoretical knowledge. It encourages analytical thinking, clinical reasoning, and decision-

making by linking basic concepts to practical situations. When integrated into a flipped classroom framework, case-based discussions optimize classroom time and foster active participation, peer learning, and faculty-student interaction [5].

Globally, several studies have evaluated the effectiveness of flipped classroom approaches in medical and health sciences education. Systematic reviews and meta-analyses have reported higher student satisfaction, improved examination scores, and better knowledge retention among students exposed to flipped learning compared with traditional lectures [6-8]. In disciplines such as anatomy, pharmacology, community medicine, and clinical skills training, flipped classrooms have shown consistent benefits, particularly when combined with interactive strategies like case-based or problem-based learning [9-11]. Case-based learning, independently, has also been shown to improve conceptual understanding and clinical reasoning among medical students. Evidence suggests that learners exposed to case-based discussions demonstrate better application of knowledge and improved problem-solving abilities than those taught through lectures alone [12,13]. The integration of case-based discussions within a flipped classroom further strengthens learning by reinforcing pre-class content through guided application during classroom sessions [14]. In the Indian context, emerging evidence supports the feasibility and acceptability of flipped classroom models in undergraduate medical education. Studies conducted in various medical colleges have reported improved student engagement, higher post-test scores, and positive learner perceptions [15-17]. However, most Indian studies have focused on short-term outcomes, single teaching sessions, or subjective feedback, with limited assessment of knowledge retention or comparative effectiveness using robust quasi-experimental designs.

Despite growing evidence supporting flipped classrooms and case-based discussions, several gaps remain. First, there is limited literature from resource-constrained and tribal settings in India, where infrastructural challenges and learner diversity may influence the effectiveness of innovative teaching methods. Second, few studies have employed a comparative quasi-experimental design with control groups to quantify the true educational impact of flipped classrooms. Third, evidence on short-term and medium-term knowledge retention following flipped classroom interventions remains sparse. Additionally, standardized and validated assessment tools are not consistently used across studies, limiting comparability of results.

Given the evolving landscape of competency-based medical education in India, there is a need for contextually relevant evidence to guide the adoption of innovative teaching strategies. Evaluating the effectiveness of a flipped classroom integrated with case-based discussions in a tertiary medical college located in a tribal district of Odisha provides valuable insights into its feasibility and educational impact in underserved settings. By using a validated assessment tool and assessing learning outcomes at multiple time points, the present study addresses key gaps in the existing literature. The findings are expected to inform educators and policymakers regarding scalable and effective pedagogical approaches for undergraduate medical education.

Objectives

The primary objective of this study was to evaluate the effectiveness of a flipped classroom with case-based discussions in improving knowledge and applied understanding among undergraduate medical students compared to traditional lecture-based teaching. Secondary objectives included assessing short-term and medium-term knowledge retention, comparing passing rates between intervention and control groups, and examining overall learner performance following the intervention.

Materials And Methods

A quasi-experimental study with a non-randomized control group design was conducted to evaluate the effectiveness of a flipped classroom with case-based discussions compared to traditional lecture-based teaching. Students in the intervention arm received structured digital learning materials one week before the scheduled classroom sessions. These materials comprised pre-recorded video lectures and supplementary digital reading materials covering the key concepts and learning objectives of the selected topic. The materials were designed to facilitate independent, self-paced learning and provide students with the foundational knowledge required for subsequent classroom activities. Students were encouraged to review these resources before attending the facilitated case-based discussion sessions. During the classroom sessions, clinical case scenarios were used to reinforce theoretical concepts, encourage application of knowledge, promote analytical thinking, and facilitate interactive peer and faculty-student discussions. The same faculty members were involved in delivering the teaching sessions to both the intervention and control groups to minimize instructor-related variability and potential teaching bias. The same curricular content, learning objectives, and allotted teaching time were maintained across both groups. While the intervention group received pre-class digital learning materials followed by facilitated case-based discussions, the control group received conventional lecture-based teaching. This approach helped maintain consistency in content delivery while allowing comparison of the two teaching methodologies. The study employed a pre-test-post-test design with additional follow-up assessments to measure knowledge retention at two weeks and six weeks. The study was carried out in a tertiary medical college located in Koraput district, Odisha, India. The institution serves students from diverse sociocultural backgrounds, including tribal and rural populations, and follows the competency-based undergraduate medical education curriculum prescribed by the National

Medical Commission.

The study was conducted over a period of three months, from July 2026 to September 2026. This duration included planning and preparation of learning materials, implementation of the intervention, and follow-up assessments. The study population comprised undergraduate medical students enrolled in the selected academic year of the Bachelor of Medicine and Bachelor of Surgery program at the study institution. All eligible students attending the scheduled teaching sessions during the study period were considered for participation.

A total of 200 students were included in the study, with 100 students in the intervention arm and 100 students in the control arm (Figure *1*). The sample size was determined based on feasibility and class strength while also being adequate to detect a moderate effect size with acceptable statistical power. Allocation to intervention and control groups was done at the class or batch level to minimize contamination between groups. Allocation was based on the existing academic batch/class division rather than individual randomization. One batch received the flipped-classroom intervention with case-based discussions, while the other batch received conventional lecture-based teaching. This batch-level allocation was adopted to minimize contamination between groups, as students within the same academic batch could potentially share pre-class learning materials and discuss intervention-related activities. Both groups received the same curricular content and were assessed using the same knowledge assessment questionnaire at baseline, immediately after the intervention, and at two-week and six-week follow-ups. Students enrolled in the selected undergraduate medical batch who provided informed consent and participated in both teaching sessions and assessments were included in the study. Students who did not provide consent, were absent during the pre-test or post-test assessments, or did not complete follow-up assessments were excluded from the final analysis.

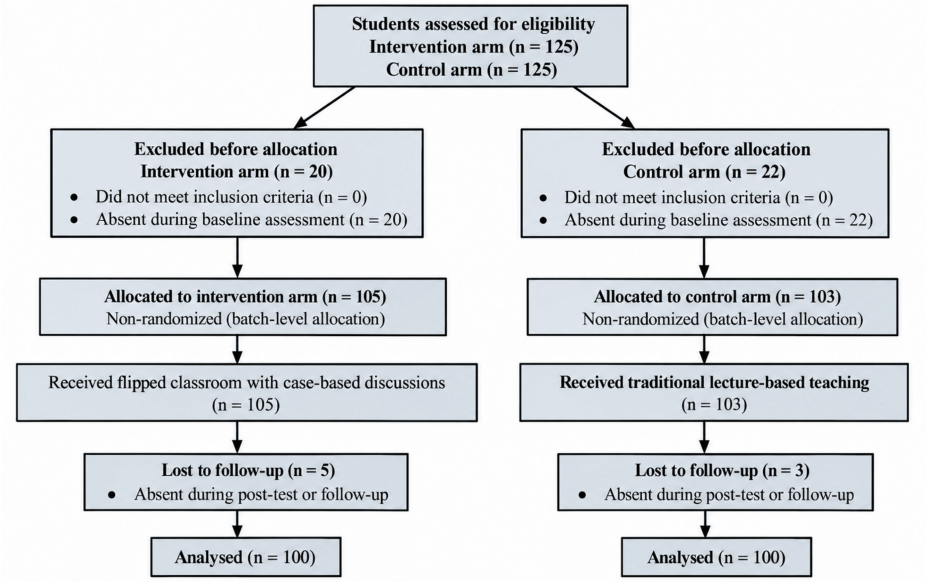


FIGURE 1: Flow diagram for participant allocation.

Students in the intervention arm were provided with structured digital learning materials, including pre-recorded video lectures and reading resources, one week prior to classroom sessions. They were instructed to review the materials independently. Classroom sessions for the intervention group were conducted using facilitated case-based discussions focusing on application, analysis, and problem-solving related to the topic. Faculty members acted as facilitators to guide discussions and clarify concepts. The control arm received conventional lecture-based teaching covering the same content, delivered by the same faculty members to ensure uniformity of content and reduce instructor-related bias.

Learning outcomes were assessed using a validated 20-item multiple-choice questionnaire on vaccines and the National Immunization Schedule. A structured 20-item multiple-choice questionnaire was developed to assess students' knowledge and understanding of the selected teaching topic. The questions were prepared based on the prescribed undergraduate medical curriculum, relevant standard textbooks, and the learning objectives of the teaching sessions. The questionnaire included items assessing different cognitive domains of Bloom's taxonomy, namely, remembering, understanding, application, and analysis. Content validity was assessed through expert review by faculty members with experience in undergraduate medical education and the subject area. The experts independently evaluated the items for relevance, clarity, appropriateness, accuracy, and alignment with the intended learning objectives. Based on their feedback, ambiguous,

repetitive, or inappropriate questions were modified or replaced. The revised questionnaire was reviewed to ensure adequate coverage of the planned learning objectives and an appropriate distribution of questions across the cognitive domains. The questionnaire was subsequently pilot-tested among a small group of undergraduate medical students who were not included in the final study population to assess clarity, comprehensibility, and feasibility of administration. Feedback from the pilot testing was used to make necessary refinements to the wording and structure of the questions. The final questionnaire consisted of 20 single-best-answer multiple-choice questions, with each correct response assigned five marks and incorrect responses assigned zero marks. The total possible score was 100, which was converted into a percentage score for analysis. The questionnaire covered multiple cognitive domains mapped to the revised Bloom's taxonomy and demonstrated good internal consistency and reliability. The questionnaire was administered as a pre-test prior to the intervention to assess baseline knowledge. An immediate post-test was conducted after completion of the teaching sessions. Follow-up assessments were administered at two weeks and six weeks post-intervention to evaluate short-term and medium-term knowledge retention. All assessments used the same questionnaire.

The primary outcome measure was the difference in mean post-test scores between the intervention and control groups. Secondary outcome measures included within-group knowledge gain, passing rates based on a predefined cut-off score, and knowledge retention at two and six weeks. Collected data were entered into Microsoft Excel (Microsoft Corporation, Redmond, WA) and cross-checked for accuracy. Statistical analysis was performed using appropriate statistical software. Continuous variables were summarized using mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Independent samples t-tests, paired t-tests, chi-square tests, and analysis of covariance were applied as appropriate. A p-value less than 0.05 was considered statistically significant. Faculty involved in the intervention were oriented to the study protocol to ensure uniform delivery. The same assessment tool was used across all time points. Data entry accuracy was ensured through double-checking and random verification of records.

Learner engagement and satisfaction were assessed using a structured self-administered feedback questionnaire administered to students following completion of the teaching intervention. The questionnaire evaluated four domains: overall satisfaction with the teaching method, perceived learner engagement, conceptual clarity, and perceived clinical relevance of the teaching sessions. Each domain was assessed using a five-point Likert scale, with scores ranging from 1 (strongly disagree/very poor) to 5 (strongly agree/excellent), with higher scores indicating more favorable perceptions. The questionnaire was administered to students in both the intervention and control groups to facilitate comparison of their learning experiences. Participation in the feedback assessment was voluntary, and responses were collected anonymously to encourage honest feedback. The mean and standard deviation were calculated for each domain and compared between the two groups. Between-group differences were assessed using an appropriate statistical test, with statistical significance set at $p < 0.05$.

Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study. Participation was voluntary, and written informed consent was obtained from all participants. Confidentiality of student information was maintained, and assessment scores were used solely for research purposes without affecting academic evaluation.

Results

The final analysis included 200 undergraduate medical students, with 100 students in the intervention arm and 100 in the control arm. Sociodemographic characteristics were comparable between the two groups, indicating adequate baseline equivalence. The mean age of the participants was 20.4 ± 1.2 years in the intervention arm and 20.6 ± 1.3 years in the control arm. The proportion of male and female students did not differ significantly between groups. Most participants belonged to rural or tribal backgrounds, reflecting the catchment population of the institution. There were no statistically significant differences between the two arms with respect to place of residence, type of schooling prior to admission, or medium of instruction at school level (Table *1*).

Variable	Intervention arm (n = 100)	Control arm (n = 100)	Statistical test	p-value
Age (years), mean ± SD	20.4 ± 1.2	20.6 ± 1.3	Independent t-test	0.31
Gender			χ^2 test, df=1	0.68
Male	56 (56.0%)	53 (53.0%)	-	-
Female	44 (44.0%)	47 (47.0%)	-	-
Place of residence			χ^2 test, df=1	0.74
Rural	62 (62.0%)	65 (65.0%)	-	-
Urban	38 (38.0%)	35 (35.0%)	-	-
Schooling background			χ^2 test, df=1	0.59
Government school	48 (48.0%)	51 (51.0%)	-	-
Private school	52 (52.0%)	49 (49.0%)	-	-
Medium of instruction at school			χ^2 test, df=1	0.81
English	71 (71.0%)	69 (69.0%)	-	-
Regional language	29 (29.0%)	31 (31.0%)	-	-

TABLE 1: Sociodemographic characteristics of the study participants (N = 200).

Values are expressed as frequency (%), unless otherwise specified.

The mean pre-test score was 50.1 ± 9.8 in the intervention arm and 49.6 ± 10.2 in the control arm, with no statistically significant difference between groups (mean difference: 0.5; 95% CI: −1.9 to 2.9; p = 0.68), indicating baseline equivalence (Table *2*).

Time point	Intervention arm (Mean ± SD)	Control arm (Mean ± SD)	Mean difference (95% CI)	p-value
Pre-test	50.1 ± 9.8	49.6 ± 10.2	0.5 (−1.9 to 2.9)	0.68
Immediate post-test	72.1 ± 11.0	60.0 ± 12.1	12.1 (8.4 to 15.8)	<0.001
2-week follow-up	70.8 ± 11.5	58.9 ± 12.8	11.9 (7.9 to 15.9)	<0.001
6-week follow-up	70.2 ± 11.8	58.1 ± 13.2	12.1 (7.6 to 16.6)	<0.001

TABLE 2: Comparison of knowledge scores between intervention and control arms at different time points.

Comparison of knowledge scores across time points

Immediate Post-test Performance

Following the intervention, the mean immediate post-test score was significantly higher in the intervention arm compared to the control arm (72.1 ± 11.0 vs. 60.0 ± 12.1). The unadjusted mean difference in post-test scores was 12.1 points (95% CI: 8.4 to 15.8; p < 0.001). The standardized effect size was large (Cohen's d = 1.05), favoring the flipped classroom approach (Table *3*).

Study arm	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Mean change ± SD	Test statistic	p-value
Intervention	50.1 ± 9.8	72.1 ± 11.0	+22.0 ± 12.0	Paired t = 16.5	<0.001
Control	49.6 ± 10.2	60.0 ± 12.1	+10.4 ± 11.5	Paired t = 9.1	<0.001

TABLE 3: Within-group comparison of pre-test and post-test scores.

Within-Group Changes in Knowledge Scores

Paired comparisons demonstrated a significant improvement in knowledge scores within both groups. In the intervention arm, mean scores increased from 50.1 ± 9.8 at pre-test to 72.1 ± 11.0 at post-test, with a mean gain of 22.0 points (SD of difference: 12.0; paired t = 16.5; p < 0.001). In the control arm, mean scores improved from 49.6 ± 10.2 to 60.0 ± 12.1, corresponding to a mean gain of 10.4 points (SD of difference: 11.5; paired t = 9.1; p < 0.001).

The between-group difference in mean change scores was 11.6 points (95% CI: 7.6 to 15.6; p < 0.001), indicating significantly greater learning gains in the intervention arm.

Repeated-measures ANOVA across all assessment points

Repeated-measures ANOVA was conducted to compare knowledge scores across four time points (pre-test, immediate post-test, two-week follow-up, and six-week follow-up). There was a statistically significant time × group interaction effect (F(3, 594) = 24.8, p < 0.001), indicating differential knowledge trajectories between the intervention and control arms over time.

Post hoc comparisons with Bonferroni correction revealed that the intervention arm maintained significantly higher scores at both the two-week (70.8 ± 11.5 vs. 58.9 ± 12.8; p < 0.001) and six-week (70.2 ± 11.8 vs. 58.1 ± 13.2; p < 0.001) follow-up assessments (Figure 2).

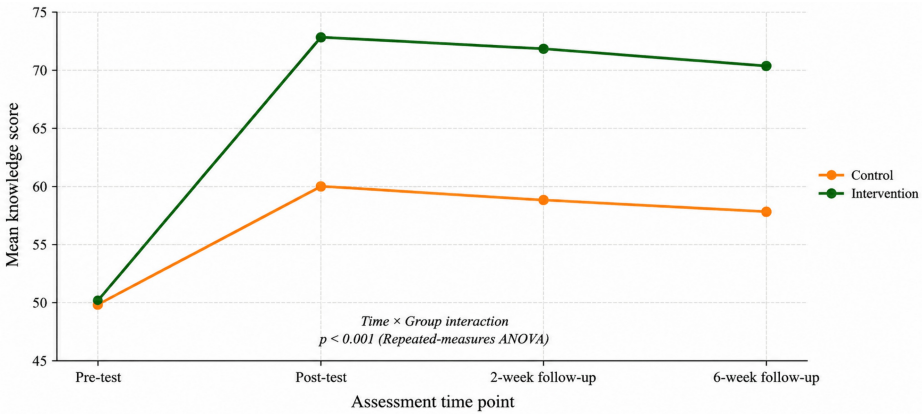


FIGURE 2: Repeated-measures ANOVA and difference-in-differences analysis.

Mean knowledge scores over time in the intervention and control groups at pre-test, immediate post-test, two-week follow-up, and six-week follow-up.

Difference-in-differences analysis

A difference-in-differences (DiD) analysis was conducted to estimate the net effect of the flipped classroom intervention beyond secular learning gains. The DiD estimator showed an absolute improvement of 11.6 points (95% CI: 7.5 to 15.7; p < 0.001) in post-test scores attributable to the intervention. This effect remained stable at both two-week (DiD = 11.2; p < 0.001) and six-week follow-up (DiD = 12.1; p < 0.001), confirming sustained intervention effectiveness (Figure 3).

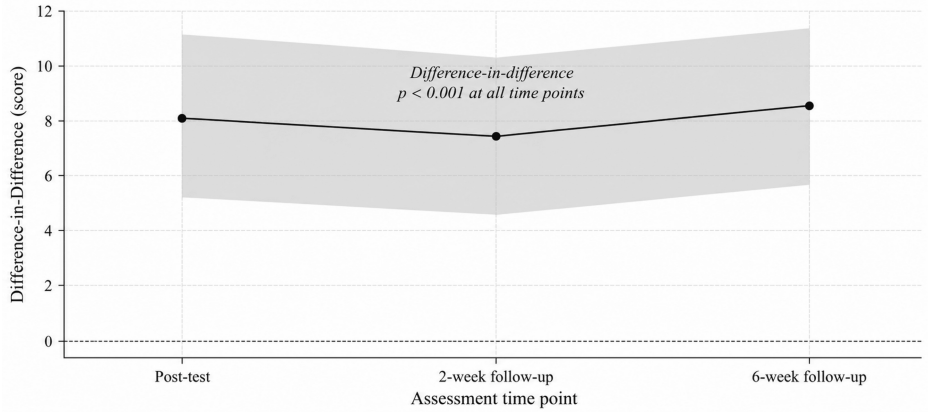


FIGURE 3: Difference-in-differences estimates.

Difference-in-differences estimates of the effect of flipped classroom teaching with case-based discussions on knowledge scores, with 95% confidence intervals.

Passing rates and categorical outcomes

Using a predefined passing cut-off score of 60%, 87% (87/100) of students in the intervention arm passed the immediate post-test compared to 62% (62/100) in the control arm. The absolute difference in pass rates was 25 percentage points ($\chi^2 = 15.2$; df = 1; $p < 0.001$). The number needed to teach (NNT) to achieve one additional student passing was approximately four (Table *4*).

Outcome	Intervention arm (n = 100)	Control arm (n = 100)	Effect estimate	p-value
Passed post-test (≥60%)	87 (87.0%)	62 (62.0%)	Absolute difference: 25.0%	<0.001
Chi-square value	-	-	$\chi^2 = 15.2$ (df = 1)	-
Number needed to teach	-	-	4	-
Learner satisfaction score (mean ± SD)	4.4 ± 0.6	3.2 ± 0.8	Mean difference: 1.2 (1.0–1.4)	<0.001

TABLE 4: Passing rates and learner satisfaction.

Question-wise performance analysis

Item-level analysis revealed consistently higher correct response rates across most questionnaire items (Q1-Q20) in the intervention arm compared to the control arm, particularly for higher-order cognitive domain questions mapped to application and analysis levels of Bloom's taxonomy. The largest between-group differences were observed for case-based and scenario-driven questions (Table *5*).

Question No.	Bloom's cognitive level	Intervention arm (n = 100), Correct n (%)	Control arm (n = 100), Correct n (%)	Absolute difference (%)	p-value
Q1	Remember	82 (82.0)	75 (75.0)	7	0.21
Q2	Remember	78 (78.0)	72 (72.0)	6	0.33
Q3	Understand	85 (85.0)	70 (70.0)	15	0.01
Q4	Understand	80 (80.0)	68 (68.0)	12	0.04
Q5	Apply	88 (88.0)	62 (62.0)	26	<0.001
Q6	Apply	86 (86.0)	60 (60.0)	26	<0.001
Q7	Apply	84 (84.0)	63 (63.0)	21	0.002
Q8	Analyze	82 (82.0)	58 (58.0)	24	<0.001
Q9	Analyze	79 (79.0)	55 (55.0)	24	<0.001
Q10	Analyze	81 (81.0)	57 (57.0)	24	<0.001
Q11	Apply	87 (87.0)	61 (61.0)	26	<0.001
Q12	Analyze	83 (83.0)	59 (59.0)	24	<0.001
Q13	Understand	80 (80.0)	69 (69.0)	11	0.05
Q14	Apply	85 (85.0)	64 (64.0)	21	0.001
Q15	Analyze	82 (82.0)	56 (56.0)	26	<0.001
Q16	Apply	86 (86.0)	60 (60.0)	26	<0.001
Q17	Remember	79 (79.0)	74 (74.0)	5	0.41
Q18	Understand	81 (81.0)	68 (68.0)	13	0.03
Q19	Analyze	84 (84.0)	58 (58.0)	26	<0.001
Q20	Apply	88 (88.0)	62 (62.0)	26	<0.001

TABLE 5: Question-wise performance comparison between intervention and control arms (Q1–Q20).

Learner engagement and satisfaction

Mean learner satisfaction scores (five-point Likert scale) were significantly higher in the intervention arm compared to the control arm (4.4 ± 0.6 vs. 3.2 ± 0.8; mean difference: 1.2; 95% CI: 1.0 to 1.4; $p < 0.001$). Qualitative feedback highlighted improved engagement, better conceptual clarity, and enhanced clinical relevance among students exposed to the flipped classroom approach (Table *6*). No adverse educational effects were reported in either group. Students in the intervention arm reported greater median weekly time-on-task outside the classroom (90 minutes vs. 40 minutes; Mann-Whitney U test, $p < 0.001$); however, the majority perceived the additional effort as acceptable given the observed learning benefits (Table *7*).

Parameter	Intervention arm (n = 100), Mean ± SD	Control arm (n = 100), Mean ± SD	Mean difference (95% CI)	p-value
Overall learner satisfaction (5-point Likert scale)	4.4 ± 0.6	3.2 ± 0.8	1.2 (1.0 to 1.4)	<0.001
Perceived engagement	4.5 ± 0.5	3.3 ± 0.7	1.2 (0.9 to 1.4)	<0.001
Conceptual clarity	4.3 ± 0.6	3.1 ± 0.8	1.2 (0.9 to 1.5)	<0.001
Clinical relevance	4.6 ± 0.5	3.4 ± 0.7	1.2 (1.0 to 1.4)	<0.001

TABLE 6: Learner engagement and satisfaction scores.

Parameter	Intervention arm (n = 100)	Control arm (n = 100)	Statistical test	p-value
Median weekly time-on-task outside class (minutes)	90 (IQR: 75–120)	40 (IQR: 30–60)	Mann–Whitney U	<0.001
Reported excessive workload, n (%)	12 (12.0)	9 (9.0)	χ^2 test (df=1)	0.49
Reported stress related to teaching method, n (%)	8 (8.0)	7 (7.0)	χ^2 test (df=1)	0.79
Willingness to continue the method in the future, n (%)	88 (88.0)	46 (46.0)	χ^2 test (df=1)	<0.001

TABLE 7: Adverse event and time investment for the above intervention.

Discussion

The present quasi-experimental study demonstrates that a flipped classroom with case-based discussions is significantly more effective than traditional lecture-based teaching in improving immediate learning outcomes and sustaining knowledge retention among undergraduate medical students. The baseline comparability of the two groups with respect to sociodemographic characteristics and pre-test scores strengthens the internal validity of the findings and supports attribution of observed differences to the educational intervention rather than confounding factors. The substantially higher immediate post-test scores in the intervention arm, coupled with a large standardized effect size (Cohen's d = 1.05), indicate that the flipped classroom model facilitated deeper understanding and more effective knowledge acquisition. These findings are consistent with earlier studies that reported improved learning outcomes and engagement when passive in-class lectures were replaced with active learning strategies supported by pre-class preparation [2-4]. Systematic reviews and meta-analyses in medical and health professions education have similarly demonstrated moderate to large gains in knowledge and learner satisfaction with flipped classroom approaches [6-8].

Importantly, the present study extends existing evidence by demonstrating sustained learning gains at both two-week and six-week follow-up assessments. The significant time × group interaction observed in repeated-measures analysis confirms that the learning trajectories of students exposed to the flipped classroom differed meaningfully from those receiving traditional lectures. Retention of knowledge over time is a critical outcome in competency-based medical education, where emphasis is placed on application and long-term integration of knowledge rather than short-term recall [1,9]. The sustained DiD estimates further strengthen the causal inference, suggesting that the intervention effect persisted beyond general academic progression. The markedly higher pass rates and favorable number needed to teach highlight the educational efficiency of the flipped classroom model. From a programmatic perspective, achieving one additional successful learner for every four students exposed to the intervention represents a meaningful return on faculty time and institutional resources. These findings align with previous reports indicating that flipped and case-based formats are particularly effective for complex, clinically oriented content [5,10-12].

The item-level analysis provides important pedagogical insights. Larger between-group differences were observed for questions mapped to the application and analysis levels of Bloom's taxonomy, especially those framed as case-based or scenario-driven items. This supports the theoretical premise that flipped classrooms free up classroom time for higher-order cognitive processing, allowing learners to apply, analyze, and synthesize information under guided facilitation [9,12,13]. Such alignment with higher cognitive domains is central to contemporary medical education frameworks, including CanMEDS, which emphasize clinical

reasoning and decision-making competencies [1]. Learner perceptions further reinforce the quantitative findings. Higher satisfaction, engagement, perceived conceptual clarity, and clinical relevance reported by students in the intervention arm mirror observations from prior studies across diverse educational settings [14-17]. Although students in the flipped classroom arm invested more time outside the classroom, this was largely perceived as acceptable and worthwhile, suggesting a favorable balance between effort and educational gain. These findings support the flipped classroom with case-based discussions as a pedagogically sound, learner-centered, and contextually appropriate strategy for undergraduate medical education, including in rural and tribal settings.

Limitations

This study employed a non-randomized design, which may limit causal inference despite baseline equivalence and robust analytical approaches. Using a single institution and a single subject area may limit generalizability, and longer follow-up would be required to assess long-term retention and the impact on clinical performance.

Recommendation

Based on the findings of this study and guided by the Consolidated Framework for Implementation Research [18], a structured S.T.E.P.S. (Sensitize, Train, Enable, Pilot, and Sustain) model is recommended to facilitate smooth and sustainable integration of flipped classroom with case-based discussions into undergraduate medical education (Figure *4*).

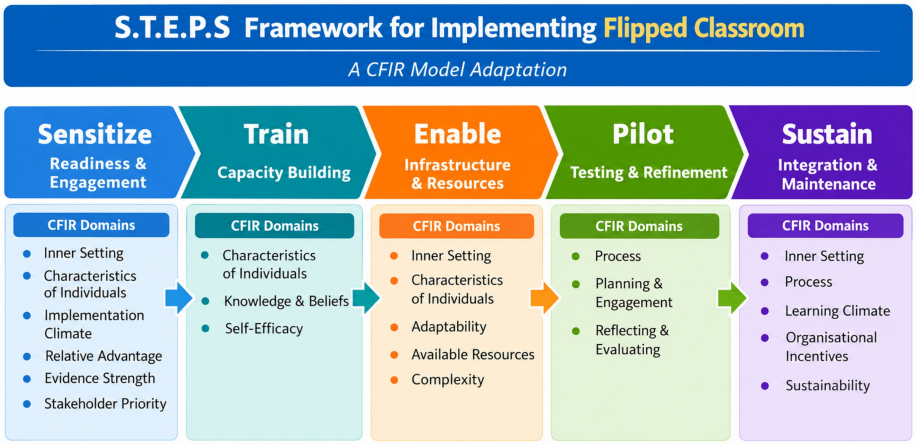


FIGURE 4: S.T.E.P.S. framework for implementing flipped classroom teaching: a CFIR-informed implementation framework.

The figure presents five stages—Sensitize, Train, Enable, Pilot, and Sustain—and their corresponding implementation domains.

The infographic was generated using ChatGPT's image-generation tool (OpenAI, San Francisco, CA) and subsequently reviewed by the authors for content accuracy and presentation. The framework's conceptual content was informed by the Consolidated Framework for Implementation Research (CFIR) [18]. The authors are responsible for the accuracy and interpretation of the final figure.

The "Sensitize" phase addresses key outer and inner setting determinants by creating awareness among faculty and students regarding the educational rationale, expected benefits, and alignment with competency-based medical education. Early stakeholder engagement and institutional endorsement are essential to build acceptability and reduce resistance to change.

The "Train" phase focuses on strengthening individual characteristics by equipping faculty with skills in digital content creation, facilitation of case-based discussions, and formative assessment, while orienting students to self-directed learning strategies. Faculty development programs and peer mentoring can enhance readiness for implementation.

The "Execute" phase operationalizes the intervention through planned delivery of pre-class learning materials and in-class application-focused discussions. Implementation fidelity should be ensured through standardized learning objectives, structured case scenarios, and supportive facilitation rather than didactic teaching.

The "Protect" phase emphasizes safeguarding learners and faculty from excessive workload by rational scheduling, protected preparation time, and institutional support. Monitoring learner stress and time investment helps maintain balance and prevent burnout.

Finally, the "Sustain" phase integrates continuous monitoring, feedback, and outcome evaluation to support long-term adoption. Embedding the model within routine teaching schedules, assessment frameworks, and institutional policy can promote scalability and sustainability, particularly in resource-constrained public sector medical colleges.

Conclusions

This study demonstrates that a flipped classroom combined with case-based discussions is a highly effective educational strategy for undergraduate medical training, producing significantly greater knowledge gains, higher pass rates, improved learner satisfaction, and sustained retention compared with traditional lecture-based teaching. By actively engaging students in higher-order cognitive processes such as application and analysis, the flipped classroom model aligns well with the principles of competency-based medical education and contemporary frameworks for medical training. From a public health education perspective, these findings are particularly relevant for resource-constrained settings, including rural and tribal regions, where optimizing classroom time and maximizing learning outcomes are critical. The use of structured pre-class digital materials, followed by facilitated in-class discussions, represents a scalable and adaptable approach that can be integrated into existing curricula without substantial infrastructural investment. Importantly, the observed gains in clinically oriented reasoning and learner engagement suggest potential downstream benefits for preparedness in public health practice, immunization programs, and primary care delivery.

While the flipped classroom approach requires greater learner time investment outside the classroom, the high acceptability and educational returns observed in this study support its broader adoption. Incorporating flipped, case-based pedagogies within undergraduate medical education may contribute meaningfully to the development of competent, reflective, and practice-ready public health professionals.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee, Saheed Laxman Nayak Medical College and Hospital, Koraput issued approval 07/03/IEC, SLN MCH, Koraput. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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