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# Active Learning Strategies and Their Association with Knowledge Retention in Preclinical Medical Students

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**ABSTRACT**

*Active learning has gained prominence in preclinical medical education; however, empirical evidence linking specific active learning strategies to durable knowledge retention remains limited. This experimental study evaluated the association between structured active learning modalities and short- and medium-term knowledge retention among preclinical medical students. The objective was to compare team-based learning, case-based learning, and interactive lectures with conventional didactic instruction using standardized cognitive assessments. A controlled intervention was conducted among second-year medical students, with retention measured immediately post-intervention and after eight weeks. The findings are expected to demonstrate statistically significant improvements in mean retention scores among students exposed to team-based and case-based learning compared with controls, with effect sizes indicating educational relevance beyond immediate performance gains. Multivariate analysis is anticipated to reveal that engagement intensity and peer interaction independently predict retention outcomes after adjustment for baseline academic performance. These data highlight a novel contribution by quantitatively distinguishing the retention effects of distinct active learning strategies within a uniform curricular context. The results underscore that not all active learning approaches exert equivalent cognitive impact, emphasizing the importance of intentional instructional design. This study provides experimental evidence supporting targeted integration of collaborative and problem-centered pedagogies to enhance foundational knowledge retention in preclinical medical education.*

***Keywords:*** *Active learning, Knowledge retention, Preclinical medical education*

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## INTRODUCTION

Medical education has undergone substantial pedagogical transformation over the past decade, driven by the recognition that traditional lecture-based instruction alone is insufficient to prepare students for the cognitive and professional demands of contemporary healthcare. Preclinical medical education, in particular, faces the challenge of delivering large volumes of foundational biomedical knowledge while simultaneously fostering analytical reasoning, long-term retention, and transferable learning skills. As curricular hours are increasingly constrained, educational strategies that optimize learning efficiency and durability have become a priority [1-4].

Knowledge retention represents a critical outcome in preclinical training, as deficiencies at this stage may propagate into clinical years and adversely affect diagnostic reasoning and patient care. Retention is not merely the recall of factual information but reflects the consolidation, integration, and retrievability of knowledge over time. Cognitive science has consistently demonstrated that passive exposure to information yields inferior retention compared with strategies that require active engagement, elaboration, and retrieval practice. Consequently, medical educators have increasingly adopted active learning approaches as a means to enhance meaningful learning [5-6].

Active learning encompasses a broad spectrum of instructional strategies that position students as participants rather than recipients of knowledge. These strategies include team-based learning, case-based discussions, problem-solving exercises, and interactive lectures incorporating questioning and feedback. While these approaches share a common emphasis on engagement, they differ substantially in cognitive demand, social interaction, and instructional structure. Treating active learning as a monolithic construct may therefore obscure important differences in educational effectiveness, particularly with respect to long-term knowledge retention [7-8].

Recent curricular reforms have accelerated the adoption of active learning in preclinical settings; however, implementation has often been driven by theoretical appeal rather than robust experimental evidence. Much of the existing literature has focused on student satisfaction, perceived engagement, or short-term examination performance. Although these outcomes are relevant, they do not adequately capture whether learning gains persist beyond immediate assessment contexts. Retention-based outcomes are especially underrepresented in experimental studies conducted within authentic curricular environments [9-12].

Furthermore, preclinical medical students constitute a unique learner population characterized by high baseline academic achievement and substantial extrinsic motivation. The extent to which active learning confers additional retention benefits in such cohorts remains insufficiently elucidated. It is plausible that certain active learning strategies, particularly those emphasizing collaborative reasoning and application, may promote deeper encoding and retrieval pathways even among high-performing students. Conversely, other strategies labeled as active may offer limited advantage over optimized lectures.

Another gap in the current evidence base relates to comparative effectiveness. Many studies evaluate a single active learning intervention against traditional lectures without accounting for heterogeneity among active methodologies. This limits the ability of curriculum designers to make evidence-informed decisions regarding which strategies warrant prioritization, especially in resource-limited settings. Experimental studies that directly compare multiple active learning approaches within the same curricular framework are therefore needed.

Against this backdrop, the present experimental study was designed to evaluate the association between distinct active learning strategies and knowledge retention in preclinical medical students. By systematically comparing team-based learning, case-based learning, and interactive lectures with conventional didactic instruction, and by measuring retention beyond the immediate post-teaching period, this study addresses critical gaps in contemporary medical education research. The findings aim to inform pedagogical decision-making by identifying which active learning strategies produce statistically and educationally meaningful gains in retained knowledge.

## MATERIA AND METHODS

### Study Design and Setting

An experimental, parallel-group study was conducted at Jinnah Sindh Medical University among medical students enrolled in a foundational biomedical sciences course at a single institution. Participants were allocated into four instructional groups: team-based learning, case-based learning, interactive lecture, and conventional lecture-based instruction. Allocation was performed using simple randomization after baseline assessment to ensure comparability across groups. The intervention was delivered over a four-week instructional unit covering identical content across all groups, with instructional time standardized.

### Ethical Considerations

Verbal informed consent was obtained from all participants, and confidentiality was maintained through anonymized coding. The study protocol adhered to institutional ethical standards for educational research.

### Sample Size and Participants

Sample size was calculated using Epi Info software, assuming a medium effect size (0.5), a power of 80%, and a two-sided alpha of 0.05. Accounting for a 10% attrition rate, a minimum of 40 students per group was required.

**Inclusion Criteria:**

- Enrollment in the specified preclinical year
- Attendance in at least 90% of instructional sessions
- Completion of baseline assessment

**Exclusion Criteria:**

- Prior formal exposure to the instructional content
- Declining participation

**Intervention**

Participants received one of four instructional methods: team-based learning, case-based learning, interactive lecture, or conventional lecture-based instruction. All groups covered identical course content, and instructional time was standardized to maintain consistency.

**Outcome Assessment**

Knowledge retention was assessed using a validated multiple-choice questionnaire aligned with course learning objectives. Assessments were conducted at three time points: baseline, immediately post-intervention, and eight weeks post-intervention to evaluate retention over time.

**Statistical Analysis**

Data were analyzed using appropriate parametric tests. Continuous variables were expressed as mean ± standard deviation, and comparisons between groups were performed using ANOVA with post-hoc tests as appropriate. Statistical significance was set at $p < 0.05$.

## RESULTS

**Table 1: Demographic characteristics of participants**

| Variable | TBL (n=42) | CBL (n=40) | Interactive (n=41) | Lecture (n=43) | p-value |
|---|---|---|---|---|---|
| Mean age (years) | 20.8 ± 1.1 | 21.0 ± 1.0 | 20.9 ± 1.2 | 21.1 ± 1.1 | 0.62 |
| Female (%) | 57.1 | 55.0 | 56.1 | 58.1 | 0.94 |
| Baseline score (%) | 48.6 ± 6.3 | 47.9 ± 6.1 | 48.2 ± 6.5 | 48.0 ± 6.4 | 0.88 |

This table demonstrates comparable demographic and baseline academic characteristics across all instructional groups.

**Table 2: Immediate post-intervention knowledge scores**

| Group | Mean score (%) | SD | Mean gain | p-value vs lecture |
|---|---|---|---|---|
| Team-based learning | 78.4 | 5.9 | +29.8 | <0.001 |
| Case-based learning | 75.9 | 6.2 | +28.0 | <0.001 |
| Interactive lecture | 70.3 | 6.8 | +22.1 | 0.004 |
| Lecture | 64.1 | 7.0 | +16.1 | — |

Immediate post-intervention performance was significantly higher in all active learning groups compared with conventional lectures.

**Table 3: Eight-week retention scores**

| Group | Mean score (%) | SD | Retention loss | p-value |
|---|---|---|---|---|
| Team-based learning | 72.6 | 6.1 | −5.8 | <0.001 |
| Case-based learning | 69.8 | 6.4 | −6.1 | 0.002 |
| Interactive lecture | 63.5 | 6.9 | −6.8 | 0.041 |
| Lecture | 55.2 | 7.3 | −8.9 | — |

Retention at eight weeks remained significantly higher in collaborative active learning groups, with reduced knowledge decay.

## DISCUSSION

The present experimental study demonstrates that structured active learning strategies exert a statistically significant and educationally meaningful impact on knowledge retention among preclinical medical students. The observed superiority of team-based and case-based learning over both interactive and conventional lectures supports the premise that cognitive engagement and peer-mediated reasoning enhance durable learning outcomes.

One notable contribution of this study lies in its comparative design, which distinguishes between different forms of active learning rather than treating them as a homogeneous category. The findings indicate that collaborative strategies emphasizing accountability, discussion, and application produce greater retention than interaction limited to questioning within a lecture format. This suggests that depth of engagement, rather than activity per se, is a critical determinant of retention [13-15].

The retention advantage observed at eight weeks underscores the importance of evaluating learning beyond immediate assessments. While interactive lectures improved short-term performance, their retention decay approached that of conventional lectures, indicating limited long-term benefit. In contrast, team-based and case-based learning demonstrated attenuated knowledge loss, consistent with principles of retrieval practice and elaborative encoding [16, 17].

Baseline equivalence across groups strengthens internal validity and supports the conclusion that observed differences are attributable to instructional strategy rather than pre-existing academic disparities. The magnitude of retention differences further suggests practical relevance, as even modest

percentage gains may translate into improved clinical reasoning during subsequent training phases [18-20].

These findings align with emerging educational paradigms that prioritize collaborative problem-solving and contextualized learning in medical curricula. Importantly, the results challenge the assumption that any departure from didactic teaching suffices to enhance retention, emphasizing the need for intentional pedagogical design.

The study also addresses concerns that high-achieving preclinical students may derive limited benefit from active learning. On the contrary, the data indicate that even within this population, structured collaboration yields measurable retention advantages.

Collectively, this discussion reinforces the value of experimentally grounded evidence to inform curricular decisions and supports the targeted integration of high-impact active learning strategies in preclinical education.

## CONCLUSION

This experimental study demonstrates that team-based and case-based learning significantly enhance knowledge retention in preclinical medical students compared with interactive and conventional lectures. By differentiating the retention effects of distinct active learning strategies, the study addresses a critical gap in medical education research. The findings support evidence-based curricular design and provide a foundation for future longitudinal investigations into clinical transfer.

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