Original Article

DOI: 10.7860/JCDR/2025/77216.20698

Physiology Section

Exploring Student Learning in Team-based Physiology Tutorials: A Quasi-experimental Study

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ABSTRACT

Introduction: Team-based Learning (TBL) has gained recognition as an effective pedagogical approach in medical education, particularly within tutorial settings. It fosters individual accountability, as students are required to prepare independently before engaging in group discussions, thereby reinforcing their understanding of the material. Additionally, TBL promotes the development of critical teamwork and communication skills among students, both of which are essential for medical practice.

Aim: To explore the implementation of TBL in physiology tutorials for MBBS Phase I students, focusing on its impact on student learning outcomes and critical thinking abilities.

Materials and Methods: A quasi-experimental study was conducted with 48 students from the Physiology Department. Participants were informed one week prior to the tutorial about the topics to be prepared for TBL. The individual Readiness Assurance Test (iRAT) was assessed using multiple-choice questions administered through Google Forms. Each group of six students completed a team Readiness Assurance Test (tRAT) and a team Application (tAPP) exercise. Descriptive statistics, such as the mean and standard deviation, were used to represent the scores of the study participants.

Results: The performance of eight teams was assessed across the iRAT, tRAT and tAPP components. Team 3 achieved the highest average total score of 36.50±2.88 (77.65±6.13%) out of a possible 47, with a score of 14.50±0.83 out of 17 in the tRAT. In contrast, Team 4 scored the lowest average total of 29.17±3.49 (62.05±7.42%), which associated with their lower individual and team RAT scores, indicating varying levels of engagement and collaboration.

Conclusion: The results suggest that TBL effectively enhances learning outcomes; however, variations in team cooperation and comprehension highlight the need for targeted interventions to support teams in achieving consistent academic success.

Keywords: Critical thinking, Individual readiness assurance test, Peer-to-peer learning, Team application

INTRODUCTION

Competency-based Medical Education (CBME) represents a paradigm shift in medical training, emphasising the development of defined competencies essential for effective clinical practice. Unlike traditional time-based models, CBME focuses on measurable outcomes, ensuring that learners achieve proficiency in the knowledge, skills, attitudes and behaviours required for patient-centered care. This approach promotes learner-centered flexibility, enabling students to progress at their own pace while meeting rigorous competency standards [1]. TBL aligns seamlessly with the principles of CBME by fostering active engagement, critical thinking and collaborative problem-solving—key competencies in healthcare practice. By integrating TBL into CBME curricula, educators can create interactive learning environments where students not only acquire knowledge but also apply it in real-world clinical scenarios, enhancing their readiness for professional roles [2].

TBL has emerged as a transformative educational strategy in medical education, particularly in tutorial settings. Unlike traditional lecture-based teaching, TBL emphasises student-centered learning through structured team collaboration. This approach is designed to foster critical thinking, problem-solving and peer-to-peer learning—skills that are crucial for clinical practice [3,4]. By engaging students in group activities that require the application of foundational knowledge to real-world scenarios, TBL helps bridge the gap between theoretical concepts and practical application.

The impact of TBL extends beyond academic performance, with studies reporting improvements in student engagement, satisfaction and long-term knowledge retention [5]. Furthermore, TBL encourages accountability, as students must prepare for sessions individually before contributing to team discussions. This preparatory work enhances their understanding of the material, while the collaborative environment cultivates essential teamwork and communication skills [6].

In tutorial settings, TBL promotes dynamic interactions where students actively discuss concepts, share diverse perspectives and refine their clinical reasoning in a supportive atmosphere. Such active engagement has been shown to improve not only cognitive outcomes but also the development of professional behaviours and attitudes required in healthcare [7]. Limited research exists on integrating TBL within CBME tutorials. While TBL and CBME are established, their combined effect in this specific setting is under-researched. This study uniquely focuses on integrating TBL within CBME tutorials. This combined approach is novel, aiming to uncover potential synergistic effects not seen when these methods are used separately [8,9].

It is hypothesised that integrating TBL into CBME tutorials would enhance student learning outcomes, critical thinking and teamwork skills compared to traditional lecture-based methods. To test this hypothesis, the study aimed to evaluate the impact of TBL on the academic performance and competency development of medical students in CBME tutorials. Additionally, it sought to assess the effectiveness of TBL in fostering critical thinking, problem-solving and the application of knowledge in clinical scenarios, as well as to analyse its role in promoting teamwork, communication and professional behaviours essential for healthcare practice.

MATERIALS AND METHODS

This quasi-experimental study, was conducted from August to December 2024 investigated the effectiveness of TBL on first-year medical students' physiology learning outcomes at Sri Siddhartha

Institute of Medical Sciences and Research Centre in Bengaluru, Karnataka, India. TBL sessions, led by a senior physiology professor experienced in innovative medical education technology. The study was approved by the Institutional Ethics and Scientific Committee (SSIMS&RC/IEC/FAC/030-2024-25, dated 06.08.2024).

Inclusion criteria: Participant inclusion required enrollment in physiology tutorials during the study period and the provision of informed consent.

Exclusion criteria: Declined consent, prior formal TBL experience in physiology or related subjects and any physical or cognitive impairments that could impact participation. These criteria ensured a homogeneous, previously TBL-naïve cohort, maximising the accuracy of assessing TBL's impact on learning outcomes.

Sample size estimation: Sample size estimation was performed based on the study by Kim HJ and Song Y, which reported a mean±SD iRAT score of 7.33±1.74. Assuming a desired power of 80% and a significance level (alpha) of 0.05, the required sample size was 48 [10]. The study involved 48 students enrolled in the 2024 physiology tutorials who provided informed consent.

TBL Implementation: The TBL was implemented in the following phases:

Preclass preparation: Students were provided with specific reading materials and videos on the tutorial topic one week in advance, along with clear learning objectives and expectations for their preparation. They were encouraged to review the materials thoroughly and be ready to answer multiple-choice questions.

Individual Readiness Assurance Test (iRAT): A timed, individual assessment was administered via Google Forms. The iRAT consisted of 17 basic-level multiple-choice questions on Miller's pyramid, designed to assess individual understanding of the preclass material. One mark was awarded for every correct answer. Students were given one minute to answer each MCQ. The purpose of the iRAT was to motivate individual preparation and identify knowledge gaps.

Team Readiness Assurance Test (tRAT): The students were organised into small groups of six members. Each group was given the same set of questions from the iRAT and was allowed to discuss them as a team. The groups collaborated, reached a consensus on the answers and submitted their responses in Google Forms with their team numbers mentioned. The tRAT was designed to promote collaborative learning, helping to identify areas where further discussion or clarification was needed.

Focused discussion: A faculty-led focused discussion followed the iRAT and tRAT sessions, addressing student queries arising from those assessments. Students were encouraged to consult relevant materials during this time. This session served to consolidate understanding and prepare students for the subsequent application exercise.

Team Application Phase (tAPP): Teams were presented with real-world case scenarios and problems that focused on the higher levels of Miller's pyramid, aligned with the tutorial topic. There were 13 MCQs in this session, with 90 seconds to answer each question. Discussion was allowed within the team. They collaborated to analyse the cases, apply their knowledge and present their solutions. The tAPP phase aimed to foster critical thinking, enhance problem-solving skills and promote effective communication.

Data collection: The following data were collected: iRAT scores (scores obtained by each student on the iRAT), tRAT scores (scores obtained by each team on the tRAT) and tAPP scores (scores obtained by each student in the team application phase).

STATISTICAL ANALYSIS

Descriptive statistics, including the mean±SD, were calculated using Statistical Package for the Social Sciences (SPSS) version 20.0 for iRAT, tRAT and tAPP scores to provide a clear summary of the data. These statistics helped in understanding the central tendency and variability of the scores within each group and across individuals. In addition to individual and group scores, the data were further analysed and presented according to team performance, allowing for a comparative assessment of how well different teams performed. This approach highlighted trends in TBL outcomes and provided insights into areas where certain groups excelled or needed improvement. By examining the data from both individual and team perspectives, a more comprehensive understanding of the effectiveness of the TBL approach was gained.

RESULTS

The mean age of the study participants was 19.1±0.4 years. There were 27 female and 21 male participants.

The performance analysis included eight teams across three assessment components: iRAT, tRAT and tAPP. Scores were provided as mean±SD, offering insights into both average performance and score variability within each team. The Grand Total row summarises overall performance across all teams [Table/Fig-1]. Total scores are an aggregate of iRAT, tRAT and tAPP scores (17+17+13=47).

Teams	iRAT (Mean±SD) (out of 17)	tRAT (Mean±SD) (out of 17)	tAPP (Mean±SD) (out of 13)	Total scores (Mean±SD) (out of 47)	Percentage of total scores (Mean±SD)
1	10.33±3.44	13.83±0.98	9.00±0.00	33.17±3.71	70.58±7.89
2	11.00±2.96	14.00±1.00	8.71±0.49	33.71±3.63	71.73±7.74
3	12.00±2.61	14.50±0.83	10.00±0.00	36.50±2.88	77.65±6.13
4	9.67±2.88	12.00±1.55	7.50±1.22	29.17±3.49	62.05±7.42
5	11.50±3.33	14.17±1.72	9.00±0.00	34.67±3.14	73.76±6.68
6	10.17±2.04	13.00±2.00	10.00±0.00	33.17±0.75	70.57±1.60
7	14.00±2.28	13.50±1.64	7.00±0.00	34.50±3.39	73.40±7.21
8	12.14±2.48	14.85±1.57	9.00±0.00	36.00±2.64	76.59±5.62
Grand Total	**11.36±2.88**	**13.76±1.60**	**8.78±1.07**	**33.90±3.56**	**72.12±7.57**

[Table/Fig-1]: Scores obtained by individual teams in TBL session.

The data reveal varying levels of performance across the teams. Team 3 achieved the highest average total score (36.50 out of a possible total not explicitly stated in the provided data, resulting in 77.65%), demonstrating strong performance across all three components. Team 8 also performed well, with a total score of 36.00 (76.59%). In contrast, Team 4 had the lowest total score (29.17, 62.05%), indicating weaker performance across the assessments.

Looking at individual components, Team 7 excelled in the iRAT (14.00±2.28), suggesting strong individual preparation within this team. Team 8 demonstrated the highest average tRAT score (14.85±1.57), indicating effective team collaboration and understanding of the core concepts. The tAPP scores reveal an interesting trend: several teams (1, 3, 5, 6 and 8) achieved perfect average scores of 9 or 10, but with an SD of 0. This perfect score with no variance indicates consistent performance within these teams in the application aspect. Team 7 had the lowest tAPP score (7.00 ± 0.00), also with no variance.

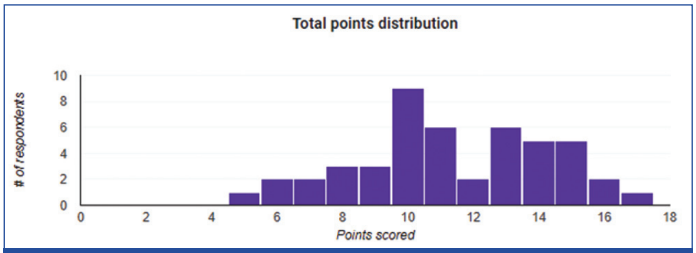
The grand total averages provide a general overview: iRAT (11.36±2.88), tRAT (13.76±1.60), tAPP (8.78±1.07), total score (33.90±3.56) and percentage (72.12±7.57%). These averages suggest that teams generally performed well on the tRAT compared to the iRAT and tAPP. The SDs highlight the variability in individual and team performance. For instance, the higher SDs in the iRAT suggest more diverse levels of individual preparedness within teams. Overall, the data points to varying team dynamics, individual preparations and abilities to apply learned concepts.

[Table/Fig-2] presents a comparison of iRAT and tRAT scores across eight teams. Scores are out of a possible 17 points and are displayed as mean±SD. Significant differences (p-value <0.05) were observed in teams 1, 3, 5 and 8, indicating that tRAT scores were significantly higher than iRAT scores in these groups. This suggests that team discussion and collaboration led to improved performance on the tRAT compared to individual performance on the iRAT. Teams 2, 4 and 6 did not show statistically significant differences between iRAT and tRAT scores.

Teams	iRAT (Mean±SD) (out of 17)	tRAT (Mean±SD) (out of 17)	p-value
1	10.33±3.44	13.83±0.98	0.028*
2	11.00±2.96	14.00±1.00	0.522
3	12.00±2.61	14.50±0.83	0.011*
4	9.67±2.88	12.00±1.55	0.253
5	11.50±3.33	14.17±1.72	0.029*
6	10.17±2.04	13.00±2.00	0.052
7	14.00±2.28	13.50±1.64	0.023*
8	12.14±2.48	14.85±1.57	0.015*

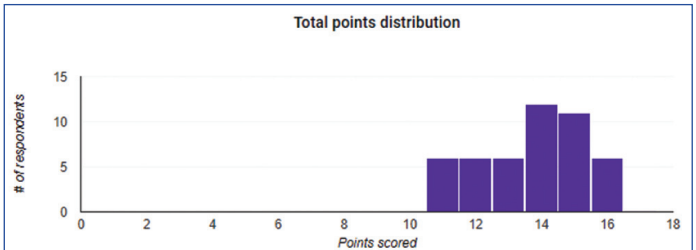
[Table/Fig-2]: Comparison of iRAT and tRAT scores in all the teams.
*Statistically significant difference

[Table/Fig-3] displays the score distribution of 48 participants on a 17-point assessment. The average score is 11.36, with a median of 11, indicating a roughly symmetrical distribution. Scores range from 5 to 17. The histogram shows the frequency of each score. The most frequent scores cluster around 10, with a noticeable peak. There is a slight right skew, with more participants scoring above the average than below. This suggests a generally good performance on the assessment, with most participants achieving scores near or above the midpoint.



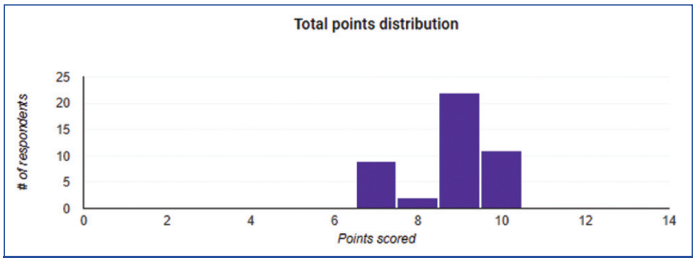
[Table/Fig-3]: Number of respondents in the iRAT assessment during TBL.

[Table/Fig-4] presents the score distribution of participants on a 17-point assessment. The average score is 13.76 and the median is 14, indicating a concentration of scores towards the higher end. The scores range from 11 to 16, showing a relatively narrow spread. The histogram visualises this, with bars clustered between 11 and 16. The highest frequency occurs at scores 14 and 15, with a slight decrease at 16. This distribution suggests generally strong performance on the assessment, with most participants achieving scores above the midpoint. The data indicates a left-skewed distribution.



[Table/Fig-4]: Number of respondents in the tRAT assessment during TBL.

[Table/Fig-5] displays the score distribution on a 13-point assessment. The average score is 8.8 and the median is 9, indicating a central tendency around these values. The scores range from 7 to 10, showing a limited spread. The histogram reveals a concentration of scores at 8 and 9, with the highest frequency at 9. There are fewer scores at 7 and 10. This distribution suggests that most participants achieved scores near the average and median, with a relatively small number scoring at the extremes of the range. The distribution is somewhat left-skewed, with a longer tail towards the lower scores.



[Table/Fig-5]: Number of respondents in the tAPP assessment during TBL.

DISCUSSION

The results of the TBL tutorial revealed significant variability in student performance across teams, reflecting differences in both individual understanding and group collaboration. Team 3 achieved the highest average total score of 36.50±2.88 (77.65±6.13%), demonstrating consistent performance in both the tRAT and tAPP components. This suggests strong group dynamics, effective preparation strategies and a collaborative approach to problem-solving. In contrast, Team 4 recorded the lowest total score of 29.17±3.49 (62.05±7.42%), which may point to gaps in comprehension or less effective group interactions that hindered their ability to successfully address the tAPP tasks. These performance discrepancies highlight the importance of both individual preparation and the quality of team collaboration in TBL settings, as suggested by previous studies [11,12].

The overall average total score of 33.90±3.56 (72.12±7.57%) reflects a generally positive outcome for the TBL approach, as most teams demonstrated competence in the material. However, the differences in performance suggest areas for improvement. Team 4, with percentages of 62.05±7.42%, may benefit from enhanced facilitation during group activities. This could help foster better communication and engagement within the teams, ensuring that all members actively contribute to the learning process. These findings align with existing literature, which emphasises that effective team dynamics play a crucial role in shaping learning outcomes in TBL [13].

The variation in performance across teams may stem from several factors, such as the quality of group interaction, differences in prior knowledge and individual engagement during preclass preparation [14]. To better understand these dynamics, future studies could incorporate qualitative assessments, such as surveys or reflection discussions, to gather insights into team interactions and student experiences [15]. Additionally, the role of the instructor in facilitating group work and providing timely, constructive feedback has been shown to significantly influence student outcomes in TBL [3].

The score distributions from the iRAT, tRAT and tAPP provide a comprehensive view of participant performance throughout the TBL module. The iRAT, with an average score of 11.36 out of 17 and a median of 11, suggests a reasonable baseline understanding of the pre-reading material. However, the right skew and wider range of scores (5-17) indicate variability in individual preparation. This highlights the importance of the iRAT in identifying initial knowledge gaps [16,17].

The tRAT shows a marked improvement, with a higher average score of 13.76 out of 17 and a median of 14, along with a narrower range of scores (11-16) and a left-skewed distribution. This shift demonstrates the effectiveness of team discussion and peer learning in consolidating knowledge and addressing individual misconceptions exposed by the iRAT [18,19]. The high scores on the tRAT suggest that teams effectively synthesised information and resolved discrepancies in understanding.

The tAPP, with an average score of 8.8 out of 13 and a median of 9, has a range of scores from 7 to 10, indicating successful application of the learned concepts. The left skew, however, suggests some difficulty in applying the knowledge to more complex scenarios. This indicates that while the core concepts were grasped, applying them to novel situations may require further reinforcement or practice [10,20].

The progression from iRAT to tRAT to tAPP reflects the core principles of TBL: individual accountability, team collaboration and application of knowledge. The observed trends align with existing literature demonstrating the positive impact of TBL on learning outcomes [21].

Limitation(s)

Although the article offers valuable insights into the application of TBL in medical education, it has several limitations. The study lacked a control group, making it challenging to isolate the specific impact of TBL on student learning outcomes. Additionally, the groups were formed randomly, without considering the varying academic levels of the students.

CONCLUSION(S)

The quantitative findings indicate that the TBL approach positively contributes to learning outcomes. However, variations in team collaboration and comprehension emphasise the necessity for tailored interventions to help all teams improve their academic performance. Future research should further explore the factors influencing team performance in TBL, such as team composition, group size and the level of instructor support. By investigating these elements, educators can implement targeted strategies to optimise the effectiveness of TBL and ensure that all students benefit from this collaborative learning model. Additionally, examining the long-term impact of TBL on student learning and clinical practice would provide valuable insights into the sustained benefits of this pedagogical approach.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Dec 12, 2024
- Manual Googling: Jan 09, 2025
- iThenticate Software: Jan 25, 2025 (7%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Dec 10, 2024**
Date of Peer Review: **Dec 31, 2024**
Date of Acceptance: **Jan 28, 2025**
Date of Publishing: **Mar 01, 2025**