Original Article

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Team-based Learning versus Problem-based Learning among First-year Medical Students in Biochemistry: A Quasi-experimental Study

Biochemistry Section

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ABSTRACT

Introduction: Team-based Learning (TBL) and Problem-based Learning (PBL), both active teaching methodologies, are known for improving problem-solving abilities, clinical reasoning, and motivating students for self-directed studies. Although both active methods, TBL and PBL, differ in methodology and required resources, it is always a challenge to choose active methods that are more feasible and effective in the undergraduate medical curriculum.

Aim: To compare two active teaching strategies, viz., the effectiveness of TBL vs. PBL in first-year Bachelor of Medicine, Bachelor of Surgery (MBBS) students in terms of learning outcomes, development of critical thinking skills, and retention of knowledge.

Materials and Methods: This quasi-experimental study was conducted at Department of Biochemistry, NKP Salve Medical College and RC Nagpur, Maharashtra, India from August 2017 to October 2017. A total of 150 first-year MBBS students were included in the study. TBL and PBL were performed following the protocols of their respective methodologies, and scores for learning gain and critical thinking were compared between the TBL and PBL groups. Student perception regarding the procedures was collected using a prevalidated structured questionnaire. The retention of knowledge was assessed by comparing scores from a pretest and a test conducted two months later. Data were statistically analysed using the Wilcoxon signed-rank test and the Mann-Whitney U test.

Results: In the present study, the mean age of the participating students was 20±2 years. Post-test results, obtained just after the intervention, demonstrated a significant learning gain in students using both methods, with a statistically higher gain in TBL (p-value <0.0001) compared to PBL. PBL was appreciated for providing freedom of learning style and facilitator guidance during discussions. Critical thinking skills improved more in PBL, particularly in terms of drawing inferences and interpretations (p-value <0.001). However, no statistically significant differences were found in knowledge retention when the test was conducted two months later in both groups.

Conclusion: Learning gain was higher with TBL compared to PBL, with no difference in knowledge retention and the effect on different parameters of critical thinking skills. Students found TBL to be more beneficial for the undergraduate curriculum.

Keywords: Active teaching learning method, Critical thinking skills, Knowledge retention, Learning gain, Medical education

INTRODUCTION

Teaching-learning methods have undergone a paradigm shift in recent decades. Although the traditional method, the lecture, is the most widely used tool to teach a large group in a shorter period, the importance of active teaching methods is becoming more significant. Active learning methods are defined as “Instructional activities involving students in doing things and thinking about what they are doing” [1]. TBL and PBL are commonly used active teaching-learning methodologies in medical education.

The TBL is a large group, single instructional active teaching methodology in which students learn in a team of 6-10 students [2]. Here, one teacher can manage nearly 20 teams; hence it can be considered a large group method. Students are instructed about learning objectives before the session and should come prepared with the topic. Their preparedness is tested with an individual readiness assessment test, and team coordination is tested with a team readiness assessment test. Students study professionally relevant problems and discuss and solve the questions with reasoning. Although TBL is an active method, students learn in a controlled environment and are directly guided by the teacher [3].

The PBL is a small-group active teaching technology that requires multiple facilitators. Teachers act as facilitators for small groups to direct students’ thinking in the proper direction. PBL offers more freedom of learning than TBL and inspires students to engage in independent learning. In PBL, students identify learning gaps in their knowledge and use these gaps to generate learning objectives for self-study [4,5]. In contrast to TBL, PBL requires more faculties, and the responsibility to learn lies with the students themselves.

A review of the literature demonstrates the important role of active learning in enhancing clinical application, group problem-solving, and the application of critical thinking skills in medical education [6]. Critical thinking can be inculcated in students by actively and skillfully conceptualising, applying, analysing, synthesising, or evaluating information gathered from or generated by observation, experience, reflection, reasoning, or communication [7]. Most universities across the world have used active methods to improve critical appraisal skills and knowledge retention [8]. Although PBL and TBL are both commonly preferred active teaching techniques, they differ in their feasibility concerning design and the need for manpower and resources.

Previously, a few studies have compared the effectiveness of PBL and TBL against traditional methods separately [9-11]. In recent years, TBL has been observed to replace PBL as a favourable active teaching method in undergraduate medical teaching [12]. Although active learning methods have advantages over traditional ones, they are more time-consuming and frequently involve more teaching faculties. Hence, choosing the right kind of active methods for teaching undergraduates is always a challenge in medical education. Therefore, the present study was conducted to compare

two active teaching strategies, namely TBL vs. PBL, in first-year MBBS students in terms of the learning outcome, development of critical thinking skills, and retention of knowledge.

MATERIALS AND METHODS

A quasi-experimental study was conducted in the Department of Biochemistry, Department of Biochemistry, NKP Salve Medical College and RC Nagpur, Maharashtra, India, for a duration of two months from August 2017 to October 2017. The study was approved by the Institutional Ethics Committee (IEC No IEC/NKPSIMS/1/2017). All students who participated in the study were provided with an explanation about the aim of the study, guaranteed anonymity, and explicitly declared their consent for the publication of the results.

Inclusion criteria: Since Biochemistry is a subject for first-year MBBS students, all 150 first-year MBBS students were chosen as participants in the study.

Exclusion criteria: Students from other allied branches like dental and physiotherapy were excluded from the study.

Sample size: A total of 150 students were divided into two groups of 75 each. Each group was further divided into small groups consisting of 10-11 students.

Study Procedure

All 150 first-year MBBS students of study institute, attending sessions of TBL and PBL, were the study subjects. The group of students attending TBL was compared with their counterparts attending both sessions of PBL. In the present study, only students who were present for the respective pretest and post-test were compared to assess learning gain. Retention of knowledge was assessed by comparing the data of students who appeared for the pretest and surprise test after two months.

a) **Implementation of TBL:** A pretest was conducted before declaring the topic to the students. The learning objectives were communicated to the students, and a pretest was performed five days before the session. Glycogen Storage Disease (GSD) was taught to the first group using team-based learning. The students were informed about the learning objectives and oriented about the procedure of TBL, as well as the possible resources of knowledge in the form of reference books and the use of the internet for information about GSD. The TBL session was conducted in a single three-hour session after five days of the pretest. The methodology of TBL was strictly followed.

   The Individual Readiness Assessment Test (IRAT) was conducted, where students individually solved 20 Multiple-Choice Questions (MCQs). The Group Readiness Assessment Test (GRAT) was also conducted, where the same MCQ sheet was solved in teams of 10 students using the scratch card technique. MCQ answer sheets were created with scratch cards, with an asterisk (*) indicating the correct option. The team of students scratched the options until they found the asterisk in the correct option. The number of attempts to arrive at the final answer was calculated. Following these tests, all MCQs were discussed by the instructor with the students in an instructor review. Afterward, five application-based problems were given to the students to solve in teams for 40 minutes. In the final step, inter group discussion was carried out to discuss all the problems. At the end of the session, peer feedback was conducted through a questionnaire. The session was followed by the post-test and the critical thinking assessment test [13].

b) **Implementation of PBL:** For the second group, PBL was conducted in two sessions, with each session lasting two hours and held one week apart. The first session of PBL was conducted on the same day as TBL for the first group. A brief introduction was given to the students, explaining their roles, group dynamics, and the approach to the demo patient case. After the pretest, a prevalidated case of Von-Gierke's Disease (GSD) was presented to the students, who were divided into groups of 10-11 students with one facilitator.

   In the first session, students studied the case, identified cues, and determined the learning gaps in their knowledge to form learning objectives. After one week, they reconvened in the same groups to solve the problems. They were even provided with an investigation report of the same patient discussed in the case. Students diagnosed the case based on their research. The post-test and the test to measure critical thinking were conducted at the end of the second session [14].

c) **Assessment of critical thinking skills:** The Watson-Glaser critical thinking assessment test module, provided by Pearson [15], was used as a template to assess the critical thinking skills of students at the end of each teaching-learning intervention. For the first group, the test was conducted on the same day as the TBL session, while for the second group, it was conducted after the second session of PBL. The test consisted of questions framed to assess the following critical thinking parameters.

To assess the five critical thinking skills, five exercises were given with proper directions to solve them according to the module. Each exercise consisted of multiple-choice answers, and one mark was allotted for correct answers. The average scores of the students were compared between the two groups. All exercises were framed related to the topics, following the directions in the Watson-Glaser critical thinking assessment test module provided by Pearson and were revalidated among peer groups. The validity of the questionnaire was tested through peer verification and by members of the medical education technology cell. The exercises were framed as follows:

(i) **Test for inference:** Students were given statements with five options of possible inferences. They were supposed to draw an inference in the form of True, Probably True, Insufficient data, Probably false, or False.

(ii) **Recognition of assumptions:** Students were given a scenario, and their ability to draw assumptions from the given statement was tested by determining whether the assumptions could or could not be made.

(iii) **Deduction:** Students were given two statements related to the topic, along with five deductions. Based on the statements, they had to determine whether the deductions could be concluded or not.

(iv) **Interpretation:** Students were given a short paragraph along with a few interpretations related to it. Their ability to choose the correct interpretation from the given exercise was tested.

(v) **Evaluation of arguments:** Students were given a statement and a few arguments based on it as sub-questions. They had to decide whether the arguments had a strong or weak correlation with the statement.

The questionnaire included five questions, each worth one mark, for each type of exercise. The questionnaires from both groups were compared based on the marks obtained by the students in each exercise.

d) **Test for the retention of knowledge:** After two months, a surprise test was conducted for all 150 students by giving the same post-test question on Glycogen storage disorders for both groups. The scores from the questionnaire were counted out of a total of 10 marks for the pre and post-test questions. All questionnaires and exercises were designed by the principal investigator to assess the knowledge of students based on the topic of glycogen storage disorders [16]. All exercises and tests were validated by all co-investigators and the medical education team at the institute. The scores from the retention of knowledge test were compared with the pretest given before

the intervention. No cut-off was considered for the scores, and only the scores were compared between both groups.

e) **Crossover of the teaching methodology:** Crossover of the methodology was done for students, following the same precision and care, in order to make students aware of both teaching techniques.

f) **Evaluation of student feedback about the effectiveness of TBL and PBL:** At the end of the crossover sessions of TBL and PBL, students were given a structured feedback questionnaire with qualitative questions to compare the methodologies implemented in TBL and PBL and gather students' perceptions on both teaching-learning tools (TBL and PBL). The questionnaire consisted of 13 statements, and students needed to rate each statement on a five-point Likert scale ranging from strongly disagree to strongly agree [17]. The authors evaluated the percentage of students marking each response.

STATISTICAL ANALYSIS

A comparison of scores between the pretest and post-test during PBL and TBL was performed using the Wilcoxon signed-rank test. The median and Interquartile Range (IQR) were obtained for the pre- and post-test scores. The Mann-Whitney U test was applied to compare the learning gain between both methods and to compare the critical thinking in TBL and PBL. The scores of critical thinking in both sessions were compared in each area of critical thinking. The feedback questionnaires with closed-ended questions were analysed on the Likert scale to observe trends in opinions among the percentage of the student population.

RESULTS

The mean age of the students participating in the study was 20±2 years. Out of 150 students, 60 (40%) were females and 90 (60%) were males. The results of the study showed that the difference between the pre- and post-test scores was statistically significant (p-value <0.0001) for both teaching methodologies. This indicates a significant learning gain in students through both TBL and PBL methods. The learning gain in TBL was found to be greater than that of PBL (p-value <0.0001) [Table/Fig-1].

Median (IQR)			
Test	**Pre**	**Post**	**p-value***
PBL (n=75)	3 (3-4)	7 (6-7)	<0.0001
TBL (n=75)	3 (3-5)	8 (8-9)	<0.0001
p-value†	0.187	<0.0001	

[Table/Fig-1]: Comparison of scores between pre-test and post-test during PBL and TBL.
*using Wilcoxon signed rank test; using Mann-Whitney U test; IQR: Interquartile range is the difference between 75th and 25th quartiles; indicate p-value and values in bold †indicate statistical significance

Comparisons of the scores of students who appeared for the pretest and the test conducted after two months showed that in both PBL and TBL, there was statistically significant retention of knowledge (p-value <0.0001). However, there was no significant difference in knowledge retention when comparing the post-test scores of PBL and TBL [Table/Fig-2].

Median (IQR)			
Tests	**Pre**	**2 months**	**p-value***
PBL (n=75)	3 (3-6)	6 (5-7)	<0.0001
TBL (n=75)	3 (2-5)	6 (4-7)	<0.0001
p-value†	0.45	0.796	

[Table/Fig-2]: Comparison of pre-test scores and after 2 months test scores to assess retention of knowledge by PBL and TBL.
*using Wilcoxon signed rank test; using Mann-Whitney U test; IQR: Interquartile range; indicate p-value and Values in bold †indicate statistical significance

The mean scores obtained on the critical thinking scale for various exercises in the PBL and TBL tests are presented. It is evident that in exercise (I), the mean score for TBL (1.29) was lower than that for PBL (1.88). The mean score of students in drawing inferences was significantly higher in PBL than in TBL (p-value=0.001). However, in exercise (IV) regarding interpretation, the mean for TBL (1.60) was significantly lower than that of PBL (2.03) (p-value=0.007). Exercise (V), concerning the evaluation of arguments, shows a statistically highly significant increase in TBL (2.59) compared to PBL (1.31) (p-value <0.0001). In the other exercises, recognition of assumptions and drawing deductions, the difference in scores between the two methods was statistically insignificant [Table/Fig-3].

Median (IQR)					
Tests	**Exercise (I) (n=75)**	**Exercise (II) (n=75)**	**Exercise (III) (n=75)**	**Exercise (IV) (n=75)**	**Exercise (V) (n=75)**
PBL	2 (1-2)	2 (1-2)	3 (2-3)	2 (2-3)	2 (0-2)
TBL	1 (1-2)	2 (1-3)	3 (2-3)	2 (1-2)	3 (2-3)
p-value*	0.001	0.542	0.874	0.007	<0.0001

[Table/Fig-3]: Comparison of scores obtained on the critical thinking scale between two methods.

The perceptions regarding the process of PBL and TBL showed that although students favoured active teaching-learning methods (60%), they could not decide whether they preferred large-group methods or small-group methods. Most of the students were neutral (34%) when comparing the levels of motivation for studying in TBL and PBL. Students liked to discuss problems within the team more than with the facilitator in PBL. Most of the students liked the directions given by the facilitators during the PBL session (54%). At the same time, they liked the active involvement of the instructor in TBL (48%). The majority of students agreed that TBL was better at improving problem-solving ability (44%), focused learning (48%), and coverage of learning objectives (54%). Most students strongly agreed (48%) to include active teaching methods in the syllabus. Students liked independent learning in PBL (40%), but they also agreed that PBL is more time-consuming (40%) than TBL [Table/Fig-4].

S. No.	Questions	Strongly disagree	Disagree	Neither agree/ disagree	Agree	Strongly agree
1	Active methods are better than conventional methods.	12 (8%)	9 (6%)	18 (12%)	60 (40%)	51 (34%)
2	I would prefer TBL to PBL.	27 (18%)	33 (22%)	27 (18%)	48 (32%)	15 (10%)
3	Motivation to learn better in TBL than in PBL.	9 (6%)	12 (8%)	51 (34%)	42 (28%)	36 24%
4	The discussion of the problems in the team was better than in the presence of a facilitator.	12 (8%)	21 (14%)	30 (20%)	51 (34%)	36 (24%)
5	Facilitator directing within group discussion is favoured more than instructor guiding at the end.	9 (6%)	9 (6%)	12 (8%)	81 (54%)	39 (26%)
6	Satisfaction with the learning process was greater in TBL than in PBL.	12 (8%)	30 (20%)	36 (24%)	48 (32%)	24 (16%)
7	I like TBL more than PBL because of the active involvement of the instructor in the clarification of problems.	9 (6%)	18 (12%)	21 (14%)	72 (48%)	30 (20%)

8	TBL improves problem-solving ability more than PBL.	12 (8%)	24 (16%)	30 (20%)	66 (44%)	18 (12%)
9	TBL helps me to focus on learning more than PBL.	12 (8%)	18 (12%)	30 (20%)	72 (48%)	18 (12%)
10	I recommend including active methods of teaching in the syllabus.	9 (6%)	18 (12%)	21 (14%)	72 (48%)	30 (20%)
11	The learning objective of a topic is well-covered during TBL than in PBL.	9 (6%)	18 (12%)	24 (16%)	81 (54%)	18 (12%)
12	I like independent learning (PBL) more than teams (TBL).	12 (8%)	33 (22%)	30 (20%)	60 (40%)	15 (10%)
13	PBL is more time-consuming than TBL.	12 (8%)	33 (22%)	36 (24%)	60 (40%)	9 (6%)

[Table/Fig-4]: Student's perception of TBL and PBL (in percentage). Values presented as n (%).

DISCUSSION

Didactic lectures are the principal method of teaching at present medical institute, and the students were well aware of its effects. Active methods like PBL and TBL were introduced to them as alternative teaching methodologies. When asked about their perception, the students reflected a preference for active methods. The results of the present study were in agreement with another study in which students supported active methods and were inclined towards the induction of active teaching-learning methods in the curriculum [18].

Among active teaching-learning methods, PBL has proven its efficacy in increasing examination scores in preclinical subjects like anatomy, physiology, and biochemistry [10,19,20]. Previous studies have also shown an increase in the cognitive scores of students through TBL [21-24]. The present study demonstrated higher learning gains among students in TBL compared to PBL. This finding can be explained by a previous study [20] that suggests PBL increases cognitive scores more in practical subjects than in theory-based subjects. The lower cognitive improvement in PBL compared to TBL in the present study may be attributed to the fact that the topics were theory-based. A previous study also found no improvement in cognitive achievement through PBL in English teaching [25]. Prereading of the topic, assessing student readiness, and teacher-initiated clarification of the topic have positive cognitive effects in TBL [26]. Individual learning, knowledge consolidation, retrieval practice, peer discussion, and feedback in TBL can be credited for better cognitive achievement [27].

In the present study, these findings have a positive implication as the majority of students agreed that TBL improved their problem-solving skills and helped them in focused learning with better coverage of learning objectives. Previous studies have also shown that clinical reasoning ability was significantly higher in students with TBL compared to non TBL students [28,29]. TBL changes the attitude of students towards teamwork and offers more comfort and satisfaction. Working with peers in TBL improves the ability to think through problems [30]. The success of TBL and PBL is not only attributed to the creation of self-managed teams but may also be due to the effective strategies used in promoting content-related discussions [31]. The findings of the present study demonstrated that the present study students preferred to discuss within their peer teams rather than in the presence of facilitators. The classroom experience created by TBL was found to be much more enjoyable and productive for both instructors and students in the present study. This may be positively associated with the fact that students were made partners in the learning process [12]. Thus, in the present study, students favoured the active role of the instructor in TBL over the passive role of the facilitator in PBL. The TBL instructor spends much more time organising content and facilitating the students' approach to helping each other. However, the role of the facilitator in PBL was appreciated for its timely interference.

Students' inclination towards independent learning in PBL may stem from the freedom to learn in their own style and explore resources themselves [28,31]. Although not statistically significant, the authors observed higher scores in PBL compared to TBL. This finding is supported by past studies where [32] it was found that PBL is more effective in knowledge retention, while TBL was more effective in short-term gain [33]. Students perceived benefits related to the active learning strategy of TBL, which encourages individual learning, knowledge consolidation, retrieval practice, peer discussion, and feedback [27]. Learning gain is greater with TBL in a study, as its structured format enforces repetition, while PBL gives students responsibility and freedom to gain knowledge; hence, the long-term effects of both methods remain the same regarding retention of knowledge.

Watson and Glaser's scale (Watson and Glaser, 2008) is a popular tool for assessing the success of critical thinking skills in programs and courses. The results of the present study demonstrated significantly higher scores in PBL than in TBL in tests evaluating the ability to draw inferences and form interpretations of data. PBL enabled students to discriminate between degrees of truth and falsity of information due to the extensive research conducted by students. PBL stimulates students to identify cues from the given case, establish correlations between the cues, and arrive at a provisional diagnosis, thus empowering students to draw inferences. In PBL, students are not limited by predetermined learning objectives but are free to explore knowledge on their own. These findings are supported by previous studies where authors found a significant increase in the critical thinking skills of students in the interpretation, analysis, explanation, and evaluation processes [25,34].

In reverse, it has been found that students with a critical thinking disposition, such as openness of mind, perform better in PBL [35]. However, studies have supported the better performance of students in TBL when it comes to evaluating arguments, which aligns with claims of an increase in clinical reasoning in TBL [28,29]. In TBL, students learn through collaboration, which encourages their accountability for the learning process and promotes better understanding and application of course material. Other studies have also shown significantly greater improvement in critical thinking skills in students with TBL compared to lecture-based courses [29,36,37]. However, the non statistical difference in the recognition of assumptions category, where students develop the ability to think about unsupported assumptions, may be an inherent effect of active teaching-learning methods that channelize the thinking process of students and provide them with a wider knowledge base. The ability to make deductions comes into play when a certain conclusion follows and the information is attributed to case-based scenarios or problems given in both methods, with guidance from facilitators. Hence, the non-significant difference in these categories may be due to the active involvement of the learner in both cases.

The present study also aligns with another study in which some students faced difficulties during PBL in conducting independent research on unfamiliar topics. Students admitted that friendly competition with peers motivated them to study and be prepared to participate in TBL [12]. The response of the students in terms of attendance and preclass preparation demonstrated that first-year students, who are in the transition zone from pedagogy to andragogy, still prefer to learn under the controlled environment of TBL than PBL.

Limitation(s)

The authors cannot eliminate the influence of other confounding factors, like study habits of students and their individual preparation levels, as the retention of knowledge test was a surprise test.

CONCLUSION(S)

Both PBL and TBL, as active teaching methodologies, are preferred by first-year MBBS students and have resulted in better learning gains. TBL motivated students to study and achieve significant learning gains, while PBL offered more freedom to explore the content. Both PBL and TBL are beneficial for students in acquiring knowledge and improving their critical thinking skills. However, students found that TBL was more beneficial in the undergraduate curriculum. The competency-based curriculum has shifted the focus of teaching to develop students into competent clinicians. Including TBL and PBL in the curriculum can contribute to the roadmap of developing students into lifelong learners. This is the first step in preparing the desired clinician for society. Proper implementation of active teaching methodologies, considering feasibility and effectiveness in students, will help medical teachers fulfill the goal of shaping an Indian Medical Graduate (IMG).

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