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ORIGINAL RESEARCH REPORTS

Classroom Versus Online Team-based Learning: Effects on Students' Learning and Performance

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Abstract

Purpose: **To date, we know little about the impact of responsive shifts from conventional to remote learning during the Covid-19 pandemic on student outcomes. If learning suffered, this may potentially have significant negative effects on students' knowledge and skills acquisition hence eventually impacting the overall quality of our doctors and the care they provide. To address this gap in knowledge, we investigated the impact of switching from classroom team-based learning (cTBL) to online TBL (oTBL) on medical student performance in class tests and end-of-year examinations.**

Methods: **Our participants were 137 second-year medical students who had cTBL experience prior to the shift to oTBL. We held the structure, activities and organisation of TBL constant. The only difference was that oTBL students engaged virtually while cTBL students met in person. We examined if there were differences between cTBL and oTBL in terms of individual (iRA) and team performance (tRA) in class and end-of-year exam scores. Our educational focus was the female reproductive system. We also examined the mean iRA and tRA scores for all modules. Analysis was via repeated-measures ANOVA.**

Results: **There was a statistically significant difference between cTBL and oTBL groups' iRA, tRA and specific exam items for female reproductive knowledge. Similarly, when we looked at year 2 teaching more generally, students scored significantly higher on the iRAs and exam items that were taught by means of oTBL compared to cTBL.**

Discussion: **During a time of educational disruption, shifting a highly structured instructional design from the classroom to online, while keeping all other factors constant, maintained learning outcomes. This reassurance of the effectiveness in respect of student learning opens the door for further research to explore the educational, social and interactional processes of both face-to-face and online TBL.**

Keywords: team-based learning, online learning, student performance, individual readiness assurance, examination

1. Introduction

The 2020 COVID-19 pandemic had a significant impact on medical education. During a relatively short timeframe, many medical schools switched from conventional face-to-face teaching to online and remote learning. How prepared individual medical schools were for this shift varied widely depending on existing digital learning management systems for communication, content delivery and assessment, infrastructure and resources [1]. Accounts of how medicals schools implemented their solution to COVID-19 in general and how they made use of video-conferencing tools are now well-documented in the literature [2–4]. Learner responses to these changes are also being reported [5–7]. However, to date, evaluations of the learning outcomes of Covid-19-necessitated online learning are mostly lacking.

This state of affairs reflects a more general issue with e-learning research. Evaluations of e-learning tend to focus on acceptability and learner satisfaction, and perceived knowledge gains, with very few examining at what happens within e-learning itself

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[8]. There have been recent calls in the literature for research clarifying the effects of online learning and the design and delivery conditions under which it can be used effectively [9].

The need to address this gap in the literature is pressing. Students across the world are being taught in different ways from those originally planned by their institutions and regulators but we do not know how effective the switch from conventional to remote learning has been in respect of student learning. Moreover, most studies of e-learning have looked at "planned" e-learning rather than what might be called emergency/rapid response e-learning [10]. The latter may be very different, particularly in terms of instructional design and outcomes [8,11].

This is an important area to study. If learning suffered, this may potentially have significant negative effects on students' knowledge and skills acquisition, hence, eventually impacting the overall quality of our doctors and the care they provide [12].

Our concern is not far-fetched. Research from the previous SARS pandemic revealed that medical students had a lot to catch-up due to cancelled lessons [13,14]. Arguably, at that time, IT capabilities were less developed than they are now. However, how on-line instruction effects medical students learning still is open to speculation [9] and demands empirical testing involving tangible academic outcomes to ensure students are not "(un)prepared for practice" [15].

This study aims to address some of these gaps in the e-learning literature by comparing processes and outcomes across a team-based learning [16–20] model of teaching which was delivered largely face-to-face (classroom- or cTBL), then shifted online during Covid-19 (online- or oTBL). The use of TBL is quite widespread in medical and other healthcare professions courses globally [21–23] but to the best of our knowledge there have been no direct comparisons of cTBL and oTBL (but see later). Moreover, reports of online TBL before and during Covid-19 have focused on student perceptions and experiences of online TBL rather than comparing outcomes across cTBL and oTBL [24–27].

Before we elaborate in more detail on the methodological considerations of the present study, we provide a brief overview of TBL (see Fig. 1). We then outline how classroom TBL shifted to online TBL in our context, a medium-sized undergraduate medical school in Singapore which uses TBL as the core pedagogy for early years teaching. This background information will be useful for interpreting the findings of the study and considering generalizability to other settings.

1.1. The setting and study

The switch from cTBL to oTBL occurred in February 2020. We maintained the timetable as scheduled so students logged on and worked together synchronously during oTBL, mirroring what would happen in cTBL. The sequence of activities was managed and delivered digitally via the same learning management system (LMS). Students prepared for the session by studying assigned preparatory materials in advance. During class, whether cTBL or oTBL, students worked in small teams and used the same LMS to take their iRA and tRA tests, raise burning questions and submit the answers to the application exercises.

The sessions were taught by the same TBL facilitators (responsible for the learning sequence) and content experts (clinicians and scientists responsible for the content) who were often familiar to the students from earlier face-to-face sessions. Clear instructions and expectations, such as the time allowed for team discussions, were made explicit in both cTBL and oTBL. Finally, facilitators and content experts could monitor students' responses for the iRA, tRA, burning questions, and application exercise via the LMS as per normal to track their progress.

The overall use of the TBL infrastructure was thus largely identical between cTBL and oTBL. However, students in the oTBL setting did not meet physically but via Zoom. Students logged in using a username and password, then entered the "main room" in Zoom, where all students could see/hear each other and the instructors. For team discussions, students in their teams were switched to a "breakout room" where they could discuss the iRA, tRA, burning questions, and application exercises. Students used the Zoom chat function to post questions to the instructors (rather than asking in person as per cTBL).

In summary, the players, infrastructure, activities and sequence of activities were the same in both modes of delivery, but in oTBL students were spatially distant and distributed (working from home), meeting virtually rather than face-to-face during TBL.

1.2. The study

Keeping many core elements of TBL constant provided some "control" for investigating the effects of changing from cTBL to oTBL on student learning. We had to assume that students would prepare for each oTBL session as well as for a cTBL session because there was no difference in how the preparation phase was conducted. Thus, we hypothesized

Team-Based Learning

TBL is usually structured in three phases [41-45]. The first phase is the individual preparation phase. During this phase, students study video-recorded lectures, book chapters, articles or digital resources, prescribed by their instructor [17]. The second phase is in class, and is referred to as the readiness assurance phase [46]. Students do an individual closed-book knowledge test (iRA or individual readiness assurance test; typically, 15-25 multiple-choice questions) to examine whether their understanding of the learning materials is sufficient. The same test is then repeated by small instructor-formed groups of 5-7 students (tRA or team readiness assurance test). During the tRA, students engage in a group discussion before they lock in their final answers as a team. The correct answers are then revealed. This group discussion may lead to additional questions about the subject-matter, sometimes referred to as "appeals" or "burning questions" (BR) for which the instructor provides clarification [47]. The third phase is the application phase or AE [48] when the groups engage in a series of real-life exercises encouraging them to apply what they have learned to a concrete medical context.

TBL seems to have several advantages over lecture-based education [49-51]. Knowledge acquisition is left to the individual student so lectures can be discarded, leaving classroom time free to engage in other learning activities. Second, students receive automated feedback on the extent of their learning (iRA), from peers when they discuss answers during the tRA and from the instructor when discussing the burning questions. Third, students actively engage in the application of what is learned to new problems, assignments, or questions during the application phase, thus consolidating learning [51,52].

Fig. 1. Descriptive overview of Team-Based Learning.

that the iRA scores would not be significantly different after changing to oTBL. On the other hand, if virtual-team discussions were less effective than face-to-face discussions, team learning would suffer, which would be represented by a significantly lower tRA score. The same would apply to the application exercise scores. However, the application exercises consist of mainly open-ended questions, of which the answers were not adequately captured in the LMS. We therefore decided to exclude the application exercise from the analysis and only included the tRA scores.

Investigating the differences in iRA and tRA as a consequence of changing to oTBL tells something about how the switch affected learning *during* TBL. However, an objective outcome measure is needed to infer how the switch affected students' academic performance. To that end, we hypothesized that if oTBL was as effective in helping students learn, no significant differences should be observed between the items on the end-of-year examination that measured content taught via cTBL and items that measured content taught via oTBL.

To test the above hypotheses, we used data from second-year medical students and examined if there are differences in terms of in class test performance (iRA and tRA) and exam scores pertaining to cTBL and oTBL respectively. Our objective in doing so was to provide insights into the effectiveness of changing to online learning, specifically, oTBL.

2. Methods

2.1. Participants

No sample size calculation was required as participants represented the whole population of Year 2 medical students in 2020. A total of 137 students (94 males and 43 females) with a mean age of 21.60 years ($SD = .86$ years) were included. All students had one year of experience with cTBL (Year 1 of their medical degree), plus two months of cTBL in Year 2 prior to the shift to oTBL.

2.2. Materials

2.2.1. TBL data

The iRA and tRA percentage scores from 79 TBL sessions were extracted for all modules, which included (1) gastrointestinal system; (2) blood and lymphatic system; (3) infection; (4) nervous system; (5) ear, nose and throat; (6) visual system; (7) female reproductive system; (8) child development and health; (9) mental health; (10) ageing; and (11) family

medicine and community health. The iRA and tRA scores are automatically recorded by the LMS and extracted for analysis

2.2.2. End-of-year examination data

The end-of-year examination scores were used in the analysis. There were 240 multiple-choice items, with five answer options (a, b, c, d, and e). Each item on the exam was tagged to content taught at a specific TBL session, which enabled identifying which item on the exam measured content that was taught with cTBL (n = 113) or oTBL (n = 85)

2.3. Procedure

After completion of the end-of-year exam, the iRA and tRA data were extracted from all TBL sessions. Out of the eight sessions of female reproductive system module, five TBL sessions were taught with cTBL and three sessions were taught with oTBL. We calculated the mean iRA and tRA scores for the five cTBL sessions and for the three oTBL sessions respectively. We were then able to compare whether there were potential differences in terms of preparation for the two different types of TBL sessions (as measured by the iRA scores) and whether there were differences in terms of the effectiveness of the team discussions (as measured by the tRA scores) between the cTBL and oTBL sessions. We were also able to calculate the mean iRA and tRA scores for all modules and then compare whether there were significant overall differences between all modules that were taught with cTBL (six modules, involving 48 TBL sessions) and oTBL (four modules, 20 TBL sessions) respectively.

Finally, all exam items were tagged to content taught in specific TBL sessions so we could identify which of the items measured content that was taught with cTBL and oTBL. We first generated the two item mean scores for the female reproductive system module and compared whether there were significant differences between the two scores. In a second step, similar to our approach with the iRA/tRA scores, we generated two grand mean scores of all items that measured content taught via cTBL and all items that measured content taught via oTBL. With these data we were then able to investigate overall differences in exam scores between cTBL and oTBL.

2.4. Analysis

The analysis was conducted in four steps. First, we analyzed the iRA and tRA data pertaining to the female reproductive system module using one-way repeated-measures ANOVA, with the within-subject factor being cTBL vs. oTBL and as the dependent variables the iRA and tRA scores respectively. The second step entailed the same analysis, but then for all modules combined that were taught via cTBL and oTBL. Third, we generated the mean exam scores of all items in the female reproductive system module that were taught via cTBL and all items that were taught via oTBL and subjected the data to a one-way repeated-measures ANOVA. The within-subject factor was cTBL vs. oTBL and the dependent variable was the exam score for the female reproductive system module. Fourth, we compared all items in the exam that were taught with cTBL and oTBL, again using a one-way repeated-measure ANOVA with the within-subject factor cTBL vs. oTBL and the dependent variable overall exam scores. The analysis was conducted with IBM SPSS Statistics (27) and for all analyses the p-value was set to .05. The study was approved by the Institutional Review Board of Nanyang Technological University, Singapore (IRB-2018-07-025).

3. Results

Table 1 provides an overview of the descriptive statistics for all iRA and tRA scores as well as the end-of-year exam scores.

The one-way ANOVA results indicated the following. There was a significant difference between the iRA cTBL and oTBL scores for the TBL session in the female reproductive systems module ($F = 290.83$, Wilks $\Lambda = .32$, $p < .001$, $\eta^2 = .68$). The iRA scores of the oTBL sessions were on average 4.03% higher than the iRA scores for the cTBL sessions. Next, we conducted the same analysis for the

Table 1. Descriptive Statistics iRA, tRA and End-of-Year Exam Scores.

Measure	cTBL Mean (SD)	oTBL Mean (SD)
Female reproductive system module iRA (N = 137)	72.35% (3.28)	76.38% (3.99)
Female reproductive system module tRA (N = 23)	92.76% (2.22)	95.01% (2.98)
All modules iRA (N = 137)	75.19% (6.74)	82.10% (4.25)
All modules tRA (N = 23)	94.79% (1.44)	95.07% (1.11)
Female reproductive system module Exam scores (N = 136)	75.37% (8.60)	82.48% (14.39)
All modules Exam scores (N = 136)	72.70% (8.40)	76.21% (5.27)

tRA scores. The results suggest that also the tRA scores were significantly higher for the oTBL sessions as compared with the cTBL sessions (2.25% higher) ($F = 20.50$, Wilks $\Lambda = .52$, $p < .001$, $\eta^2 = .47$).

We compared the mean iRA and tRA scores of *all* modules that were conducted with cTBL with *all* modules that were conducted with oTBL. The results suggest that the iRA scores were significantly higher for the modules that were conducted with oTBL as compared with cTBL (6.91% higher) ($F = 260.67$, Wilks $\Lambda = .33$, $p < .001$, $\eta^2 = .66$). The results for the tRA analysis suggest that the differences between the oTBL and cTBL sessions were not significant (.28% higher) ($F = 2.27$, Wilks $\Lambda = .91$, $p = .15$, $\eta^2 = .09$).

We then compared the mean scores of all exam items for which the content (pertaining to the female reproductive system module) was taught by means of cTBL and all exam items by means of oTBL. The results of the analysis suggest that the mean score for the oTBL items was significantly higher than the mean score for the cTBL items in that particular module (7.11% higher) ($F = 34.32$, Wilks $\Lambda = .80$, $p < .001$, $\eta^2 = .20$).

Finally, we investigated whether there were differences between the mean scores of all items on the exam that were taught by means of cTBL and all exam items that were taught by means of cTBL. The results of the analysis suggest that students scored significantly higher on the exam items that were taught by means of oTBL than on cTBL (3.51% higher) ($F = 37.56$, Wilks $\Lambda = .77$, $p < .001$, $\eta^2 = .22$).

Overall, the results of the six one-way repeated-measures ANOVAs suggest that the scores obtained, be it iRA, tRA and exam scores, were consistently higher for the oTBL sessions as compared with the cTBL sessions. See Fig. 2 for a visual summary of these differences.

Although most elements of TBL were kept constant, without a control it is not possible to eliminate confounders. We considered using a historical control, to compare this cohort and a previous cohort that was not exposed to oTBL. However, as is often the case, aspects of the curriculum were restructured/renamed between the current and previous cohorts, making it difficult to identify all TBL sessions and compare them between cohorts. Nonetheless, we managed to identify two TBL sessions in the female reproductive system module that were identical between both cohorts. We used the iRA and tRA scores of these two TBL sessions to conduct a post-hoc analysis. Since we had one session before implementation of oTBL and one session thereafter, we could test if there are significant differences between cohorts. The iRA analysis suggested that there was a non-significant difference between both cohorts prior to the implementation of oTBL ($F = 1.62$, $p = .20$, $\eta^2 = .01$) and a significant difference post implementation ($F = 7.32$, $p = .01$, $\eta^2 = .03$) favoring oTBL. The results for the tRA suggest that there were no significant differences between both cohorts prior ($F = 1.11$, $p = .30$, $\eta^2 = .03$) and post implementation of oTBL ($F = .06$, $p = .78$, $\eta^2 = .002$).

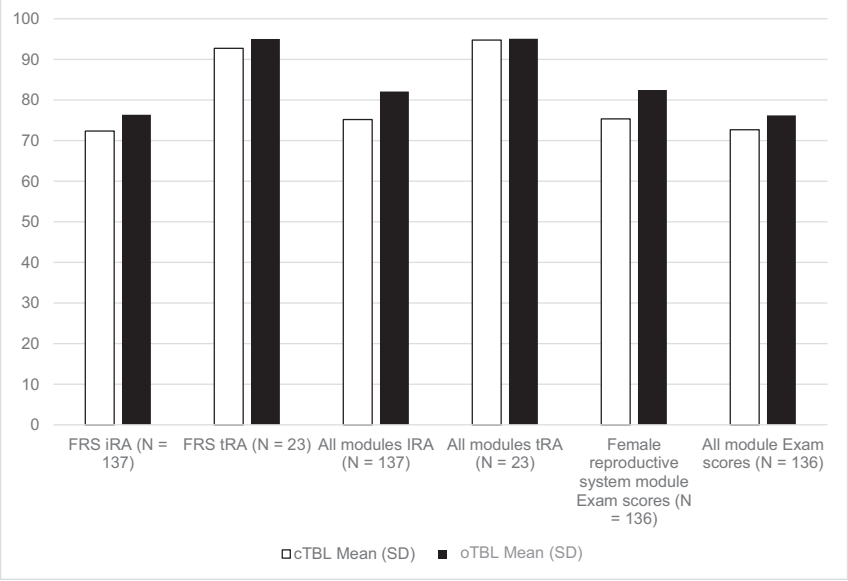

Fig. 2. Graphical representation of the mean differences between cTBL and oTBL session for all six analyses (FRS = female reproductive system).

4. Discussion

4.1. Main findings

Our objective was to extend understanding of what happens within e-learning itself. We did so by examining the extent to which the switch from cTBL to oTBL influenced student learning. We compared the iRA and tRA scores prior and post implementation of oTBL. We also included end-of-year examination scores to investigate whether there were significant differences between the scores obtained on items that were taught via cTBL versus oTBL.

Contrary to our hypothesis, the iRA results suggest that students generally prepared better for oTBL sessions compared to cTBL sessions despite no changes in the preparation phase or materials. The tRA results suggest that students performed slightly better during oTBL, indicating that virtual team- and class-discussions appear to be as least as effective as conventional face-to-face meetings. Finally, the results suggest that the switch from cTBL to oTBL did not negatively affect academic performance as measured by outcomes on the end-of-year examination.

4.2. Implications

What are the implications of our findings? First, the team interactions did not appear to suffer from the shift to a virtual meeting space. It appears that students can effectively engage in synchronous online discussions with each other and the instructors. Our data suggest that the advancement of video-conferencing technology has reduced the barriers of online communication so it can now be considered a viable part of the educational landscape. However, TBL may lend itself particularly well for the switch to oTBL because it is highly structured. Further research is needed to examine if other, less structured approached to online learning are as effective as oTBL.

More broadly, this study highlights the importance of existing systems for managing disruption. We compared learning outcomes from classroom and online learning under relatively ideal conditions: well-designed learning materials, a robust online learning management system, support from a Digital Learning team, a context where internet access is uniformly good, and both teachers and learners had prior familiarity with learning structure and materials. We appreciate that not all medical schools have the infrastructure or resources to shift from classroom to online teaching seamlessly. However, we urge those planning medical education to consider how best to set up teaching and learning to be able effectively to adapt in times of crisis using whatever resources are available [12].

4.3. Comparison with prior research

Our findings align with prior research that suggests that e-learning is as effective as traditional classroom teaching in respect to knowledge gains and learner satisfaction [28–31]. However, the quality of studies in this field is generally weak [9,32–34], and our study adds to the literature in terms of its methodology.

Interestingly, the only study we know of which claims to compare cTBL and oTBL found student outcomes (participation, exam scores) deteriorated during oTBL [35]. When we scrutinized this paper, we found that the authors were comparing apples and pears. The pre-Covid-19 cTBL described was similar to our own, but the oTBL was completely different: asynchronous, the TBL structure of iRA, tRA and AE was removed; discussions were pre-recorded rather than student-directed, and there was no group work. In short, the comparison was of cTBL and a different instructional design.

4.4. Limitations and future research

As with all research, this study has limitations. First, our study lacks experimental control. Although we could control the teaching processes and content, we had no control over what the students were doing outside the TBL "classroom". Given Covid-19 limited all activities, not just those associated with medical education, the strong student performance may have been due to them spending all their time studying rather than the oTBL itself. However, we are reassured by the tRA results. These depend on teamwork in the moment as well as preparation and prior knowledge, and indicate that students were indeed engaged with oTBL.

Our post-hoc analysis of scores across cohorts suggested cTBL and oTBL are equally good in terms of learning. We were unable to conduct a similar historical comparison with the end-of-year examination data because of question and blueprinting changes. This is an area for future research.

Second, because students were remote, staff could not monitor whether they accessed their notes while doing the (closed-book) iRA. However, we believe this was unlikely as the time limit for the iRA was the same in both cTBL and oTBL [students tend to take more time to find answers when they can access resources during testing [36]].

This is a quantitative study focused on outcomes, and so does not provide an understanding of student responses to the transition from face-to-face to online TBL. Qualitative research inviting students to share their perceptions and views of oTBL is needed. There is also an urgent need to look at how technology shapes what teachers and students do in both cTBL and oTBL: what is the "choreography" between the human (e.g., facilitators, content experts, students) and the material (the LMS, Zoom, WhatsApp), and how this may shape activities and learning [37,38]. It would also be useful to compare perceptions of social communication, team cohesion and engagement with learning during cTBL and oTBL [39]. Answering these questions requires qualitative work. Other quantitative work may include using data analytics to examine patterns such as who asks questions during cTBL and oTBL, and if there are differences in the quality and frequency of questions between students and instructors.

Finally, e-learning is highly heterogeneous in terms of its instructional design [40]. Our study compares one specific instructional design, TBL, when delivered face-to-face and online teaching, and our findings cannot be assumed to be generalizable to other formats or pedagogies. Our context is also relevant. Participants were familiar with face-to-face TBL and had worked in their teams before the shift to online teaching. The students, university and country are very focused on digital learning, technology and communications, so students may have found the shift from cTBL to oTBL relatively un-challenging both in terms of the technical aspects of e-learning and their attitudes towards technology as a mediator in education. Again, this means our findings may not be generalizable across different student groups or contexts.

5. Conclusion

During a time of educational disruption, shifting a highly structured instructional design from the classroom to online, while keeping all other factors constant if not controlled, maintained learning outcomes. This reassurance of the effectiveness in respect of student learning opens the door for further research to explore the social and interactional processes of both face-to-face and online TBL.

Ethical approval

The study was approved by the Institutional Review Board of Nanyang Technological University, Singapore (IRB-2018-07-025).

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Other disclosure

None.

Conflicts of interest

There is no conflict of interest.

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