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Original Article

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Effectiveness of Teaching with Riddles Using Team-Based Learning: A Prospective Study on Third Phase (1) Medical Students

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Abstract

Background and Objectives: The study aimed to evaluate the effectiveness of teaching toxicology using "Toxic Riddles" in a Team-Based Learning (TBL) format compared to traditional didactic lectures (TDL). The objectives were to assess the impact of this novel teaching approach on student learning outcomes and to explore student perceptions and attitudes toward TBL in the context of clinical toxicology education. ***Materials and Methods:*** This prospective study was conducted on third-year medical undergraduates at a tertiary medical institution. Ethics approval was obtained from the institutional ethics committee. A controlled comparison between TBL and TDL was performed using a modified crossover design. Two critical topics from chemical toxicology, Pesticides Poisoning (PP) and Corrosives Poisoning (CP), were selected for the TBL sessions. These topics were chosen due to their high incidence in our hospital. TBL sessions were structured around clinical scenarios where students worked in teams to analyze cases, make evaluative decisions, and formulate management plans for poisoned patients. The effectiveness of TBL was assessed through pre- and post-intervention tests, while student perceptions were gathered using structured questionnaires. ***Results:*** The results indicated that students in the TBL group showed a statistically significant improvement in their post-test scores compared to the TDL group (10.61% vs 4.23%, mean difference 6.38%, 95% CI 0.7-8.3%, p = 0.021). ***Conclusion:*** The use of toxic riddles in a TBL format proved to be an effective and engaging method for teaching clinical toxicology, outperforming traditional didactic lectures in both student learning outcomes and satisfaction.

Keywords: ***Team-Based Learning (TBL), Medical Education, Active Learning, Problem-Based Learning, Undergraduate Medical Students.***

Introduction

Team-based learning (TBL) is a pedagogical approach that emphasizes on small group based active learning where the students can apply the conceptual knowledge through individual and team work with provision for immediate feedback. It makes the teaching more engaging especially for large groups, and simultaneously making the learning simpler and more enjoyable [1]. In recent years, TBL has gained popularity in medical education because it is student centric and resource efficient at the same time. It is an innovative form of interactive learning which can be used efficiently for large group teaching in medical education [2]. The structured format of TBL can be successfully used for a specific and significant problems, giving opportunities to students to a build conceptual knowledge and apply it in clinical problem-solving activities [3]. TBL not only encourages self-learning and critical thinking in students, but also helps them in developing their communication and collaboration skills along with better understanding and greater retention of knowledge [4]. Team-Based Learning (TBL) is an active learning instructional strategy that consists of three phases: advance preparation, individual and team readiness assurance tests, and the application phase. While TBL has been extensively studied, particularly in Health Professions Education (HPE) programs, there remains some debate regarding its effectiveness in improving learner outcomes compared to traditional teaching methods [5]. Research indicates that TBL is superior in enhancing cognitive outcomes,

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particularly in the short term, when compared to Traditional Didactic Learning (TDL). However, findings on long-term retention of knowledge are mixed. TBL has shown favourable results in clinical performance and student engagement, with notable improvements in self-study abilities, decision-making, and emotional intelligence [4,5]. Despite the positive outcomes associated with TBL, there are challenges, such as an initial increase in faculty workload. Additionally, while learners express higher satisfaction with TBL compared to traditional lectures, they tend to prefer case-based learning over TBL in terms of overall satisfaction [4-6]. In the context of Clinical Toxicology education, TBL aligns with the goals of promoting collaborative problem-solving and real-world application of knowledge by incorporating active learning strategies like application exercises, case based scenarios, games and puzzles like scavenger hunt and escape rooms. This hands-on approach not only enhances students' understanding of toxicology principles but also prepares them for the complexities and uncertainties of diagnosing and treating toxic exposures in clinical settings [4-6]. The theoretical framework of team-based learning in Clinical Toxicology education emphasizes the importance of collaboration, communication, and critical thinking skills in preparing students for the dynamic and multidisciplinary nature of toxicology practice. By fostering a supportive learning environment that encourages active participation and peer interaction, TBL can effectively enhance students' ability to address complex toxicology cases, make informed clinical decisions, and ultimately improve patient outcomes in the field of Clinical Toxicology. Existing literature on the effectiveness of team-based learning (TBL) in medical education, particularly in the context of Clinical Toxicology, has shown promising results in improving student outcomes and engagement [6,7]. Overall, the existing literature supports the use of team-based learning as an effective pedagogical approach in medical education, including Clinical Toxicology, due to its ability to enhance student outcomes, engagement, and collaborative skills essential for future healthcare professionals [7,8]. The gap in the literature regarding the use of team-based learning in undergraduate Clinical Toxicology education lies in the limited focus on the application of this pedagogical approach in the context of toxicology education specifically at the undergraduate level. While team-based learning has been widely studied and implemented in medical education, there is a lack of research that specifically examines its effectiveness in enhancing student learning outcomes, critical thinking skills, and knowledge retention in the field of Clinical Toxicology among undergraduate students.

Through this study we have tried to assess the impact of team-based learning involving interesting and engaging activity like Riddles and puzzles on Clinical Toxicology education.

Aim & Objectives

1. To evaluate the effectiveness of Teaching Toxicology in a unique, engaging format such as an “TOXIC RIDDLES”
2. To compare the traditional teaching method of individual learning through didactic lectures (TDL) with team-based learning (TBL) through Toxic riddles.
3. To explore student perceptions and attitudes towards team-based learning in the context of Clinical Toxicology education.

Material and Methods

Our research was primarily focused on third-year medical undergraduates from a Tertiary Medical Institution. Ethics approval was obtained from the institutional ethics committee prior to commencing the research. For our study, we conducted a controlled comparison of Team-Based Learning (TBL) versus Traditional Didactic Learning (TDL) using a modified crossover design. Two topics from Chemical Toxicology, Pesticides Poisoning (PP) and Corrosives Poisoning (CP), were selected for TBL due to their high frequency of occurrence in our hospital. These topics were taught through clinical scenarios that required participants to make evaluative decisions and judgments to reach a final diagnosis and management plan for treating a poisoned patient case.

Between February 2024 and July 2024, a total of 208 third-year undergraduate medical students were invited to participate in the study. However, only 144 students who were regular in attending the classes were included in the study. Each batch was divided in a non-randomized manner into two cohorts (Group A and Group B) of 72 students, further divided into 9 teams with 8 students in each team based on their roll numbers in sequential order.

TBL was implemented as the active learning intervention in two cohorts. The first cohort received TBL in PP, while the second cohort received TBL in CP. Additionally, both cohorts simultaneously received Traditional Didactic Learning (TDL) in the topic not covered by TBL. This design allowed for TBL and TDL to be administered concurrently, preventing a carryover effect of TBL learning principles to the control group. We took the TBL cohort as the intervention arm involving 3 phases. In the first phase students were asked to do self-directed learning by reading independently before the actual sessions of TBL & TDL.

In phase 2 were subjected to Individual Readiness Assurance Test (IRAT) to assess their grasp of the knowledge and concepts learned in Phase 1. In phase 3 the students were divided into 9 teams or groups serially as per their roll number and Group Readiness Assurance Test (GRAT) was done related to General Toxicology. Students worked in teams on assignments that allow them to apply knowledge gleaned in Phases 1 and 2 to clinical problems in the form of Toxic Riddles. The riddles used in this activity addressed the key concepts in toxicology such as identifying and naming the toxicity. Solving the riddles revealed clues to a patient case. Students were then tasked to compile and analyze these clues to successfully identify the toxicity and recommend appropriate treatment. The TBL method allows flexibility on the part of the teachers to selectively use one or more of the phases, depending on the context and demands of the course. We performed a modified TBL focusing on Phases 1 and 2. We first prepared the students by meeting them to explain the purpose and learning objectives of TBL. The students were then given lecture notes one week before the scheduled TBL and asked to read in preparation for Phase 2. Phase 2 was conducted in a demonstration room over 2 hours with eight facilitators. The students first performed the IRAT on clinical scenarios with four or five plausible choices. The questions required students to recall facts or concepts learned in Phase 1, and apply this knowledge to derive the correct answer. Six scenarios were used for PP IRAT; seven for CP IRAT.

After IRAT, the class formed into 10-student teams for GRAT; students were serially assigned to teams. Each team went through the same toxicology riddle simultaneously. They were given three minutes for group discussion and to formulate a team answer by consensus. After group discussion, teams had to simultaneously display their consensus answer on a card; each team could thus see all other teams' choices. The teams had to discuss and justify their answers, with the facilitators clarifying concepts or misconceptions. Teams were allowed to appeal if they felt they had a valid point. Finally, the correct answer was provided, team scores were tabulated, and teams moved to the next scenario. The Traditional

Didactic Learning cohort was taken as the Control arm in this study. Students undergoing the TDL topic were also provided lectures notes on the topic at TBL Phase 1 and told to do advance reading. However, the students were unaware which topic (PP or CP) would be used for the TBL Phase 2 until the start of IRAT. By doing so, we aimed to ensure that they read equally diligently for both topics before TBL Phase 2.

Outcome measurement

The students were assessed through three closed book tests. Initial baseline Pre Test was done. We performed three closed-book tests to assess the knowledge which was our primary outcome. Baseline 'pre-test' was administered just before IRAT at Phase 2; the second test ('post-test 1') was done after completion of GRAT at the end of Phase 2; the third test ('post-test 2') was done two days after TBL; this timing was chosen as knowledge attrition occurs three days after passive learning

Each test consisted of 20 MCQs, covering 10 clinical scenarios (five about PP; five about CP). Questions were designed such that the correct answers required both recall and application of Phase 1 knowledge. Post-tests 1 and 2 consisted of the same scenarios as the pre-test, but with the order of scenarios and questions randomly scrambled. The maximum score was 20 each for PP and CP sections. Students were allotted 20 minutes for each test. Finally, students were evaluated through two summative assessments with 10 application and 10 recall based questions. First SA was taken after the completion of first topic in both the groups, and second SA was taken at the end of completion of the second topic in both groups.

For the primary outcome, we measured the change between each student's post-test score (both post-test 1 and 2) and the baseline pre-test score, and expressed it as a percentage of the total score for that section (PP or CP). For a student who scored 10/20 in the CP section of the pre-test, then 12/20 for post-test 1, and 15/20 for post-test 2, the outcomes would be represented as: 0% (baseline), +10% (post-test 1), +25% (post-test 2).

We measured self-reported student engagement as a secondary outcome, using a modified version of a validated tool Engagement was measured anonymously using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). We also measured the proportion of correct IRAT & GRAT answers during Phase 2.

We collected data on students' gender and their internal assessment marks. Students who scored (< 50% of maximum score) were graded 'F'. Other Students were graded from 'A' to 'D' by quartiles ('A' 80-90%, 'D' 50-60% of maximum score); there was no 'E' grade. We used Internal Assessment Grade as a proxy measurement of each student's baseline medical knowledge.

Data Analysis

Statistical analyses included testing for differences in proportions between the TBL and TDL groups using the $\chi 2$ test, and differences in means using the two-sample t-test when normality and homogeneity assumptions were met; otherwise, the non-parametric Mann-Whitney-U test was utilized. A mixed model ANCOVA was conducted, accounting for repeated measures per student, to assess variances between the TBL and TDL groups in the primary outcome, while adjusting for gender and examination grades. Interaction effects between TBL and gender, TBL and topic, and TBL and IA grades were examined, with significance set at $p < 0.05$. Statistical analyses were carried out using SPSS 26.0 with 2-sided tests, and significance was defined as $p < 0.05$.

Observation & Results

Our results showed a significant improvement in student engagement during Team Based Learning sessions. Active participation was observed during riddle-solving session. Teamwork skills were enhanced through collaborative learning.

Our study was done on One Hundred and forty-four students with two cohorts each having n=72. Those students who were irregular in attending classes were declined participation. The mean age of our participants was 21.6 ± 0.1 years. Males comprised of 63% were and 37% were females GRAT scores were found to be significantly higher than IRAT scores with 70.3% correct answers in GRAT as compared to IRAT with only 52.4 % correct answers. The mean baseline Pretest scores of both cohorts were not statistically significant(p=1.0); No gender specific difference was noted ($p = 0.37$) but the scores were higher with high grades (A, B) in internal assessment in comparison to C/D grades (15.03 ± 0.25 vs 13.08 ± 0.44, $p < 0.001$).

The increase in post test scores after TBL sessions was significantly higher than TDL sessions Even the number of students scoring more than 90% was higher post TBL sessions

The mean percentage change in the TBL group test scores was significantly greater than in the TDL group (10.61% vs 4.23%, mean difference 6.38%, 95% CI 0.7--8.3%, $p = 0.021$). In the TBL group, test scores increased by the end of TBL. We found no significant interaction of gender or TBL topic with the effect of TBL on the primary outcome. However, the effect of internal assessment grades on improvement in test scores was significant from baseline to post-test 1 ($p = 0.007$). We dichotomized the students into 'strong' (A-B examination grades) versus 'weak' (C-D grades) students. In both strong and weak students, the TBL group showed a larger increase in the primary outcome compared to the TDL group. The effect size however was greater in the weak students for both post-tests ($p < 0.02$) (Table -1).

Table 1 Baseline characteristics of students and results of tests

	TBL (n =144)	TDL (n = 144)	P value
Age in years, mean (SEM)	21.6 (0.1)	21.6 (0.1)	1.0
Male, n (%)	63	63	
Female (%)	37	37	
Internal Assessment grades IA (%)			
A	5	5	
B	67	67	1.0
C	32	32	
D	34	34	
IRAT	7.43±1.96	-	
GRAT	9.65±0.92	-	
Unadjusted test scores, mean (SEM)			
Pre-test	8.63	10.4	

Post-test	19.24	14.63	0.021
Students scoring ≥ 90%, n (%)			
Pre-test	2	2	1.0
Post-test	29	17	0.003

TBL = Team based learning; TDL = Traditional Didactic learning; SEM = standard error of the mean

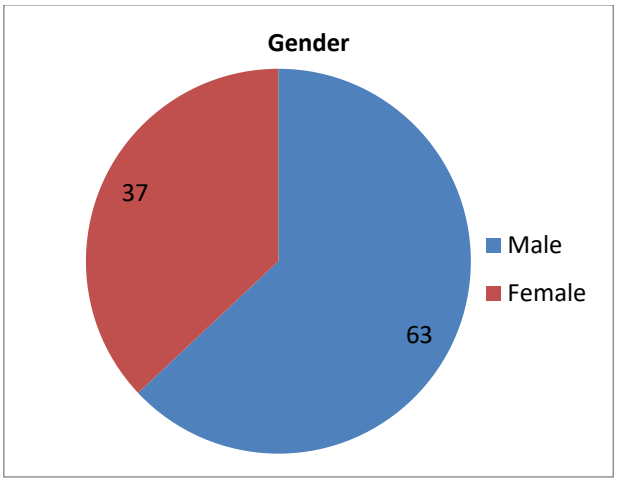

Fig-1 Gender based distribution of study subjects

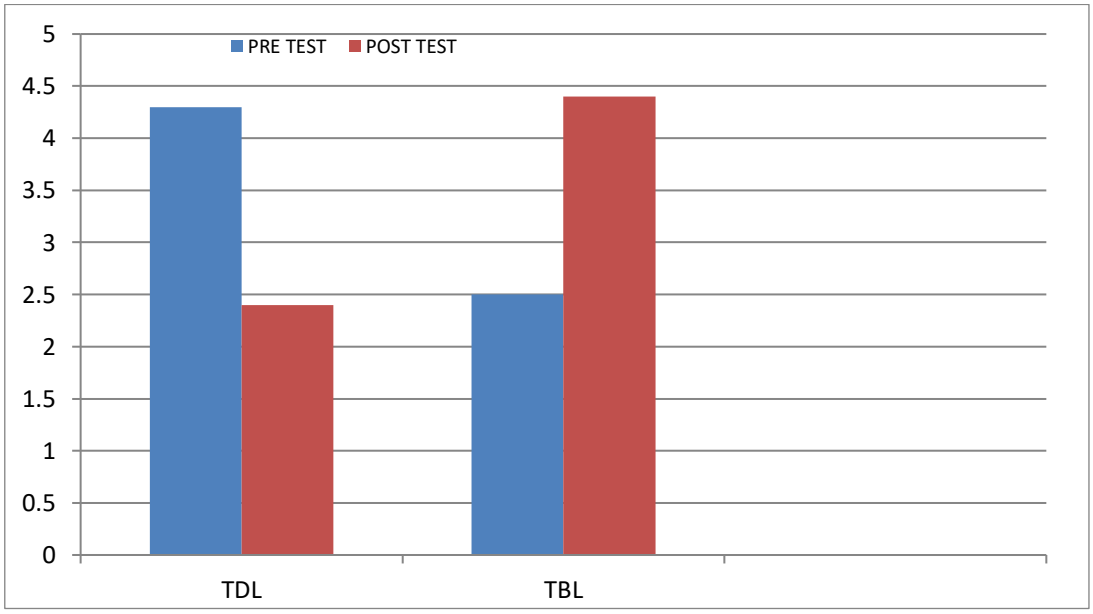

Fig-2: Percentage improvement in the Pre Test and Post Test scores in TBL and TDL cohorts

Measures of engagement were high in the TBL group most students reported active participation in themselves and their peers. The majority (83.12%) preferred TBL to conventional tutorials (Table 2).

Table 2 Measures of engagement in TBL group (n =156)

Statement	Percentage responding as 'agree' or 'strongly agree'	Median Score*
I actively participated in discussion today	80.8	4
I was mostly an active learner	80.8	4
Most students were actively involved	75.4	4
I had a chance to share my answers, or have my questions answered	81.7	4
TBL is more enjoyable than conventional teaching	96.9	5

Brief Discussion

We have used an engaging method of riddles to explore the effect of TBL as an active learning method compared to TDL, measuring knowledge outcomes immediately after intervention. Students receiving TDL also showed initial improved scores but the percentage improvement was less than seen in TBL scores. In addition, this effect of TBL is larger in academically weaker students compared to strong students.

An earlier randomized controlled trial comparing TBL against conventional lectures among residents did not demonstrate superiority in knowledge outcomes, possibly due to loss to follow-up or learner heterogeneity [9]. Another group found improvement in some, but not all topics [10]. Our study had complete follow-up data,

and involved students from the same academic year, which may have allowed us to demonstrate superiority of TBL over TDL.

The additional improvement in scores 48 hours later in TBL group support the fact that TBL encourage self directed learning leading to reinforcement and retention of knowledge whereas the score deteriorated in TDL group.

Using toxic riddles as a teaching tool was effective. It stimulated critical thinking and problem-solving skills. The active learning approach promoted a deeper understanding of toxicology.

Our finding that TBL has a greater effect in academically weaker students is consistent with extant literature [11]. We believe that this finding has relevance to clinical toxicology education as it can help the academically not so strong undergraduates gain and reinforce knowledge compared to passive learning methods.

The strengths of our study include learner homogeneity, use of a TDL comparator, matching of TBL and TDL groups and mitigation of the carryover effect using our study design, blinding of students to study design and testing, relevance of topics measures taken to minimize the practice effect, delayed post-testing 48 hours later, and complete follow-up.

We selected self-reading as the TDL comparator, although previous studies have compared TBL with lectures tutorials or small-group learning. There is no consensus as to what would be a suitable comparator for studies assessing an active learning method; both passive and active methods have been used. Similar to a clinical trial, our treatment (TBL) should be compared to a placebo to show efficacy. For ethical reasons, we cannot use a placebo as it would be tantamount to not teaching students a topic. We therefore selected reading as the TDL based on prior studies that showed reading as the most passive learning method. Using reading as a TDL comparator allows the control students a way to learn, thereby fulfilling ethical imperatives, while methodologically serving as a fair comparator for TBL. After study completion, each student cohort also received a didactic lecture on their TDL topic to reinforce learning.

In our TBL implementation we adhered wherever possible to core TBL principles by using a scorecard and the '4S' principles [12]. Some authors are concerned that partial TBL implementations may lead to negative conclusions about the efficacy of TBL [13]. Despite a modified TBL programme, we found TBL superior to TDL; a full implementation may have shown an even greater effect.

Conclusion

Team-Based Learning (TBL) enhances knowledge retention in undergraduate Clinical Toxicology education, showing consistent and lasting improvement post-learning. This impact is more pronounced in students with lower academic performance. Those instructed through TBL express heightened engagement levels, potentially fostering increased self-directed learning. Given the growing focus on active learning in Clinical Toxicology, our findings indicate that TBL could serve as a valuable supplementary teaching approach for undergraduate education, especially beneficial for students who may struggle academically. Incorporating toxic riddles into toxicology education can be a valuable teaching strategy. It enhances student engagement and fosters collaborative learning. However, we would recommend further research to explore the long-term impact of this approach.

Declarations

Contributions

RC, SG and SB were involved in the conception and design of the study.

RC was involved in the collection and analysis of data, and interpretation of the results. PKY contributed in the preparation and writing of the manuscript, ensuring its accuracy and scientific quality. SG and SB critically reviewed the manuscript before submission All Authors gave their final approval of the manuscript and were in agreement with the content and readiness for publication.

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Conflict of Interest Statement

There is no potential conflict of interest involved of any of the authors.

Supporting Resources

None

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