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Opening the Black Box of Team-Based Learning: The Impact of Teacher Decisions and Student Preparation on Team-Learning Dynamics

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Introduction

Team-Based Learning (TBL) is a collaborative instructional strategy designed to foster deep learning and develop essential skills in becoming healthcare professionals, such as clinical reasoning, problem-solving, and collaboration (Reimschisel et al., 2017). TBL consists of structured series of team-learning activities divided into three phases. The first phase is individual *preparation*, where students engage in reading and e-learning assignments to equip themselves for problem-solving in the subsequent phases. The second phase, *readiness assurance*, employs individual and team Readiness Assurance Tests (iRATs and tRATs) to activate both individual and collective knowledge and insights. The final phase, *application*, involves problem-solving exercises that stimulate in-depth discussions and promote a deeper understanding of the material, concluding with peer evaluations. While existing research on TBL has primarily focused on its effects on learning outcomes, yielding positive findings regarding student perceptions and attitudes, recent reviews suggest that this focus represents only a narrow aspect of the broader conceptual framework that underpins TBL (e.g., Roossien et al., 2025). Key elements, including the processes by which team learning unfolds and the specific interactional dynamics that are shaped by individual student preparation and teacher decisions, and how they contribute to team learning, remain underexplored. This lack of understanding limits the potential of TBL to foster the learning processes that enable teams and individuals to adapt, innovate, and perform effectively in complex environments.

Decuyper, Dochy and Van den Bossche (2010) conceptualize team learning as a cyclical and integrative process characterized by sharing, co-construction, and constructive conflict. *Sharing* facilitates the exchange of information, knowledge, and feedback, which helps identify and negotiate diverse standpoints, forming a foundation for learning. *Co-construction* involves collaboratively developing new understandings or solutions by synthesizing contributions. *Constructive conflict* engages students in debates that challenge assumptions and stimulate critical thinking. Together, these processes cultivate shared understanding and coordinated action, supported by intra- (reflection within the team over time) and inter- (collaboration across various domains) system loops fostering individual and team development. Importantly, team learning should not be viewed as a linear accumulation of knowledge. Instead, it is an evolving interplay of cognitive, social, and emotional factors shaped by context. Building on this perspective, Mulder (2022) emphasizes the need to recognize the inherent complexity and non-linearity of team learning, arguing for new approaches that capture dynamic and emergent patterns, moving beyond static, outcome-based measures.

Therefore, to deepen our understanding of how TBL operates in practice, it is essential to conduct research that transcends traditional outcome metrics and explores the “black box” of team learning. Our study addresses this gap by examining interactional dynamics of team learning behaviours during the application phase, focusing on how these relate to teacher decisions and student preparation.

Methods

Two online TBL application sessions from twelve teams in a second-year Bachelor medical course at the University of Amsterdam were observed and audio-recorded, forming the basis of the study (Roossien et al., 2024). Seventy-three students across teams (6-7 students per team) participated voluntarily. Ethical approval was granted by the NVMO Ethical Review Board (2020.8.4).

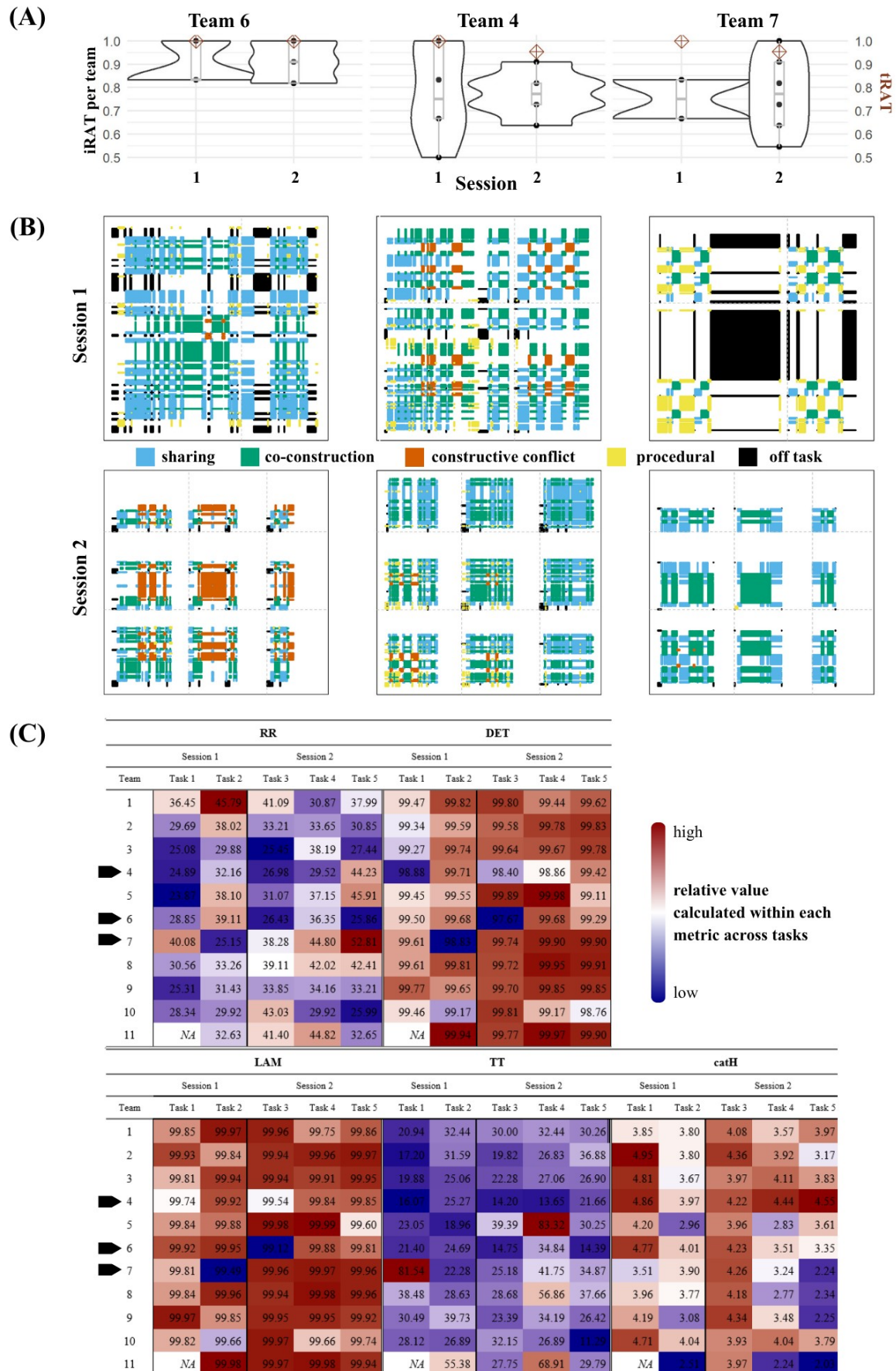
Teacher decisions were defined as the number of questions within the task and the task difficulty operationalized by 1 minus the average number of correct answers per task. Student preparation was measured using iRAT and tRAT scores. The first session focused on psychological trauma, with two diagnostic tasks: one involving an adolescent with a traumatic childhood (task 1; 2 questions, difficulty: 33%) and another on PTSD in a war refugee (task 2; 2 questions, difficulty: 0%). The second session addressed paediatric orthopaedics, with three diagnostic tasks on leg deformities (task 3; 8 questions, difficulty: 37%), leg length discrepancies (task 4; 6 questions, difficulty: 42%), and hip abnormalities in children (task 5; 3 questions, difficulty: 21%). Sessions were verbatim transcribed and coded for five team-learning behaviours (sharing, co-construction, constructive conflict, procedural, off-task; Roossien et al., 2024). Coded transcripts were transformed into one-second-resolution time series and analysed using chromatic recurrence plots (cRPs) and recurrence quantification analysis (RQA). cRPs are graphical tools that visualise patterns of recurrence or same states (sequence of specific behaviours). The colour identifies the occurrence of the same behaviour, providing a clear view of recurring patterns and their distribution over time. RQA extracts numerical features from the cRPs such as Recurrence Rate (RR), Determinism (DET), Laminarity (LAM), Trapping Time (TT), and Categorical Entropy (CatH), offering insights into the temporal dynamics. RR reflects how frequently states recur within the time series. DET indicates the predictability of the system by assessing the proportion of recurrent points. LAM represents periods where the system remains in the same state over consecutive time steps. TT quantifies how long the system typically remains in a recurring state. CatH measures the variability or complexity of state transitions.

To analyse differences between teams and tasks, we conducted non-parametric Repeated Measure ANOVAs for RR, DET, LAM, TT, and catH, accounting for the repeated measures design for tasks and teams, respectively. Next, pairwise post-hoc non-parametric t-tests were applied to further investigate differences among the teams and tasks. To describe differences in interactional dynamics based on team characteristics, we selected team 6 as a well-prepared and work-focused, team 4 as a medium-prepared and highly social, and team 7 as less-prepared and disinterested example (see **Figure 1A**. Selections were informed by both quantitative and qualitative data. To capture differences based on teacher decisions, we compared distributions of RQA metrics between sessions and tasks.

Results

Teams varied in the distribution of team-learning behaviours, particularly during the second session. This session showed an increase in sharing and co-construction while episodes of procedural or constructive conflict decreased. cRPs revealed substantial variability in sequences among teams and tasks (see **Figure 1B** for examples). While some teams alternated smoothly between behaviours (e.g., team 4, session 1), other teams remained in prolonged stretches of co-construction (e.g., team 7, session 2) or constructive conflict (e.g., team 6, session 2). While interaction patterns did not differ across all teams, pairwise post-hoc tests indicated significant differences between specific teams (e.g., for DET: 1 vs. 6 and 7, $p < .001$, $p = .007$; 4 vs. 6, $p = .042$; for TT: 4 vs. 7, $p = .032$; for catH: 4 vs. 6, $p = .008$; 4 vs. 7, $p < .001$). Furthermore, RR differed statistically significantly across tasks ($\chi^2 = 11.196$, $p = .0245$), particularly task 1 in comparison to the other tasks (vs. 2, $p = .035$; vs. 4, $p = .011$; vs. 5, $p = .043$). Lastly, catH highlighted differences between tasks ($\chi^2 = 18.915$, $p < .001$).

Figure 1. (A) Preparation for team 6, 4 and 7 by session. (B) cRPs for team 6, 4 and 7 by session (grey lines divide tasks). (C) RQA metrics per team per task.



Interactional dynamics of team-learning behaviours exhibited greater variability (higher catH) at the beginning of the sessions (tasks 1 and 3) compared to later tasks across all teams (see **Figure 1C**). Notably, team 4 displayed increasing variability throughout the sessions. Moreover, session 2 seems to elicit more predictable and enduring states (higher DET & LAM) compared to session 1. While dynamics were the least predictable (low DET) with medium complexity (medium catH) across all teams in task 2 (low task difficulty), the extent to which teams remained in a recurring state differed across teams (large range in TT) in task 4 (high task difficulty). Overall, team-learning dynamics demonstrated patterns of low state recurrence (RR), characterized by predictable and lasting states (high DET & LAM), without becoming trapped (low TT) in specific states, and indicating smooth state transitions. This pattern seems to be most outspoken in well-prepared teams (e.g., team 6). In contrast, team 7 exhibited distinct patterns, showing relatively high metrics during task 1 and relatively low values across all metrics during task 2.

Discussion

Our study shows how interactional dynamics of team-learning behaviours vary across teams and tasks, indicating that patterns are shaped by unique combinations of teacher decisions and student preparation. While (well-prepared) teams generally conform to recognizable patterns, the presence of either low or high values across all metrics may signal patterns that potentially impede team learning, requiring intervention to address these unhelpful dynamics. Our findings open in part the black box of team learning, emphasising the importance of intentionally designing TBL tasks (e.g., number of tasks, task difficulty) to encourage beneficial dynamics that facilitate team learning. Looking ahead, future research should systematically manipulate various task elements to explore how these affect team learning and outcomes. For instance, varying the level of preparatory support offered prior to sessions or adjusting task difficulty could yield insights into how these factors influence interactional dynamics. By investigating these relationships, we can identify optimal conditions for enhancing team learning, ultimately leading to improved educational practices and learning outcomes.

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