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ORIGINAL ARTICLE

Team-based learning in neuroanatomy

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Objective: Team-based learning (TBL) is an active learning method in which student teams participate in individual work, teamwork, and the application of learned concepts to problem solving. It has been widely adopted in the education of health professions. The aim of this study was to assess whether TBL in tutorials would be beneficial to students' assessed knowledge and subjective sense of satisfaction as compared to traditional modes of teaching.
Methods: In 2018, TBL was introduced into the tutorials of a clinically oriented undergraduate course of neuroanatomy, and its benefits in improving student grades and satisfaction were assessed. The Welch 2 sample *t* test was used for group differences in continuous variables, and Pearson's χ^2 test with Yates' continuity correction was used for group differences in dichotomous variables. Linear modeling was used to look for group differences while adjusting for significant baseline characteristics.
Results: Our study found that in comparison to more traditionally delivered teaching, TBL did not improve grades or alter overall satisfaction. A post hoc pairwise comparison of satisfaction among lectures, tutorials, and practical classes showed that students appeared to be most dissatisfied with the TBL.
Conclusion: Analysis of our methods, results, student comments, and the literature indicate that the length of the tutorials, at 1 hour, was too short to conduct TBL to the standards required. In addition, there is an imperative to persist in preparing students for a different knowledge-transfer paradigm, and it takes a few iterations to improve the approach and application of this method of teaching.

Key Indexing Terms: Team-Based Learning; Neuroanatomy; Teaching Methods; Active Learning

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INTRODUCTION

Team-based learning (TBL) was pioneered in business education in the 1970s by Larry K. Michaelsen, Professor Emeritus of Management at the University of Oklahoma.[1] TBL became increasingly popular in health professional education,[2–5] predominantly in the United States in undergraduate medicine programs.[6] According to Haidet and coworkers,[7] no medical schools were using TBL in 1998, but by 2014 over 100 schools worldwide were using TBL to some extent. It is used in the educative fields of medicine, nursing, dentistry, pharmacy, and residency programs in many parts of the world, in about 22 countries, including the United States, Australia, Japan, Korea, Singapore, and in the Middle East.[1,6]

TBL is an active learning method that involves the creation of small teams within a larger group and is a tutor-directed peer-interactive process.[2] In TBL, student teams participate in a recursive sequence of activities that involve individual work, then teamwork, and then the application of learned concepts to novel problem solving with immediate feedback.[5] It does not replace lectures or practical elements of the course but rather is a method of teaching and learning in practical classes. It is no coincidence that TBL has been adopted more fully by educators in the health care professions than in any other area. Health professionals need to work in collaborative teams to assess clinical cases critically, applying their knowledge and experience to each patient they encounter. It is very suited to professions that have an imperative to prepare students for "intense workplace-based learning which is often in a high stakes setting that requires attention to multiple domains of competency such as teamwork and collaboration."[1]

Traditional education is teacher centered and strives to transfer information from teacher to students. However, in addition to absorbing and memorizing information, students need to apply that knowledge. TBL is a dialectic teaching method in which discussion based on acquired knowledge leads to problem solving.[8,9] It is grounded in constructivist teaching theory, in that students must go through a cognitive process to construct their individual knowledge in a way that logically is consistent with new

Table 1 - Baseline Characteristics of the 2 Cohorts of Students Enrolled Into the Neuroanatomy Unit in 2011 and 2018[a]

Characteristics	2011 Cohort	2018 Cohort	*p*-Value
Mean age (SD)	22.3 (3.5)	21.7 (4.7)	.521
Number of female students (%)[b]	29 (33)	92 (50)	.016
Number of domestic students (%)	65 (82)	123 (90)	.170
Number of native English-speaking students (%)	61 (77)	109 (80)	.737
Number of students with previous degree (%)	24 (30)	13 (10)	<.001
GPA (SD)	2.67 (0.67)	2.3 (0.8)	<.001
Preadmission ranking[a,c]	78.9 (11.0)	73.4 (12.6)	.003
Hours of self-directed study per week (SD)	4.1 (2.2)	5.8 (4.9)	<.001

[a] Data based on survey responses (79 responses in 2011, 137 in 2018).
[b] Data based on all students that completed the unit.
[c] UAI (2011)/ATAR (2018).

information and with their experience. The learning is student centered and self-directed.[10] It aligns with Vygotsky's social constructivism in that the learning occurs in peer groups that undergo a common experience and whose learning is supported by sufficient scaffolding provided by the course.[8,9] TBL gives students the opportunity to apply learned knowledge through peer-to-peer teaching.[11]

Reports on TBL are generally positive; however, as one author pointed out, it is to be expected that advocates of TBL would aim to promote it.[12] Some studies indicate that TBL works best for academically weaker students or those who are at risk of failing, compared to those at the other end of the performance spectrum.[6,13,14]

The aim of this study was to assess whether the introduction of TBL into tutorials within an existing unit of neuroanatomy would be beneficial in terms of students' assessed knowledge, and students' subjective sense of satisfaction, as compared to traditional modes of teaching in tutorials. The specific objectives were (1) to determine whether TBL improved knowledge as measured by the attained course grades; (2) to determine whether TBL improved the students' satisfaction with the course or components of the unit; and (3) to determine whether self-assessment of knowledge and understanding and the hours spent in self-directed study were associated with course grades or student satisfaction. The outcomes of this study will provide beneficial insights into effective teaching methods, which has implications for the wider teaching community and for future students in the program.

METHODS

Study Population and Sample

In 2018 we introduced TBL into a course of neuroanatomy. While much research has investigated TBL in medical and health professional education, in which the subject matter or focus is on its application in medicine, pharmacy, toxicology, nursing, clerkship, and so forth, its effectiveness in the context of anatomy as a subject has been less studied.[1,6,7,12,15,16] While the clinical application of the neuroanatomy content of this course was an important focus, the course itself requires mastery and retention of a great deal of content, and we were interested to see whether students would see a benefit in their grades using this methodology.

To analyze the impact of introducing TBL, we compared this student cohort's grades and satisfaction to available data of a cohort for the same course studied in 2011 that received traditional modes of teaching in tutorials. The content and composition of the course was the same for the 2 cohorts. In the present study, we compared our cohort to the earlier cohort (please see referenced earlier published study)[17] and used the same questionnaire and a similar protocol as was used in that study.

All students who were enrolled in the neuroanatomy course in 2018 were invited to participate in this study. The initial number of enrolled students in 2018 was 204, compared to 95 students in 2011. In 2018, 21 students dropped out (10%), compared to 5 (5.6%) in 2011. The mean age was the same in the 2 cohorts; there were more females in 2018; and there was no difference in percentage of domestic and international students and native English-speaking students between the 2 cohorts (Table 1).

The composition of enrolled degrees varied between the 2 cohorts; in 2011, 81% of the students were enrolled in a bachelor of chiropractic degree program. Another 13% of the students were in a postgraduate qualifying year, which allowed students with a previous health-associated degree to enter into the master of chiropractic science degree, co-badging with the undergraduate students. The remaining 6% were from a general bachelor of science degree program. In 2018, the mix was different: 41.9% were bachelor of chiropractic students; 25.1% were in the bachelor of medical science degree program, which was not available in 2011; 12.8% were in the bachelor of human sciences degree program; and the remainder were a mix of bachelor of science and bachelor of arts students. In 2018, the postgraduate qualifying year was no longer available as a 3-year alternative master of chiropractic degree had been introduced for these students, and thus none of the postgraduate students were co-badged into this unit. This difference likely accounts for the difference in the percentage of students with previous undergraduate degrees ($p < .001$) and may also have influenced the difference in the grade point average (GPA) ($p < .001$), although the entrance University Admission Index (UAI, used in 2011) or Australian Tertiary Admission Rank (ATAR, used in 2018) was also different between the 2 groups ($p = .003$). The 2018 students were spending

Table 2 - Comparison of Assessment Tasks for HLTH214 in 2011 and 2018 and Their Contribution to the Standard Numerical Grade (SNG)

Assessment Task	Weighting 2011	Weighting 2018
Weekly revision quizzes	10%	15%
Assignment	15%	10%
Midsemester test	15%	15%
Practical exam	20%	20%
Final theory exam	40%	40%

significantly more time in self-directed study compared to the 2011 students ($p < .001$), which could indicate more pretutorial preparation. The baseline characteristics of the 2011 and 2018 cohorts are summarized in Table 1.

Materials and Data Collection

The project was approved by the Macquarie University Human Ethics Committee (reference number 5201832653734). Students were fully briefed on the nature of the study and its aims and objectives, and they were asked whether they wished to participate in the study. The students were invited to give their consent to the use of their GPA and grades and to filling out a questionnaire of their assessment of the unit. The Participation Information and Consent Form (PICF) was modified from the original used in 2011 only in its reflection of the year of participation. Both the questionnaire and PICF were administered during the tutorial session in week 12. Students were assured that if they did not wish to participate, there would be no consequences as the questionnaire was anonymous and would be sealed and assessed only when the grades were collected for analysis after the examination period.

The questionnaire was based on the University Learner Evaluation of Unit survey (see Appendix A available as supplemental online content at journalchiroed.com). The questionnaire provides demographic data and information on the students' satisfaction with the unit overall and with the components of the unit, namely lectures, practical examinations, and tutorials. Two other questions asked were regarding the amount of time spent on self-directed study, which could be useful to indicate whether more time was given to pretutorial assigned work in 2018, and the level of confidence students had in their knowledge, which could give insight into cognitive bias.

Neuroanatomy Course

This course focuses on the structure and function of the human nervous system. It utilizes an integrated approach to gross anatomy, histology, embryology, and clinical and applied anatomy. This focus has not changed since 2011. The prerequisite for this course is the introductory anatomy course. Overall, the course, from its inception in 2011, has had 6 hours of contact a week: 3 hours of lectures, a 2-hour laboratory practical class, and a 1-hour tutorial class. The total 36 hours of face-to-face lecture material provides a detailed scaffolding of all the knowledge students require in order to obtain a comprehensive understanding of human neuroanatomy, and the detailed power point slides and audiovisual recordings have always been available to the students online. The 2011 and 2018 cohorts covered the same content and had the same assessments (weekly quizzes, a presentation assignment, a midsemester test, and a practical and a final theory exam), but with a slightly different weighting (Table 2). The technology available to the students has changed from using Blackboard Learn (Blackboard Inc, Washington, DC) to iLearn Learning Management System (iLearn Inc, Marietta, GA) software and ECHO360 (Cloisters Square, WA) audiovisual recordings, but in essence has not changed in providing online information and lecture recordings, although these latter are now available in real time. In the practical sessions, the student-to-tutor ratio was 10:1 in 2011 and 18:1 in 2018. In the tutorials, the student-to-tutor ratio was 23:1 in 2011 and 27:1 in 2018. The few students with identified disabilities were registered through student services and were accommodated within the program through recommended modifications and, if necessary, additional in-class support. Tutors were either qualified chiropractors or graduates in higher-degree research, were of equitable gender distribution, and had prior teaching experience. Occasionally, new tutors would be mentored and supervised by a more experienced tutor.

Tutorials and TBL

TBL was incorporated into every session of the 2018 weekly 1-hour tutorials through the 12 weeks of the semester. Tutorials are here understood to be a learning strategy in which 10–30 students participate in interactive group work that is focused on meeting a certain set of objectives.[18] Students in each of the 5 alternative tutorial sessions formulated their own groups in the first tutorial class. The names of the students in each group were recorded on a spreadsheet to maintain consistency of group members throughout the semester. To enhance team collaboration and to build collegial motivation and interteam competition, groups were asked to formulate their own team names. In addition to enabling team synergy, this also created a more relaxed and social learning environment, as many teams used anatomy-related inspiration to develop creative, humorous names for their groups. The average team size varied from 4 to 6 per group, with most groups at the maximum size.

The TBL involved 3 phases.[3,5,9,19,20] In phase I, students completed individual pretutorial assigned work by going to the lectures or watching its audiovisual recording and completing the assigned prereadings. Phase II consisted of an individual readiness assurance test and team readiness assurance test, in which students completed the same 10-minute quiz on the preclass work, individually and then in teams. The individual quiz result counted toward the assessment of the unit and was handed in for marking, after which the teams as a group decided on the answers to the quiz. This was reflection in action, as students compared their own constructed knowledge to that of the group. One member of each group wrote their choices

Table 3 - Overview of Unadjusted and Adjusted Results From the 2011 and 2018 Neuroanatomy Courses

Source	HLTH 214 2011	HLTH 214 2018	Unadjusted *p*-Value	Adjusted *p*-Value
SNG (SD)[a]	64.5 (11.7)	58.6 (18.3)	.002	.942
Self-rated knowledge (SD)[b]	63.5 (14.0)	63.5 (15.7)	.996	.644
Satisfaction (SD)[b]				
Overall	14.0 (3.3)	14.7 (3.5)	.165	.368
Lectures	13.5 (3.4)	14.9 (3.6)	.006	.022
Practicals	15.2 (3.4)	16.5 (3.6)	.014	.034
Tutorials	14.1 (3.7)	13.2 (4.7)	.144	.268

[a] Data based on all students who completed the unit, adjusted for GPA and gender.
[b] Data based on survey responses, adjusted for preexisting degrees and hours of self-directed study per week.

on the whiteboard. In the feedback session that immediately followed, the answers to the quizzes were discussed. The difficulties and issues were identified, misconceptions were dealt with, and the group with the most correct answers gained a mark that jackpotted to a total mark for the group at the end of the semester. This was a fun mark and was not counted. Finally, phase III was the focused application task, a team-based problem-solving exercise based on case studies. This was followed by a discussion and a feedback session.

The 2011 tutorials consisted of individual quizzes on the previous week's lecture content and similar case studies that were handled as a class discussion led by the tutor. The number of hours spent in tutorials were the same in both groups.

Statistical Analysis

All analyses were conducted after the final grades were officially released. Questionnaire responses were tabulated and scored, and the means with SDs for GPA, UAI/ATAR, SNG, and grade distributions were calculated. The Welch 2 sample *t* test was used to check for group differences in continuous variables (eg, age, hours of self-directed study, self-assessed knowledge, GPA, SNG, UAI/ATAR, and satisfaction scores), while the Pearson's χ^2 test with Yates' continuity correction was used to check for group differences in dichotomous variables (eg, gender, native English speaking vs non-native English speaking, previous degree vs no previous degree, and domestic vs international student). Linear modeling was used to look for group differences while adjusting for significant baseline characteristics. All statistical analyses were performed using the R statistical package (version 3.5.1; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Table 3 provides a detailed overview of both the unadjusted and adjusted results. The course grades were not significantly different for the 2 cohorts ($p = .942$), and likewise, the students' perception of their level of knowledge was similar ($p = .644$). The overall satisfaction with the unit ($p = .368$) and satisfaction with each component of the unit was similar between the 2 cohorts (lectures, $p = .022$; practicals, $p = .034$; tutorials, $p = .268$). The extra hours the 2018 cohort spent in self-directed study ($p < .001$) did not translate into any difference in their self-assessment of their knowledge nor to their grades or satisfaction with the course.

Figure 1 shows a comparison of the grade distribution in 2018 and 2011. From the results in 2018, there appears to be no advantage that TBL has given to either the low or high end of the grade spectrum when compared to the grade distribution in 2011.

A post hoc pairwise comparison of satisfaction of lectures, practicals, and tutorials was conducted within each cohort (Tables 4 and 5). In general, the findings follow the same pattern in 2018 as in the previous findings, which is that students are still most satisfied with the practicals. However, the pattern appears to have become even more accentuated. The surprising finding from these analyses is that while satisfaction with both lectures and practicals has increased, the satisfaction with tutorials has declined in 2018 compared to 2011.

DISCUSSION

Our study found that in comparison to a more traditionally delivered method of teaching neuroanatomy in the tutorials, TBL did not improve grades nor alter overall course satisfaction. It also did not seem to work better for academically weaker students, as the literature suggests.[6,14,21] The students seemed the most dissatisfied with the tutorials that were run using TBL, in comparison to any other aspect of the course, and were less satisfied

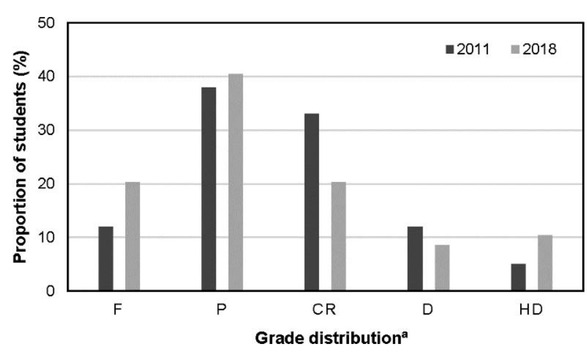

Figure 1 - Comparison of the grade distribution between the 2011 and the 2018 cohorts. The results show no particular advantage to low- or high-level performers in the introduction of TBL in 2018.

Table 4 - 2011 Post Hoc Pairwise Comparison of Satisfaction With Lectures, Practicals, and Tutorials for the 2011 Cohort

2011 Cohort	Lectures	Practicals
Lectures (mean = 13.5)		
Practicals (mean = 15.2)	.002	
Tutorials (mean = 14.1)	.324	.040

Table 5 - 2018 Post Hoc Pairwise Comparison of Satisfaction With Lectures, Practicals, and Tutorials for the 2018 Cohort

2018 Cohort	Lectures	Practicals
Lectures (mean = 14.9)		
Practicals (mean = 16.5)	<.001	
Tutorials (mean = 13.2)	.001	0.001

with this aspect of the course compared to their counterparts in 2011.

The results showing dissatisfaction with the tutorials using TBL were unexpected. A 2017 meta-analysis of 17 studies on the effect of TBL on content knowledge showed an overall mean effect size of 0.55, indicating a moderate positive effect on acquired knowledge.[16] What follows is a discussion of possible factors that may explain these findings, including a broader analysis of the literature with which to contextualize our results.

Implementation of TBL

Burgess and coworkers[22] conducted a systematic review of the application of Michaelsen's 7 core TBL design elements and found both significant variability across the 20 included studies in the application of the methodology and failure to implement all aspects, in many cases. Similarly, a review of 84 articles published in 2014 found that 25% of the studies did not fully implement Michaelsen's TBL method.[7]

The 7 core elements of TBL[5,7,19,22] are team formation processes, readiness assurance processes, immediate feedback methods, in-class sequencing of learning activities, the application of the 4 *S's* (significant problem, same problem, specific choice, simultaneous reporting), grading incentive structures, and peer review processes. When analyzing how we specifically applied TBL to the neuroanatomy tutorials did the following:

1. We allowed students to make their own team choices. This was done because the teams were formed at the start of the semester and before tutors had enough familiarity with the students. However, more carefully constructed teams may have helped to balance strengths within the teams. Parmelee and Michaelsen,[23] in their 12 tips for effective TBL, suggest a transparent process in which student strengths and diversity are evenly distributed.
2. Many students said that the readiness assurance processes (individual and team quizzes) were useful and forced them to stay on top of the content. However, many students commented on how much of the 1-hour tutorial time the quizzes took up and that there was not enough time spent on the case studies. Many said that the tutorials needed to be longer. There were comments such as "the tutorials focused too heavily on the quizzes. As a result, we seemed to go through the questions on repeat, then rush through the focused application task," and "quizzes and going through them are not time efficient." There were many comments regarding making the tutorials longer.
3. The sequencing of the activities was maintained but with great curtailment of the time for the focused application task and feedback time.
4. The 4 *S's* were applied through the use of meaningful case studies related to the area of neuroanatomy. Students worked as groups on the same set of focused questions related to the case study, and groups reported at the same time. The students' feedback showed their interest in the case studies and that they were keen to spend more time on them.
5. The individual quizzes were graded and contributed to the student grade, which is always a great incentive. However, the tutors were so rushed for time that the process of rewarding the teams with the highest mark each week with the intent of rewarding the best team at the end of the semester did not materialize. This could have created a great incentive with a prize awarded in the last tutorial.
6. We did not apply a peer review process, which would have taken even more of the 1 hour we had for the tutorial.

Our strength was in applying the TBL program to every week of the program; in the studies reviewed by Burgess and coworkers,[22] the TBL programs were applied in a range of different ways, some in as little as 2–3 sessions. Our group size appeared to be optimal; class sizes in the literature ranged from 4 to 12 members, with 5–7 students considered an optimal number.[6] But a weakness in our design appeared to be in the length of the tutorials; many programs in the literature were 1.5–2 hours long, with a mean length recorded at 119 minutes.[16,22] For example, a TBL study conducted by Burgess and coworkers[19] allocated an hour to the Clinical Problem-Solving Activity alone and a total session time of 2 hours.

Analysis of the Literature

There have been a few systematic reviews on TBL. Many report majority improvements in knowledge scores.[1,6,7] However, this does not mean that reviews did not find mixed outcomes, in both grades and student satisfaction. A 2013 review of 14 papers published up to 2011 found that 29% of studies reported no difference in grades. Only 1 of the studies reported improved student satisfaction, while another showed significant preference for the comparator, and for the rest there was either no significant difference in student satisfaction or this aspect was not reported.[1] A review published in 2014[7] reported on a few studies that found lower student enjoyment and satisfaction. Reimschisel and coworkers[6] conducted a review published in 2017 on 85 studies and found that although 61% of papers found TBL to be an effective instructional technique, the reported scores did not all improve; some stayed the same. Some reviews are less favorable. A review published in 2018, specifically looked at the benefits of TBL in nursing and midwifery as published between 2011 to 2017 and found the research to be sparse and inconclusive.[12]

The quality of the studies was also a concern. The 2017 meta-analysis of Swanson and coworkers[16] may have concluded an overall mean effect size of 0.55, but the authors reported low confidence in the findings due to poor study design. A review published in 2016 that evaluated TBL in nursing, as blended with technology,[15] concluded that the design of studies in this area was not robust. Another 2018 meta-analysis of 14 papers specifically evaluated the effectiveness of TBL in the medical education system in China[24] and found great heterogeneity among the study designs and varying quality.

Issues Raised in the Literature

Parmelee and Michaelsen,[23] in their 12 tips for doing effective TBL highlight the importance of developing accountability in students and found that this requires communication and transparency on the part of teaching staff to create the correct environment for TBL to work. The mixed reaction of students in some of the studies identified by Fatmi and coworkers was thought by the authors to possibly reflect increased demands on learners and resistance to the greater responsibility and accountability they must foster.[1] Dearnley and coworkers[12] did not avoid discussing the challenges of TBL and said that it required a sustained and structured approach and a willingness on the part of staff and students to understand and persist with the process. Persistence is particularly important in the teaching staff, as TBL certainly means increased workloads in the initial stages, as they became familiar with the method and prepare the material. TBL constitutes a steep learning curve and high time investment that would likely factor into the success of the program initially.[7]

Of interest is the possibility raised by Haidet and coworkers[7] that those students and teachers who found the method less enjoyable, less effective, and less efficient than lecture-based methods may be struggling with the knowledge-transfer paradigm. TBL requires that participants adopt a practice-based paradigm and not look for facts told that can just be memorized. If teachers do not understand the nature of the process, they tend to want to lapse into didacticism during the session, which has the effect of "shutting down learners' creativity, openness, and critical thinking." Students who are not made adequately aware of the intent of the process can feel "cheated out of hearing more facts," and the process includes how both teachers and learners understand and adapt to the process.[7] This attitude seemed to exist in some of our survey comments, such as "would like to be taught more rather than independent study"; "maybe a review of weekly content instead of re-marking quiz"; "less group learning would allow more time for tutor discussion"; "tutorials were not as enjoyable as it was not completely reiterating the practicals and lectures to the extent I would have liked"; "tutorials could be better at covering lecture content." The flip side of this argument is that perhaps TBL is not the best for a course in neuroanatomy, which has such high knowledge content. Although TBL helps with the application of knowledge to clinical scenarios, perhaps the time is better spent at this early stage in more didactic development of that knowledge base. Thus, an important finding of this study may be that TBL, while being successful for clinical courses, may not improve student performance but rather only lead to more dissatisfaction in heavy knowledge-acquisition courses.

Aside from the many issues raised above, it is important to note that it can take a few iterations of the method for students to accept TBL.[6] Initial resistance is quite common, and acceptance increases as the course material is refined.[12]

In summary, the research is mixed in terms of quality and outcomes, and clearly not all studies concluded that TBL either improved grades or that the students preferred it to more traditional teaching methods. The lack of improvement in grades and the dissatisfaction with TBL that we found in our study is likely attributable to many of the factors mentioned in our analysis of our procedure and gleaned from the literature, namely, the tutorials were simply too short to meaningfully cover the phases of TBL; the application of the methodology takes a few iterations in order to work through the problems; and the teaching staff must persist in preparing students for this knowledge-transfer paradigm. This is influenced by how accustomed students are to passive learning in the more traditional forms of teaching in both secondary and tertiary experiences.[25] But the possibility exists that more traditional forms of teaching may be more suitable for heavy knowledge-acquisition courses and that TBL is more successful in clinical courses.

Limitations

The results of the 2018 research were compared to a 2011 cohort. Although the baseline differences between the 2 groups were statistically adjusted for in the analyses, the generational differences that may affect the outlook of students in 2011 and in 2018 could have influenced the outcomes of this study. However, the comments and level of satisfaction expressed by the 2018 cohort provides reasons for the quantitative outcomes of this study. It is also our opinion that these students were not so markedly different in their outlook that it would warrant a discussion of a generational change in the needs of students.

Future Directions

The results obtained from this present study may indicate that TBL is less suitable for basic acquisition courses. However, more research is recommended. Imperative to optimizing success is the understanding teachers have of this knowledge-transfer paradigm and their ability to prepare students in adopting a practice-based approach removed from memorization of facts. Teachers must also be prepared to be persistent in identifying problems and constantly modify their technique. Different tutorial lengths and permutations should also be attempted to identify the optimal time to successfully execute this teaching technique.

CONCLUSION

TBL is considered to be appropriate in courses in which a primary goal is to apply learned information to solving problems and answering complex questions.[16] As this neuroanatomy course delivers a great amount of content and prepares many students to go on to clinical courses, it seemed useful to investigate its possible benefits on student grades and satisfaction with the course. Although the research is mixed in terms of outcomes and quality, TBL has been shown to have a moderate positive effect on acquired knowledge. Our research found that it neither improved grades nor satisfaction with the course. Analysis of our methods, results, student comments, and the literature indicate that 1 hour is too little time to conduct TBL to the standards required. While we acknowledge that it takes a few iterations to improve the methodology and application of this teaching tool, and our results could benefit from this process, the possibility is raised that this method of teaching may be more useful for students at a more advanced level of clinical studies rather than at the level of basic knowledge acquisition.

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