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Geographic Trends in Team-based Learning (TBL) Research and Implementation in Medical Schools

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Abstract

Purpose: Team-based learning (TBL) is an active approach to learning that can be implemented in large enrolment classes. This study aims to document the extent of implementation of TBL in medical schools and characterize the geographic distribution in the trends of TBL research.
Method: To examine the geographic distribution and curricula of medical schools from the published TBL literature, a systematic review of the Web of Science Core Collection was performed on articles published between 2000 and 2018. To fill in the gaps on implementation of TBL outside of the published literature, a questionnaire was developed and sent to a global network of TBL researchers and practitioners. The articles and questionnaire responses were assessed according to seven core design elements described in TBL implementation guidelines.
Results: The systematic review yielded 69 journal articles, with 39 (56.52%) from schools that use TBL in their curriculum. Publications in earlier years were mainly from North America, although Asia is now a key driver in TBL research and implementation. The questionnaire which received 27 valid responses indicated that TBL in most schools (74.07%) feature all seven core elements. Both the systematic review and questionnaire revealed that TBL is used more in the pre-clinical curriculum, often as an adjunct to other teaching methods. Survey respondents cited reasons such as inertia and faculty preference for TBL's limited use. However, a few schools in the US and Singapore report using it extensively throughout the medical curriculum.
Discussion: TBL is rapidly becoming established in Asia, hence more work needs to be done to uncover research and implementation in various non-English contexts. Factors that enable institutions to scale and sustain TBL as a main educational tool throughout the curriculum also merit further research.

Keywords: Team-based learning; Team learning; Medical schools; Systematic review

1. Introduction

In recent years, there have been calls for medical education to undergo a paradigm shift away from the traditional lecture approach toward "flipped-classroom" models that engage students in more active learning or risk being disrupted by the wide availability

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of free and high-quality content.[1] These classroom models are gradually being adopted throughout the continuum of medical education though the evidence for its efficacy is inconclusive.[2] Team-based learning (TBL) is a highly structured approach to the "flipped-classroom" that has been growing in popularity in medical schools and a recent systematic review by Reimschisel, Herring, Huang, Minor[3] justifies its effectiveness in achieving academic outcomes. A cursory search of the literature will reveal a growing number of publications on TBL in medical education. However, it is difficult to determine the extent, design, and quality of TBL implementation without a more scholarly review of both the published literature and testimony from medical educators using TBL.

1.1. Team-based learning

Team-based learning (TBL) was initially pioneered for use in a business curriculum at the University of Oklahoma by Professor Larry Michaelsen due to growing class sizes, his discomfort with didactic teaching, and a need to facilitate application of knowledge to real-life scenarios.[4] It has since been adapted to various educational contexts and the principles of TBL,[5] its fundamental elements[6] and guidelines for its implementation[4] are well defined. As a structured form of small-group learning, TBL comprises three fundamental phases: pre-session preparation, individual and team readiness assurance tests (IRAT, TRAT), and application exercises (AEs).

TBL can be applied to classes of varying sizes with reports of class sizes as large as 386.[7] Students are divided into groups of 5–8 students stay together for multiple TBL sessions to facilitate optimal group discussions.[6] The entire TBL session is facilitated by 1–2 instructors who may facilitate discussion and encourage class participation and/or content experts who are familiar with the content of each lesson. Before every lesson, learners are given preparatory materials in the form of videos, notes, or assigned readings on specific topics alongside specific learning outcomes. Each TBL session begins with IRAT, a set of knowledge-based multiple choice questions (MCQ) testing concepts and facts from the preparatory materials. The IRAT is followed by the TRAT, where groups collectively answer the same set of questions and obtain immediate feedback by knowing if their selected answer is right or wrong. The team discussions during the TRAT, often lead to additional questions about the subject matter, which can then be discussed class wide or clarified by the content expert(s).[4] After clarifying doubts in filling in gaps in their knowledge, groups proceed to AEs, higher-order questions set according to the four S's principle: groups are assigned the *same*, *significant* case and report a *specific* choice *simultaneously*.

Each component of TBL is deliberately designed to achieve distinct outcomes. Assessing individual students using IRATs encourages adequate preparation before every lesson whereas TRATs encourage intra-group discussions. Immediate feedback during TRATs and opportunities to ask questions after the TRAT allow students to clarify content misunderstandings before they become entrenched.[6] Application exercises featuring significant problems that are applicable to real-world issues increase learner engagement while having different groups work on the same problem and simultaneously reporting specific choices facilitates class discussion, with students having to communicate and justify their answers.[4]

1.2. Team-based learning in medical education

Team-based learning (TBL) has been gaining traction in medical education since it was first piloted at the Baylor College of Medicine in 2000.[8] As will be discussed later, it is now used by many medical schools worldwide to varying extents. As TBL is a relatively recent development in the field, majority of published articles are descriptive accounts of how TBL was implemented at an institution or programme. However, the growing body of empirical research does point towards various positive outcomes. At the Boonshoft School of Medicine in the United States, Koles, Stolfi, Borges, Nelson, Parmelee[9] found that preclinical students fared better in assessments covering content taught using TBL compared to examinations testing knowledge taught using other methods, with weaker students benefiting more. Meanwhile, at Akdeniz University in Turkey, Alimoglu, Yardim, Uysal[10] discovered that use of TBL in a neurology clerkship increased knowledge retention and was associated with higher student satisfaction. Given the various benefits of TBL in both preclinical and clinical classes, it is imperative to study the geographic trends of TBL research and implementation worldwide.

1.3. Current gaps in knowledge

While the advantages of TBL in medical education have been thoroughly documented,[3] there is a dearth of

published literature documenting geographic trends in TBL research, the geographic distribution of medical schools using TBL, and how TBL is implemented in different medical schools.

Burgess, McGregor, Mellis[11] conducted a systematic review of published articles on TBL between 2002 and 2012 with the aim to document the extent, design and practice of TBL in undergraduate medical education. The authors identified 20 articles which met the inclusion criteria, and reported significant variability in how TBL was implemented and described. At the time of their review, half of the articles originated from the United States and three-quarters of TBL implementation was in the preclinical years. However, a limitation of this review is that it may have missed TBL implementation beyond the confines of peer-reviewed publications.

Six years on is timely to investigate how the publication landscape has changed, and survey educators on the practice of TBL within their medical programmes. Understanding the extent of the implementation of TBL in each medical school is important as it allows readers of articles on TBL to better understand the nuances of the study in the context of the school's curriculum and local cultural norms.

2. Methods

2.1. Overview

A systematic review was performed to summarise the origins of published literature on TBL in medical education and understand the educational context of their respective medical schools. Additionally, an original questionnaire was created to survey TBL practitioners and researchers to understand the implementation of TBL in their medical schools.

The study of TBL implementation was guided by the 7 core elements underlying TBL[6] (Table 1): firstly, optimally sized teams of 5–8 maximises learning; secondly, readiness assurance promotes learner accountability; thirdly, providing immediate feedback by immediately showing answers during TRATs promptly clarifies any misconceptions; fourthly, proper sequencing of discussions deepens content engagement; fifthly, AEs should be set based on the four S's to facilitate application of knowledge to high-order problems; sixthly, grading of performance incentivises out-of-class preparation; lastly, peer review improves learner behaviour.

Table 1
Core elements of TBL identified by Haidet et al. (2012).

Core element	Significance
Team formation	Heterogeneous teams develop communication skills and optimal team sizes promote engagement.
Readiness assurance	Individual and team readiness assurance encourages accountability to prepare adequately for TBL sessions.
Immediate feedback	Obtaining answers immediately after the TRAT allows clarification of misconceptions before they become ingrained.
Sequencing of in-class discussions	Various discussion dynamics allow for varied engagement with content material.
Four S's	The four S's increase interest in the problem and encourage thorough discussions.
Incentive structure	Grading of individual and team performance incentivises adequate preparation for lessons.
Peer review	Peer feedback motivates good behaviour and cultivates communication skills.

The systematic review and questionnaire also obtained details such as use of TBL in the pre-clinical and/or clinical curriculum, the extent of use of TBL in the curriculum, class and team sizes, and whether it was modified to suit lesson needs.

2.2. Systematic review

A systematic review was done in August 2018 on the Web of Science (WoS) v5.30 Core Collection as it is a comprehensive database comprising over 20,000 high impact journals from six online databases of various disciplines curated by full-time subject experts who look for publishing quality and the impact of the scholarly literature. Additionally, the provider of the WoS, Clarivate Analytics, is not a primary publisher and does not have any conflict of interest in the curation of scientific content. Finally, the WoS indexes all authors of the articles, their addresses, and cited references.

The following search term was used: TITLE: ("team-based learning" OR "team based learning" OR TBL OR "team learning") *AND* TOPIC: ("medical student" OR "medical students" OR "school of medicine" OR "medical school" OR "medicine" OR "medical education") for articles published from 1900 to August 2018 and yielded 120 journal articles (Fig. 1). Following an initial review of the titles and

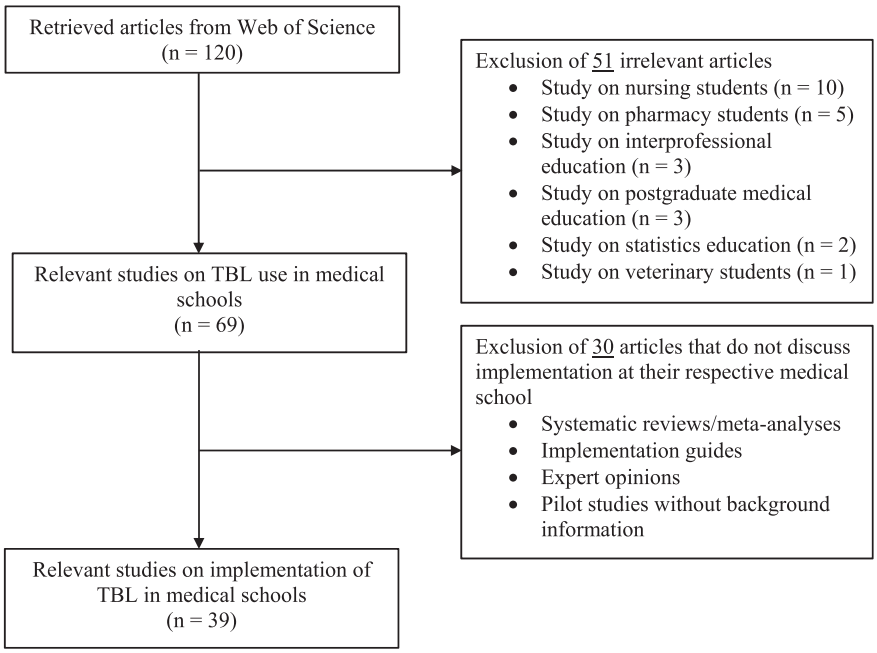

Fig. 1. Flowchart of systematic review.

abstracts only articles about TBL use in medical schools were included (n = 69), with exclusion of studies involving other healthcare students or post-graduate doctors (e.g. residents). From these articles, authors' contact details, medical schools, countries, and years of publication were compiled into Microsoft Excel Version 15.32 by a single reader.

We then conducted a full review of the 69 articles, of which 39 (56.52%) were included for further analysis on TBL implementation. As the focus of our review was articles describing the use of TBL within the medical school curriculum, we excluded articles that were pilot studies of TBL or experiments done outside of the classroom. We also excluded expert opinions and other commentaries that did not describe implementation within a specific medical school.

Further analysis was conducted on the 39 articles by noting how TBL was implemented in their school. Our analysis of these articles was guided by the 7 core elements of TBL.

2.3. Questionnaire

However comprehensive a review of the published literature is, it is unlikely to completely capture the implementation of TBL in medical schools worldwide. Many educators may not perform TBL research or have published their studies in peer-reviewed journals captured by the database given the time-consuming process of academic publication. To widen the scope of our study, a questionnaire (Appendix A) was designed to provide insight into where and how TBL is implemented in medical education. It was created on Qualtrics, with questions in English explicitly asking about each of the 7 core elements of TBL. To ensure that essential details of TBL implementation were captured as well as to establish face validity, the questionnaire was reviewed by experts in TBL research and implementation such as Professor Dean Parmelee from the Wright State University, United States, and Professor Larry Michaelsen from the University of Oklahoma, United States. To improve response rates, the questionnaire was designed to be completed under 5 min and comprised mainly multiple-choice questions. The questionnaire was approved by the Nanyang Technological University-Institutional Review Board and sent to authors of the abovementioned articles (n = 58) and TBL practitioners from the TBL-Collaborative (n = 110) and TBL listserv (n = 1039) for a total of 1207 recipients. The questionnaire was sent to members of the TBL-Collaborative as it was established in 2003 and comprised pioneers of TBL in medical education[12] and the TBL-listserv due to its larger number of TBL practitioners to maximise

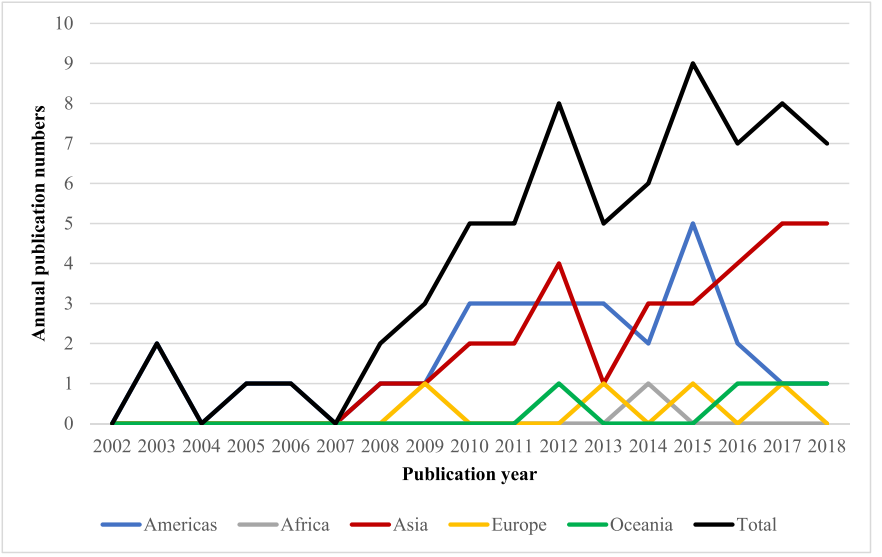

Fig. 2. Chronological trends in annual publication numbers.

response rates. After a 2-week window without reminder emails, 27 valid responses, defined as fully completed questionnaires, from educators using TBL in medical schools were obtained and analyzed.

3. Results

3.1. Geographic trends in TBL research and implementation

Of the 69 articles, the first article was published in 2003 and yearly publication numbers have been increasing (black line, Fig. 2). The principal driver in early years was the US (blue line, Fig. 2), with the first non-US publication from Singapore in 2008. Yearly numbers from the Americas peaked at 5 in 2015, dropping to 1 in 2017 and 2018. Conversely, publication numbers from Asia have been rising, with 5 articles in 2018 (red line, Fig. 2).

At a continental level (Table 2), Asia published the most articles (31, 44.92%), mainly from the Middle East (15, 21.74%). The Americas published 29 articles, with most from the US (26, 37.68%) that is the most productive country in TBL research. The US is followed by Singapore and Lebanon, which each published 5 (7.25%) articles; the publications from Singapore are from researchers of all 3 local medical schools whereas all publications from Lebanon are from researchers of the American University of Beirut. In terms of geographic distribution, the proportion of the 69 published articles on TBL research is similar to that of the 39 articles describing current implementation of TBL (Table 2).

From Table 2, most of the 27 survey respondents are from the US (16, 59.26%) followed by Singapore (4, 14.81%), with only one response from the Middle East (3.70%). Notably, there are schools from Argentina and Chile that have implemented TBL in their curricula without publishing TBL research.

3.2. TBL implementation: systematic review findings

Of the 39 articles that reported use of TBL in the medical curriculum, only 8 (20.51%) articles described if AEs were created according to the four S's principles (Table 3). Conversely, most articles (92.31%) stated if TBL was used in the preclinical and/or clinical curriculum, with TBL being used mostly in preclinical classes (69.44%). Apart from peer review (35.00%), most articles' medical schools feature core elements of TBL (bolded, Table 3). The mean class size is 152.21, ranging from 42 to 386. Team sizes averaged at 6.28, ranging from 3 to 12.

3.3. TBL implementation: questionnaire findings

In most medical schools, TBL is used in less than 25% of the preclinical (53.85%) and clinical (87.50%) curriculum (Table 4), usually to

Table 2
Geographic distribution of TBL publications and survey respondents.

Continent	Regions, countries,	Articles (n = 69)	Articles from schools that use TBL (n = 39)	Questionnaire responses (n = 27)
Asia		**31 (44.92%)**	**17 (43.59%)**	**8 (29.63%)**
	Middle East	**15 (21.74%)**	**10 (25.64%)**	**1 (3.70%)**
	Lebanon	5 (7.25%)	5 (12.82%)	
	Saudi Arabia	3 (4.35%)	3 (7.69%)	1 (3.70%)
	Turkey	2 (2.90%)	1 (2.56%)	
	UAE	2 (2.90%)		
	Iran	2 (2.90%)	2 (5.13%)	
	Oman	1 (1.45%)	1 (2.56%)	
	Eastern Asia	**7 (10.15%)**	**2 (5.12%)**	**3 (11.11%)**
	China	4 (5.80%)	1 (2.56%)	1 (3.70%)
	Japan	2 (2.90%)	1 (2.56%)	2 (7.41%)
	South Korea	1 (1.45%)	1 (2.56%)	
	Southeast Asia	**6 (8.70%)**	**5 (12.82%)**	**4 (14.81%)**
	Singapore	5 (7.25%)	4 (10.26%)	4 (14.81%)
	Malaysia	1 (1.45%)	1 (2.56%)	
	South Asia	**3 (4.35%)**		
	India	2 (2.90%)		
	Pakistan	1 (1.45%)		
Americas		**29 (42.03%)**	**14 (35.90%)**	**18 (66.67%)**
	USA	26 (37.68%)	12 (30.77%)	16 (59.26%)
	Canada	2 (2.90%)	2 (5.13%)	
	Colombia	1 (1.45%)		
	Argentina			1 (3.70%)
	Chile			1 (3.70%)
Oceania		**4 (5.80%)**	**2 (5.13%)**	
	Australia	4 (5.80%)	2 (5.13%)	
Europe		**4 (5.80%)**	**2 (5.13%)**	**1 (3.70%)**
	Netherlands	1 (1.45%)		
	Austria	1 (1.45%)	1 (2.56%)	
	Germany	1 (1.45%)	1 (2.56%)	
	Scotland	1 (1.45%)		1 (3.70%)
Africa		**1 (1.45%)**	**1 (2.56%)**	
	Zimbabwe	1 (1.45%)	1 (2.56%)	

Bold denotes the total for each region.

Table 3
Systematic review findings with core TBL elements bolded.

Component	Findings		Count (n = 39)
Use in curricula	Preclinical	25 (69.44%)	36 (92.31%)
	Clinical	10 (27.78%)	
	Both	1 (2.78%)	
Class size	Mean ± sd	152.21 ± 75.72	31 (79.49%)
	Minimum	42	
	Maximum	588	
Team size	Mean ± sd	6.28 ± 1.26	30 (76.92%)
	Minimum	3	
	Maximum	12	
	# between 5 and 8	28 (93.33%)	
Duration of each session	Mean ± sd (hours)	2.04 ± 0.87	20 (51.28%)
	Minimum (hours)	1.00	
	Maximum (hours)	6.00	
Four S's	Applied to AE creation	6 (75.00%)	8 (20.51%)
	Not applied to AE creation	2 (25.00%)	
Incentive structure	TBL is graded	19 (86.36%)	22 (59.41%)
	TBL is not graded	3 (13.64%)	
Peer review	Present	7 (35.00%)	20 (51.28%)
	Absent	13 (65.00%)	

complement other educational methods. Accordingly, less than 25% of the teaching faculty is engaged in TBL at most schools (53.85%). Of the 4 schools (15.38%) using TBL in more than 75% of their pre-clinical curricula, 2 are from Singapore (Lee Kong Chian School of Medicine and Duke-NUS) and 2 are from the US (Duke University, other is anonymous). The anonymous American school is the only medical school that uses TBL in more than 75% of its clinical curriculum.

Majority of respondents' schools (74.07%) employ all 7 core TBL elements (bolded and labelled in Table 4) described by Haidet, Levine, Parmelee, Crow, Kennedy, Kelly, Perkowski, Michaelsen, Richards.[6] The average class size is 137, ranging from 24 to 700, while the mean team size is 6.85 and ranges from 5 to 9. Students' grades are often determined by examinations (96.00%), IRAT/TRAT performance (85.17%), and occasionally AE performance (42.31%).

4. Discussion

4.1. Geographic trends in TBL research and implementation

While a significant proportion of the articles included in our systematic review have been previously studied by other authors such as Reimschisel, Herring, Huang, Minor[3] who have summarised the content of

Table 4
Survey findings about implementation of TBL with core TBL elements bolded and labelled.

Component	Responses		Count (n = 27)
Percentage of pre-clinical curriculum taught using TBL	25%<	14 (53.85%)	26
	25–50%	7 (26.92%)	
	50–75%	1 (3.85%)	
	>75%	4 (15.38%)	
Percentage of clinical curriculum taught using TBL	25%<	21 (87.50%)	24
	25–50%	2 (8.33%)	
	50–75%	0	
	>75%	1 (4.17%)	
Proportion of teaching faculty engaged in TBL	25%<	14 (53.85%)	26
	25–50%	5 (19.23%)	
	50–75%	4 (15.38%)	
	>75%	3 (11.54%)	
Class size	Mean ± sd	137.00 ± 125.02	27
	Minimum	24	
	Maximum	700	
Team size	Mean ± sd	6.85 ± 1.04	27
	Minimum	5	
	Maximum	9	
	(1) # between 5 and 8	25 (92.59%)	
(2) Readiness assurance	Present	27 (100%)	27
	Absent	0	
(3) Immediate feedback	Present	27 (100%)	27
	Absent	0	
(4) Proper sequencing of in-class discussions	Present	24 (96.00%)	25
	Absent	1 (4.00%)	
(5) Application exercises following four S's	Present	25 (96.15%)	26
	Absent	1 (3.85%)	
(6) Peer review	Present	20 (74.07%)	27
	Absent	7 (25.93%)	
Graded assessments	Examinations	24 (96.00%)	25
	(7a) IRAT Performance	23 (85.19%)	27
	(7b) TRAT Performance	23 (85.19%)	27
	Peer review	14 (70.00%)	20
	AE performance	11 (42.31%)	26
	Absent	7 (25.93%)	

existing publications on TBL, our study presents a novel approach by studying the geographic trends of TBL research and implementation rather than the content of each individual publication.

As TBL was first implemented at the Baylor College of Medicine (US) in 2000,[13] it is unsurprising that both articles in 2003 were from the school. The large number of publications from the US in early years have established the benefits of TBL in the local milieu,[8] possibly reducing the need for research in following years. Meanwhile, the rising publication numbers in Asia could be due to pilot studies to assess the applicability of TBL to the local context, particularly in the Middle East, where TBL was conducted with single-gender teams due to cultural sensitivities at the College of Medicine of Alfaisal University in Saudi Arabia.[14]

Interestingly, Singapore has the 2nd highest number of publications despite its low number of medical schools, with all 3 medical schools being involved in TBL research. Reasons include Singapore's small land size, how faculty may teach students from multiple schools, and the frequency of local and regional medical education conferences such as the annual Asia-Pacific Medical Education Conference.[15] These factors facilitate knowledge exchange and collaboration in pedagogical formation across schools.

Given how the US is an established leader in TBL research and implementation, it is unsurprising that most respondents are from the US. This finding is corroborated by the Association of American Medical Colleges (AAMC): TBL is commonly used in the preclinical curricula of the American medical schools in its database, ranging from 42% of schools for Embryology (n = 24 of 57) to 69% of schools for Physiology (n = 75 of 109) (S. Cook, personal communication, September 12, 2019).

However, in contrast to the systematic review findings, there is only one response from the Middle East. This poor response rate may suggest a sampling bias due to a few possible reasons: they may be underrepresented in groups to which the questionnaire was sent to or may have faced language barriers in filling in the survey. More effort must be spent to find out how TBL is implemented in this region.

4.2. TBL implementation in medical education

At most schools, TBL is used alongside other teaching methods, such as problem-based learning (PBL). Respondents cited a variety of reasons, such as inertia in overhauling the curriculum, faculty preference, manpower issues, and evidence supporting concurrent use of PBL and TBL.[16] However, there are several schools such as the Lee Kong Chian School of Medicine[17] and Duke-NUS[18] from Singapore and Duke University from the United States that have TBL as the main educational method in the preclinical curriculum. Ultimately, there is no one-size-fits-all approach to medical education and the curriculum must be individualised to suit institutional needs.

Unsurprisingly, TBL is used more in the preclinical compared to the clinical curriculum. While research has shown advantages of TBL in both preclinical[19] and clinical classes,[20] there are more publications about use of TBL in preclinical lessons. Furthermore, there are practical difficulties in implementing TBL in a clinical setting as students may be at different healthcare sites and faculty may lack the time to undergo formal TBL training due to clinical commitments.

The incentive structure is as anticipated; examinations are necessary to assess candidates' proficiencies. Grading IRATs motivates students to prepare for classes whereas grading TRATs prompts teams to collaborate.[6] Application exercises may be ungraded as the main objective is to foster discussion and stimulate high-order thinking through the four S's rather than incentivise students.[21]

4.3. Relationship between TBL research and implementation

There are a few schools that were not using TBL performing TBL research; in such cases, trials are usually pilot studies to compare the efficacy of TBL to the school's current curriculum. For example, Anwar, Shaikh, Dash, Khurshid[22] from the University of Sharjah showed that groups taught using TBL performed better than groups taught using its conventional PBL-based curriculum, with the school's curriculum committee subsequently recommending the implementation of TBL in preclinical classes.

Conversely, there are also schools where implementation of TBL precedes TBL research; in these scenarios, the research is mainly evaluative rather than interventional. There are also schools that use TBL without having published TBL research, such as the Universidad de Buenos Aires from Argentina and

Universidad de Tarapaca from Chile. Such trends could be because the effectiveness of TBL in medical education has already been established.[9]

For the few schools mentioned above that implement TBL extensively in their respective preclinical curricula, there is the unique opportunity to conduct longitudinal studies of the efficacy, scalability, and sustainability of large-scale TBL use in medical education rather than small-scale pilot studies.

4.4. Limitations

Using the systematic review to study TBL implementation has three limitations: firstly, most publications only provide contextual information relevant to the study. For example, Deardorff, Moore, McCormick, Koles, Borges[23] published a paper about a study in pre-clinical students but failed to describe the use of TBL in its schools' clinical curriculum despite their school using TBL for its internal medicine clerkship.[24] Secondly, the articles may not be up-to-date; for example, a publication in 2016 by Burgess, Ayton, Mellis[25] from the University of Sydney did not describe use of TBL but a later article in 2017 by Burgess, Bleasel, Haq, Roberts, Garsia, Robertson, Mellis[26] stated that TBL has since been incorporated into the school's curriculum. Thirdly, the literature review only included peer-reviewed publications published in databases included in the WoS Core Collection. While the WoS Core Collection comprehensively covers high quality peer-reviewed publications in various databases, its stringent selection criteria may have led to the exclusion of some publications about TBL in medical education. Hence, future studies could be broadened by searching more databases. Furthermore, given the time needed to publish results from research in peer-reviewed journals, other research materials such as conference proceedings could be included in the study of geographic distribution of TBL research.

The questionnaire thus aimed to overcome these shortcomings and obtain comprehensive, up-to-date information. The 27 responses received provided specific and up-to-date details of TBL implementation. However, one should be conscious of potential sampling bias due to the selection criteria and language limitations. The questionnaire received only one response from China. However, a recent review[27] of the effectiveness of TBL on medical education in China included 13 articles that were mostly published in Chinese. Similarly, only two responses were received from the Middle East even though the review of the published research indicates that Middle Eastern schools are actively publishing on TBL. Additionally, there were only a few respondents from European medical schools, which may hinder the ability to gain insight into the pedagogy unique to this region. To enhance response rates from educators worldwide, the questionnaire could be translated into different languages and disseminated to more groups of TBL practitioners. Furthermore, as some respondents were unsure how TBL is implemented in their respective schools, direct correspondence with school administrators can be conducted in the future. With these changes, the questionnaire could be a potential cornerstone in understanding the essential details about TBL implementation in the different medical schools worldwide.

5. Conclusions

While the US continues to be a stronghold of TBL research and implementation, the popularity of both TBL research and implementation, especially in the pre-clinical curriculum, is growing worldwide. In Asia, Singapore is a leader in both TBL research and large-scale pedagogical implementation while Lebanon is a leader in research. More must be done to study how TBL is implemented in non-English-speaking contexts including Chinese and Middle Eastern medical schools and the sustainability of large-scale TBL implementation in medical education.

Disclosure

Ethical approval

Ethical approval has been granted from the Nanyang Technological University Institutional Review Board for research involving collection of behavioural data from participants through survey (14 September 2018, IRB-2018-08-030).

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None.

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Appendix A.

Questionnaire

Page 1 – Introduction

Dear Sir/Madam, this short questionnaire is intended to survey practitioners of Team-Based Learning (TBL) to understand how and to what extent TBL is implemented in medical schools worldwide. Your participation is greatly appreciated and this survey will take less than 5 min. Thank you for your time.

If you have any queries, please feel free to contact me (XXX) or my supervisor, XXX (XXX).

Page 2 – Demographics

- Designation:
- Course(s) responsible for:
- Name of Medical School:
- Country:

Page 3 – Extent of TBL use

(1) When did your school begin using TBL? [drop-down, years]
(2) How was TBL implemented in your school?
  a. Schoolwide implementation
  b. Implemented by individual lecturer(s)
  c. Others
(3) Is medicine the first course in your school to be taught using TBL? (Y/N/unsure)
(4) If not, what courses were already being taught with TBL?
(5) What is the duration of the medicine course? [drop-down, years]
(6) What is the duration of the pre-clinical component? [drop-down, 0.5 years]
(7) What is the duration of the clinical component? [drop-down, 0.5 years]
(8) What percentage of pre-clinical classes are taught using TBL?
  a. Drop-down (0–25%, 25–50%, 50–75%, 75–100%, unable to estimate)
(9) What percentage of clinical lessons (excluding clinical rotations, e.g. ward rounds/clinic attachments) are taught using TBL?
  a. Drop-down (0–25%, 25–50%, 50–75%, 75–100%, unable to estimate)
(1) If TBL was not used for the entire pre-clinical course, please describe what other educational methods were used:
  a. Problem-based learning (Y/N)
  b. Other flipped classroom learning (Y/N)
  c. Lecture/tutorials (Y/N)
  d. Others:
  e. (Optional) please explain why these methods were chosen over TBL for the specific courses
(2) If TBL was not used for the entire clinical course, please describe what other educational methods were used:
  a. Problem-based learning (Y/N)
  b. Other flipped classroom learning (Y/N)
  c. Lecture/tutorials (Y/N)
  d. Others:
  e. (Optional) please explain why these methods were chosen over TBL for the specific courses

Page 4 – TBL Logistics

(1) Faculty
  a. What proportion of the teaching faculty is engaged in conducting TBL lessons?
    i. Drop-down (0–25%, 25–50%, 50–75%, 75–100%)
  b. Are faculty required to undergo formal training before conducting TBL lessons?
    i. Y/N
  c. Of the faculty involved in TBL, on average, how many years of experience do they have with TBL?
    i. Drop-down with years + unable to estimate

(2) Students
  a. How many students are assigned to each group?
    i. Drop-down (4 or less, 5, 6, 7, 8 or more)
  b. How many groups are there in each class?
    i. Open question
  c. How are teams formed?
    i. Drop-down (self-formed vs instructor-assigned)

d. If teams were formed by instructors/schools, what criteria were used? (optional)
e. How long do the teams stay together before being reformed?
   i. (open)

Page 5 – TBL Implementation

(1) Preparation materials
   a. Are preparatory materials given before TBL sessions? (Y/N)
   b. If yes, what types of materials are given? Tick all that apply.
      i. School-prepared notes/slides
      ii. Lecture videos
      iii. Assigned readings from textbooks
      iv. Others
   c. If no, how are students advised to prepare for sessions?

(2) Readiness assurance process
   a. What is the average time spent on the readiness assurance process? (optional, hours)
   b. Is individual readiness assessment (iRAT) a component of lessons?
      i. Yes/No
   c. Is team readiness assessment (tRAT) a component of lessons?
      i. Yes/No
   d. Is immediate feedback given during tRAT?
      i. Yes/No

(3) Application exercises
   a. What is the average time spent on application exercises? (optional, hours)
   b. Do application exercises follow the four S's principle?
      i. Yes/No/Unsure

(4) Discussion details
   a. Are there intrateam discussions during TBL sessions? (Y/N)
   b. Are there interteam discussions during TBL sessions? (Y/N)
   c. How does the time dedicated to interteam discussion compare to time dedicated to intrateam discussion? (1–5)
      i. 1 – significantly less
      ii. 2 – slightly less
      iii. 3 – about the same
      iv. 4 – slightly more
      v. 5 – significantly more

(5) Peer review
   a. Are learners required to complete peer reviews? (Y/N)
   b. If yes, how many times a year to do they do a peer review?
      i. Drop-down, 1,2,3,4, 5 or more
   c. Does the peer review affect students' grades in TBL?
      i. Yes/No
   d. Are the following components assessed in peer feedback?
      i. Learner proficiency (Y/N)
      ii. Learner attitude (Y/N)
      iii. Learner communication skills (Y/N)

(6) Incentives
   a. Do the following assessments contribute to the student's final grade?
      i. iRAT performance (Y/N)
      ii. tRAT performance (Y/N)
      iii. Application exercise performance (Y/N)
      iv. Individual projects (Y/N)
      v. Group projects (Y/N)
      vi. Tests and examinations (Y/N)
      vii. Others: _____
   b. How are the various assessments weighted?

(7) Other comments

(8) (Optional) If you are willing to be contacted for further clarification, please leave your contact details here. Rest assured that collected data will be used solely for the purposes of this study and not shared with third-parties.
   a. Name
   b. Email

Page 6 – (Optional) Curriculum details

(1) Is your school's pre-clinical curriculum topic-based (e.g. anatomy, physiology) or systems-based (e.g. cardiovascular system)?
   a. (If topic-based) Please describe the extent of TBL used in the following topics (nil, single session, multiple sessions, entire course):
      i. Anatomy
      ii. Biochemistry
      iii. Embryology
      iv. Physiology
      v. Pathology

vi. Pharmacology

b. (If systems-based) Please describe the extent of TBL used in the following topics (nil, single session, multiple sessions, entire course):
   i. Basic sciences
   ii. Cardiovascular
   iii. Respiratory
   iv. Gastrointestinal
   v. Renal
   vi. Endocrine
   vii. Musculoskeletal
   viii. Dermatology
   ix. Neurology

(2) Please describe the extent of TBL used in the following clinical topics (nil, single session, multiple sessions, entire course):
   a. Internal medicine
   b. General surgery
   c. Family medicine
   d. Paediatrics
   e. Obstetrics and gynecology
   f. Psychiatry

Appendix B.

Comprehensive results about implementation in the schools that use TBL from the systematic review (n = 39) are shown below (Table A).

Table A
Systematic review findings in ascending sample size

Component	Findings		Count (n = 39)
Four S's	Applied to AE creation	6 (75.00%)	8 (20.51%)
	Not applied to AE creation	2 (25.00%)	
Peer review	Present	7 (35.00%)	20 (51.28%)
	Absent	13 (65.00%)	
Duration of each session	Mean ± sd (hours)	2.04 ± 0.87	20 (51.28%)
	Minimum (hours)	1.00	
	Maximum (hours)	6.00	
Grading system	TBL is graded	19 (86.36%)	22 (59.41%)
	TBL is not graded	3 (13.64%)	
Team allocation	–		27 (69.23%)
Team size	Mean ± sd	6.28 ± 1.26	30 (76.92%)
	Minimum	3	
	Maximum	12	
	# between 5 and 8	28 (93.33%)	
Class size	Mean ± sd	152.21 ± 75.72	31 (79.49%)
	Minimum	42	
	Maximum	588	
Number of TBL sessions	Mean ± sd	13.18 ± 14.30	31 (79.49%)
	Minimum	1	
	Maximum	70	
Type of TBL	Classic TBL	24 (70.59%)	34 (87.18%)
	Modified TBL	10 (29.41%)	
Use in curricula	Preclinical	25 (69.44%)	36 (92.31%)
	Clinical	10 (27.78%)	
	Both	1 (2.78%)	

Appendix C.

Comprehensive results about implementation in the schools that use TBL from the questionnaire (n = 27) are shown below (Table B).

Table B
Questionnaire findings about implementation of TBL at medical schools

Component	Responses		Count (n = 27)
Percentage of pre-clinical curriculum taught using TBL	25%<	14 (53.85%)	26
	25–50%	7 (26.92%)	
	50–75%	1 (3.85%)	
	>75%	4 (15.38%)	
Percentage of clinical curriculum taught using TBL	25%<	14 (87.50%)	24
	25–50%	2 (8.33%)	
	50–75%	0	
	>75%	1 (4.17%)	
Proportion of teaching faculty engaged in TBL	25%<	14 (53.85%)	26
	25–50%	5 (19.23%)	
	50–75%	4 (15.38%)	
	>75%	3 (11.54%)	
Schools requiring faculty to undergo formal training for TBL	Required	19 (70.37%)	27
	Not required	8 (29.63%)	
Class size	Mean ± sd	137.00 ± 125.02	27
	Minimum	24	
	Maximum	700	
Team size	Mean ± sd	6.85 ± 1.04	27
	Minimum	5	
	Maximum	9	
	# between 5 and 8	25 (92.59%)	
Duration of each session	Mean ± sd (hours)	2.85 ± 1.75	20
	Minimum (hours)	1.20	
	Maximum (hours)	8.00	
Immediate feedback	Present	27 (100%)	27
	Absent	0	
Proper sequencing of in-class discussions	Present	24 (96.00%)	25
	Absent	1 (4.00%)	
Four S's	Present	25 (96.15%)	26
	Absent	1 (3.85%)	
Peer review	Present	20 (74.07%)	27
	Absent	7 (25.93%)	
Peer review components	Learner communication	17 (85.00%)	20
	Learner attitude	16 (80.00%)	
	Learner proficiency	14 (70.00%)	
Graded assessments	Examinations	24 (96.00%)	25
	IRAT Performance	23 (85.19%)	27
	TRAT Performance	23 (85.19%)	27
	Peer review	14 (70.00%)	20
	AE performance	11 (42.31%)	26
Team allocation	School/instructor-assigned	24 (88.89%)	27
	Student-decided	1 (3.70%)	
	Others	2 (7.41%)	

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hpe.2019.11.005.

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