Express Team-Based Learning (eTBL): A Time-Efficient TBL Approach in Neuroradiology

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Abbreviations

eTBL
express team-based learning

IF-AT
immediate feedback assessment technique

iRAT
individual readiness assurance test

MCQ
multiple choice question

MEQ
modified essay question

PBL
problem-based learning

RAT
readiness assurance tests

TBL
team-based learning

tRAT
team readiness assurance test

4 S's principle
Significant, Same, Specific, Simultaneous

Rationale and Objectives: Team-based learning (TBL) is a student-centred, teacher-directed instructional method that promotes active learning. The application phase of TBL stimulates group discussion and critical thinking, which could be useful for learning radiology. We designed and evaluated two modified TBL-sessions on computed tomography and magnetic resonance imaging diagnostics in neuroradiology. Our aim was to examine what effects engaging students in in-class team application tasks had on student learning.

Materials and Methods: A cross-over study was conducted, including 105 third-year medical students using two modified TBL sessions as the active learning intervention compared with two traditional lectures as a control. Student learning was assessed by results on the neuroradiology part of the end-of-year written examination. Student engagement and perceptions were assessed using the Student Self-Report of Engagement Measure and an additional four Likert-type items.

Results: There were no statistically significant differences in student scores on the examination. Students reported high levels of engagement, and reported being more satisfied overall with the TBL sessions than traditional lectures. Students rated the TBL sessions higher than lectures on ability to make difficult material comprehensible, ability to engage students and to give them feedback.

Conclusion: The modified TBL sessions halved in-class teaching time and by omitting the readiness assurance tests, there was more in-class time to focus on problem-solving of real clinical cases. Moreover, shorter sessions may ease implementation of TBL in the curriculum and allow for more frequent sessions. Students were more satisfied with eTBL than lectures, and reported high levels of engagement.

Key Words: Medical education; team-based learning; active learning; learning effect; student engagement.

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INTRODUCTION

Team-based learning (TBL) is a student-centred instructional strategy that promotes active learning whilst maintaining a high student-teacher ratio (1). TBL was originally developed for business education, but is increasingly being used in both undergraduate and graduate medical education (2). It is well-suited to the rapidly growing field of medicine which demands that we educate life-long learners, and prepare students for the interprofessional and team-oriented field of practice (1). We believe it is especially well-suited for visual topics such as radiology, as it engages and facilitates group discussion of real-life complex radiological cases.

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The original application of TBL consists of three phases (3). During the first phase, students do preparatory reading or other advance assignments before the TBL session. In the second phase, students complete an individual readiness assurance test (iRAT) that tests basic facts and concepts of the advance assignment, before retaking the same test in teams of 5−7 students (team readiness assurance test, tRAT). This test is answered using immediate feedback assessment technique (IF-AT), usually in the form of a scratch card, motivating the students to collaborate until all answers are correct (3). During the third phase (team application), the teams apply their knowledge to solve clinical problems that they are likely to meet in their professional careers. In line with TBL principles for effective problem design (4 S's principles), the problems should be significant for the students, the same for all teams, and the teams must make a specific choice and simultaneously report their answers (1,3). This ensures that students get immediate feedback and are accountable to explain and defend their answers (1).

There is a growing body of evidence suggesting that academic outcomes are as good or better with TBL compared to traditional teaching strategies (4,5). In a systematic review of 14 studies in health professions education, seven studies showed improved knowledge scores in the TBL group compared with a non-TBL group (4). No studies reported a decrease in scores for the TBL group. Learner attitudes toward TBL are generally positive, emphasising the active learning style and interaction with their peers (5).

By emphasising or skipping one or more of the phases of TBL, the method allows for flexibility in design (6). Although this variability can be a challenge in medical education research, it enables teachers to tailor TBL to course context and learner needs (7). After piloting TBL in its original format in our medical programme, evaluations showed that although students were positive, TBL was perceived as time-consuming with one session taking up a total of three 45-minute blocks (8). Many courses have tested modified versions of TBL and common to most of these is maintaining the RAT (9,10).

In this study, we describe and test a modified and time-efficient TBL method we have called Express TBL (eTBL). By omitting the full RAT, content learning was moved to out-of-class preparation, leaving in-class time to focus on problem solving of real-life complex cases. The aim of the study was to answer the following questions: Compared to traditional lectures, what effect does eTBL have on student learning assessed with a summative examination? How do students perceive this approach as compared to lectures? Does eTBL actively engage students?

MATERIALS AND METHODS

Study Setting

The six-year undergraduate medical programme at the Norwegian University of Science and Technology (NTNU) is integrated and problem-based, with one oral and one written summative examination at the end of each year. The third year covers 16 clinical specialties (including radiology) and four paraclinical sciences. Lectures and problem based learning (PBL) sessions are organized around weekly themes. In addition, students attend clinical rotations at the university hospital. Lectures are predominantly based on traditional didactic teaching, but students have previously had one TBL session in general pathology during their second year and several lecturers have started converting some of their lectures to TBL (8).

Study Design

The study was conducted during the academic year of 2016/2017 using a 2 × 2 cross-over study design (Fig 1). Neuroradiology, which had previously been taught in two 90-minute lectures in computed tomography (CT) and magnetic resonance imaging (MRI) diagnostics, was chosen for the intervention. Third-year medical students were divided into two

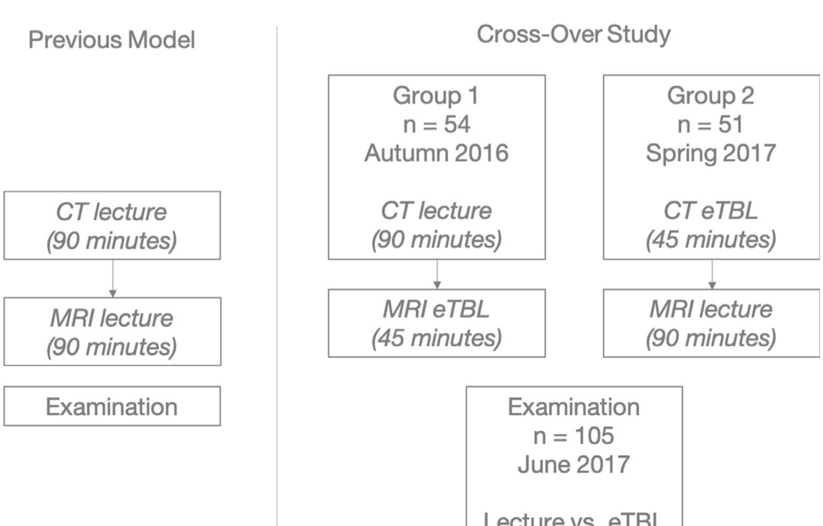

Figure 1. Study design. Lecture: Traditional didactic lecture. eTBL, express team-based learning.

groups at the start of the academic year. Group 1 ($n = 54$) undertook teaching in neuroradiology in August 2016. This group received teaching in CT diagnostics by a 90-minute didactic lecture and MRI diagnostics by a 45-minute eTBL session. Group 2 ($n = 51$) undertook teaching in neuroradiology in January 2017. This group received teaching in MRI diagnostics using a 90-minute didactic lecture and CT diagnostics by a 45-minute eTBL session. This cross-over design ensured that both groups experienced one traditional lecture and one eTBL session. Both groups ($n = 105$) sat for the same summative written examination in June 2017.

Intervention: eTBL

The different phases of eTBL are shown in Figure 2. One week prior to the eTBL sessions, students were sent preparatory reading consisting of a presentation on MRI physics, and a handout on CT and MRI sequences and common findings related to tumors, cerebrovascular and inflammatory diseases of the brain. Both groups received the same material. For eTBL sessions, students sat in teams according to their already established PBL groups, consisting of 6−8 students. Students are randomly assigned to PBL groups (corrected only for gender distribution) and the groups stay constant for each term.

The two-step method of readiness assurance (Phase 2) was reduced to a quick warm-up exercise of 10 multiple-choice questions (MCQs) that students answered individually using an online student response system (Kahoot! AS, Oslo) (11). Individual responses were selected over team responses for time-saving reasons. The majority of the time was spent on application exercises (Phase 3). The exercises were based on real clinical scenarios and included relevant information from the history and clinical examination, as well as CT or MRI images that students had to interpret. One eTBL session typically covered three clinical cases which were formatted as MCQs. In keeping with the 4 S's principles, all groups worked on the same problem and revealed their answers simultaneously. Groups were randomly picked to explain and defend their answers, and each clinical case ended with a summary by the teacher.

Student Performance

At the end of the academic year, students sat the same six-hour written examination, consisting of 100 MCQs and four modified essay questions (MEQs). All items are reviewed and approved by a multidisciplinary examination committee prior to use. The examination covered all subjects taught during the third year. Neuroradiology was tested in one MEQ which consisted of seven sequential questions for a possible total score of 10 points, accounting for 10% of the total score on the examination. The questions were written by the same teacher who held all lectures and eTBL sessions in neuroradiology. The questions were divided into: (a) content covered in MRI teaching (questions 2, 5, and 6) and (b) content covered in CT teaching (questions 3, 4, and 7). This allowed us to compare the two groups of students on how they scored on the two parts of the neuroradiology question. The MEQ was marked against a rubric by the item writer who was blinded for what group the students belonged to.

Student Evaluations

Student performance was our primary outcome measure, but after positive student feedback following eTBL in 2016/2017 we were interested in collecting student evaluations and measures of engagement. We prepared an anonymous 17-item survey for third-year students who had just completed an eTBL session in both CT and MRI diagnostics in the spring of 2018. The survey included the nine-item Student Self-Report of Engagement Measure (Table 1) which measures engagement using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) (12). Students were also asked to rate eTBL and traditional lectures on a five point Likert scale with regards to overall satisfaction (1 = very dissatisfied, 5 = very satisfied), ability to make difficult material comprehensible, ability to engage, and perception of receiving feedback on their own knowledge (1 = to a very small extent, 5 = to a very large extent).

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 24. Mann-Whitney *U* tests were used to compare student scores on the neuroradiology MEQ for CT and MRI questions separately. Wilcoxon signed-rank tests were used to compare student evaluations of eTBL and traditional lectures. Nonparametric tests were used because scores were not normally distributed. Two-tailed significance was set at $p < 0.05$.

Ethical Considerations

The TBL sessions and lectures were organized as noncompulsory learning activities and student evaluations were anonymous. Examination results were extracted and analyzed anonymously. In accordance with the Norwegian Center for Research Data (NSD) guidelines, approval for this study was deemed unnecessary because only anonymous data was processed.

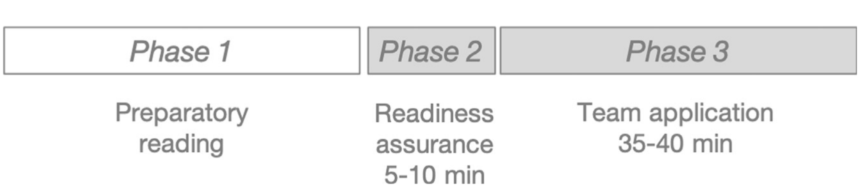

Figure 2. Phases of eTBL. The white field represents out-of-class preparations and gray fields represent in-class time.

TABLE 1. Student Self-Report of Engagement Measure in eTBL group. Response Categories for Items Ranged From 1 (Strongly Disagree), 2 (Disagree), 3 (Neither Agree Nor Disagree), 4 (Agree), to 5 (Strongly Agree)

Item	Mean Scores (SD)
1. I contributed meaningfully to class discussions today.	4.35 (0.80)
2. I was not paying attention most of the time in class.[a]	4.95 (0.22)
3. I contributed my fair share to class discussions.	4.48 (0.75)
4. I participated in class discussions today.	4.60 (0.63)
5. I talked in class with other students about class material.	4.73 (0.51)
6. I was mostly a passive learner in class today.[a]	4.40 (0.87)
7. I paid attention most of the time in class.	4.73 (0.72)
8. I was mostly an active learner in class today.	4.30 (0.99)
9. Most students were actively involved in class today.	4.15 (0.95)
Mean total score	4.52 (0.49)

[a] Denotes items that were reverse scored. Total score was calculated by reverse scoring items 2 and 6, and averaging the nine items.

RESULTS

Student Performance

Figure 3 shows a box plot of the median, quartile, and range of scores on CT and MRI questions in the neuroradiology MEQ in the end-of-year examination based on teaching method. Mann-Whitney *U* tests were conducted to compare student performance. Median scores on MRI questions (questions 2, 5, and 6, maximum score 4.0) in the lecture and eTBL group were 2.0 and 2.5, respectively, and did not differ significantly ($U = 1255$, $p = 0.415$). Median scores on CT questions (questions 3, 4 and 7, maximum score 4.0) in the lecture and eTBL group were 3.5 and 4.0, respectively, and did not differ significantly ($U = 1191$, $p = 0.182$).

Student Evaluations

Of 41 students who participated in the eTBL session in 2018, 40 completed the student evaluation. The Student Self-Report of Engagement Measure (Table 1) showed that students reported high levels of engagement, with a mean total score of 4.52 (12).

Figure 4 shows median scores on Likert-type items comparing student evaluations of eTBL and lectures. For better legibility, a bar chart was constructed instead of a box plot. A Wilcoxon signed-rank test indicated that students were more satisfied overall with eTBL ($Mdn = 5$) than traditional lectures ($Mdn = 3$, $Z = 4.96$, $p < 0.001$). Students rated eTBL higher than lectures on ability to make difficult material comprehensible ($Mdn = 4$ vs. 3, $Z = 4.57$, $p < 0.001$) and on its ability to engage students ($Mdn = 5.0$ vs. 3.0, $Z = 5.10$, $p < 0.001$). Additionally, students perceived eTBL superior to traditional lectures on ability to give them feedback on their own knowledge ($Mdn = 4.5$ vs. 2, $Z = 5.17$, $p < 0.001$).

DISCUSSION

With more institutions adopting TBL, it is necessary to understand how greater efficiencies can be gained from the method. In this study, we used a cross-over design to explore the educational effects of a modified and time-efficient TBL method in neuroradiology. Traditional lectures were chosen as the control because passive teaching methods still constitute the majority of teaching in undergraduate medical education (13). Results showed that there were no statistically significant differences in student performance on the end-of-year examinations based on teaching method. This is consistent with other studies in medical and health professions education where examination or test results remain the same after implementation of TBL, or when compared to traditional lectures (5,14−17). However, a meta-analysis of findings from 17 studies across a variety of different fields at undergraduate and graduate level, found a moderate positive effect of TBL on content knowledge (18).

The lack of impact of eTBL compared to traditional lectures in this study may be explained by several factors. First, students may have learned content at other points in the curriculum, for example in clinical teaching or through the preparatory reading material that was given to all students. Second, the intervention was small with only one eTBL session per group. Third, end-of-year summative examinations may be a poor measure of effectiveness. Medical students spend an extensive amount of time preparing for examinations, probably compensating for the use of ineffective teaching methods (19). Additionally, written examinations fail to assess other aspects that TBL aims to promote, such as teamwork and communication skills (1). Finally, a number of studies have indicated that the impact of TBL seems to be largest for academically weaker students (6,20−22). In the studies of Kang et al, and Koles et al, the lowest quartile was the only group who showed a significant improvement in test scores (20,21).

The purpose of the RAT is to link advance preparations to the application exercises, and when done well, is said to give effective content coverage, better teamworking skills, and insight about the value of diverse input (23). After a search of the literature, there seem to be few studies that examine the claims made about the RAT. A study by Rotgans et al examined how cognitive engagement fluctuates during a TBL session, and found that students are significantly more engaged when working together during the tRAT and application exercises (24). Although this does not validate all claims made about the readiness assurance procedure, it indicates that the tRAT is able to foster student engagement. Two studies have examined the RAT's effect on students' knowledge of the material. Carbrey et al found that performance on a knowledge test after traditional in-class RATs was equal to having learners complete the iRAT at home

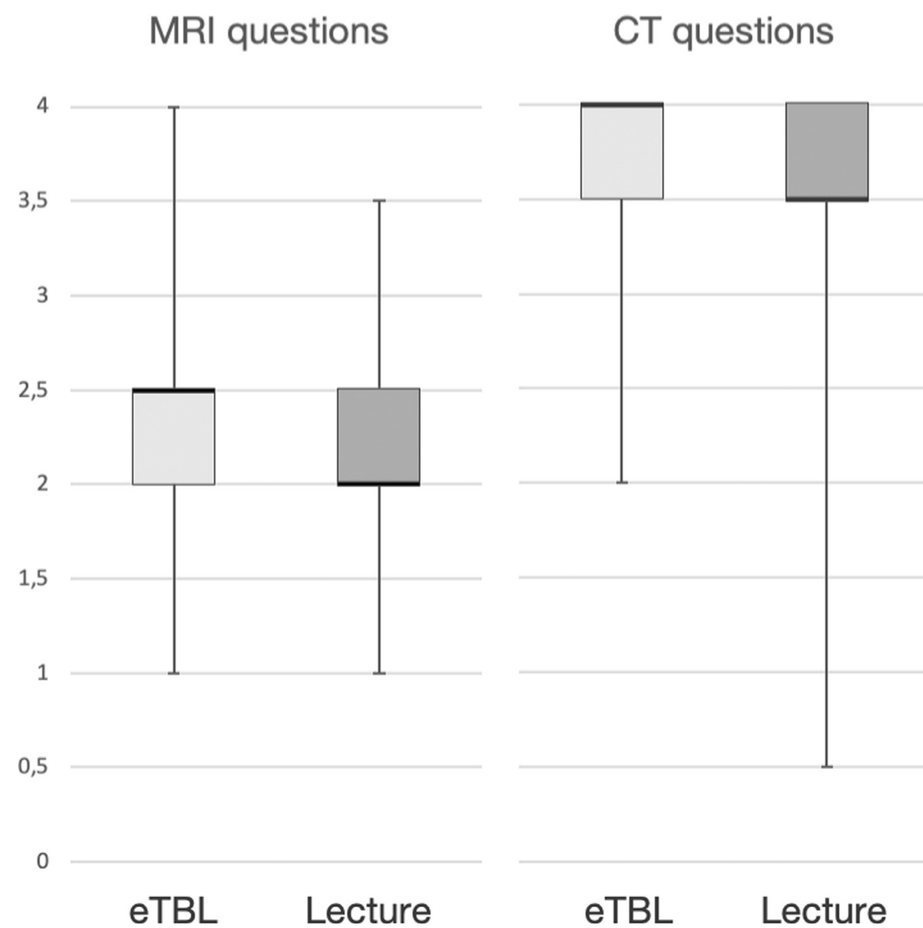

Figure 3. Box plot of scores on neuroradiology MEQ. The graphs display the median, quartiles and range of scores by teaching method on the two parts of the MEQ: MRI questions (maximum score 4.0) and CT questions (maximum score 4.0). CT, computed tomography; MEQ, modified essay question; MRI, magnetic resonance imaging.

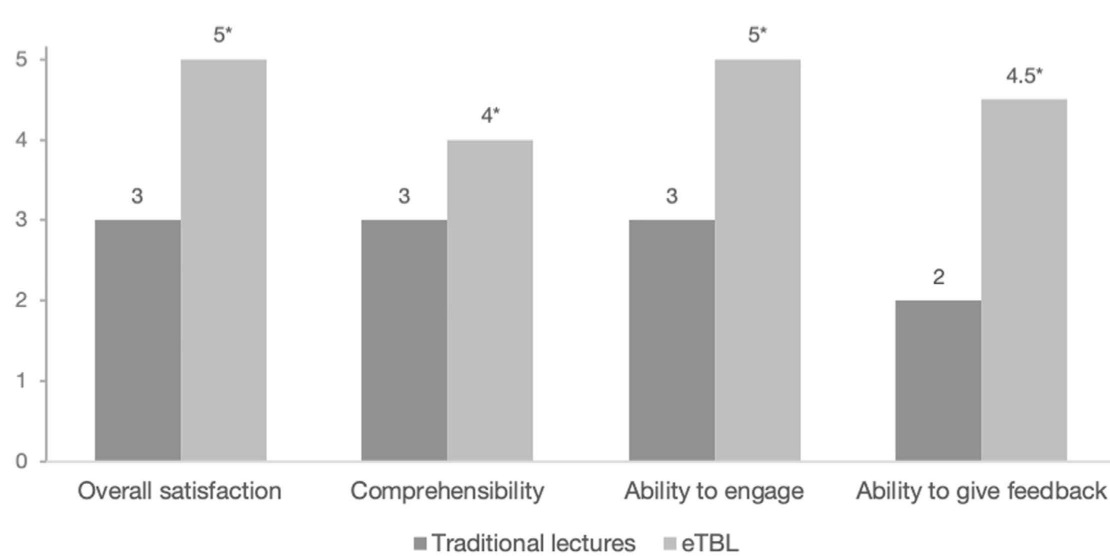

Figure 4. Student evaluations in eTBL group. The graph displays median scores on Likert-type items relating to overall satisfaction with traditional lectures and eTBL, their ability to make difficult material comprehensible, engage students and perception of feedback. *Note:* * indicates statistically significant differences at $p < 0.001$.

without a tRAT (25). Another study by Gopalan et al found that although the iRAT helps teams earn higher tRAT scores, it does not affect students' examination scores (26).

The eTBL method skips full administration of the RAT, allowing for a more time-efficient administration of TBL. Our study cannot determine whether the RAT has additional effects on teamwork skills or knowledge that students do not gain through the application exercises. However, curriculum overload has long been recognized as a challenge in medical education, and lecture hours cannot be expanded in parallel with the rapid growth of biomedical knowledge (27). By delivering content in the eTBL format, classroom hours were reduced from 90 to 45 minutes, and by reducing the RAT to a short warm-up exercise, there was more in-class time to focus on problem solving. Shorter sessions may also ease implementation of TBL in the curriculum and allow for more frequent sessions. However, studies have found that when students are taught using overly contextualized knowledge, they may have issues with transferring that knowledge to other situations (28). Therefore, we must be careful that problem-solving is an application of what the student has learned, and not the only way that the information is presented to them.

The secondary goal of this study was to document student engagement, and student opinions of eTBL compared with traditional lectures. Several studies link student engagement to positive learning outcomes such as critical thinking and grades (29). Student engagement was measured by a nine-item self-report instrument which has previously shown good internal consistency (Cronbach's alpha of 0.84) (30). Validity evidence is further provided by a similar pattern of results between the self-report instrument and levels of observed engagement (12). In our study, students reported high levels of engagement during eTBL, with a mean total score of 4.52. This is in line with other studies reporting high levels of engagement both for full and modified implementations of TBL (6,24,31−34). Using the same self-report instrument, Sharma et al found that ratings of engagement were higher during TBL than during traditional lectures for five of the measures (31). Although not surprising, the ability of TBL and eTBL to foster active learning in a large-group setting makes it attractive compared to other forms of active teaching strategies that have lower student to staff ratios.

In this study, students reported that they were significantly more satisfied with eTBL than traditional lectures. This is in line with the literature previously discussed, with student attitudes toward TBL being generally positive (5). Further research is needed to see if this persists over time, as several studies have shown that learner satisfaction and perception of the usefulness of TBL decreases with time (16,35,36). Students rated eTBL significantly higher than lectures on ability to make difficult material comprehensible, on its ability to engage students and its ability to give them feedback on their own knowledge. Interestingly, the greatest difference between eTBL and traditional lectures was students' perception of receiving feedback on their own knowledge. In eTBL students receive feedback from performance on application exercises, peers, and staff. This finding is in contrast with the hypotheses that students are unable to recognize feedback and therefore give poor feedback ratings (37). This deserves further study, to confirm the finding and to clarify which aspects of eTBL students perceive as feedback and whether this supports self-directed learning.

CONCLUSION

Introducing eTBL in a neuroradiology course halved in-class teaching time, and by reducing the RAT to a short warm-up exercise, there was more in-class time to focus on problem-solving. Shorter sessions may ease implementation of TBL in the curriculum and allow for more frequent sessions. This study showed no difference in student performance when comparing eTBL to lectures, but students reported high levels of engagement, and they were more satisfied with eTBL compared to lectures. Additionally, students rated eTBL higher on its ability to make difficult material comprehensible and its ability to give them feedback on their own knowledge.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi: 10.1016/j.acra.2019.04.022.