Applying Established Guidelines to Team-Based Learning Programs in Medical Schools: A Systematic Review

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Abstract

Purpose
Team-based learning (TBL), a structured form of small-group learning, has gained popularity in medical education in recent years. A growing number of medical schools have adopted TBL in a variety of combinations and permutations across a diversity of settings, learners, and content areas. The authors conducted this systematic review to establish the extent, design, and practice of TBL programs within medical schools to inform curriculum planners and education designers.

Method
The authors searched the MEDLINE, PubMed, Web of Knowledge, and ERIC databases for articles on TBL in undergraduate medical education published between 2002 and 2012. They selected and reviewed articles that included original research on TBL programs and assessed the articles according to the seven core TBL design elements (team formation, readiness assurance, immediate feedback, sequencing of in-class problem solving, the four S's [significant problem, same problem, specific choice, and simultaneous reporting], incentive structure, and peer review) described in established guidelines.

Results
The authors identified 20 articles that satisfied the inclusion criteria. They found significant variability across the articles in terms of the application of the seven core design elements and the depth with which they were described. The majority of the articles, however, reported that TBL provided a positive learning experience for students.

Conclusions
In the future, faculty should adhere to a standardized TBL framework to better understand the impact and relative merits of each feature of their program.

Parmelee and colleagues[1] defined team-based learning (TBL) as "an active learning and small group instructional strategy that provides students with opportunities to apply conceptual knowledge through a sequence of activities that includes individual work, team work, and immediate feedback." Although TBL can be applied to both large (>100 students) and small classes (<25 students), it generally involves multiple groups of five to seven students.[1] In its purest format, TBL is highly structured and requires the implementation of specific steps and recommended core design elements.[1]

Originally developed more than 20 years ago by Dr. Larry Michaelsen for use in business schools, TBL has gained popularity in medical education in recent years.[1] A growing number of medical schools have adopted TBL in some format.[2,3] Haidet and colleagues[4] found a variety of combinations and permutations of TBL across a diversity of settings, learners, and content areas in health sciences education. They subsequently proposed a set of guidelines for standardizing the way in which TBL is both reported and critiqued in the medical and health sciences literature. Using this standardized framework for both the implementation and reporting of TBL will ensure its fidelity as a learning strategy and will provide a greater opportunity for others to replicate the activities and gauge outcomes.[4] According to these guidelines, in addition to outlining the scope (class size, subject, etc.) of the program, researchers should also report on the "seven core design elements that underlie the TBL method."[4] These elements are team formation, readiness assurance (RA), immediate feedback, sequencing of in-class problem solving, the four S's (significant problem, same problem, specific choice, and simultaneous reporting), incentive structure, and peer review.

Despite the increasing number of publications providing a significant evidence base for TBL, no published systematic review has detailed the extent of TBL within medical schools. Therefore, the aim of this review was to summarize the published evidence regarding the extent, design, and practice of TBL programs within medical schools to inform curriculum planners and education designers, particularly those who are considering modifications to current teaching pedagogies and TBL strategies.

Method

In this review, we wrote and used the following definition of medical students: students enrolled in undergraduate or graduate entry university medical programs that lead to the qualification of medical doctor. Our search

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Acad Med. 2014;89:678–688.
First published online February 19, 2014
doi: 10.1097/ACM.0000000000000162

strategy included combinations of the following search terms: medicine; medical education; medical education, undergraduate; team-based learning; team learning; and TBL. Because of their known indexing of publications in medicine and education, we searched the MEDLINE, PubMed, Web of Knowledge, and ERIC databases. We also searched the reference lists of all identified articles. We limited our search to original articles published in the past decade (2002–2012).

Because the primary focus of our review was articles reporting on undergraduate medical education, we excluded articles reporting on postgraduate medical education, including resident training, continuing medical education, and professional development. We also excluded TBL programs in nursing and the other health sciences. Because we were interested in which components of TBL programs were implemented and how, we included articles that reported on modified TBL programs, provided the researchers considered TBL the primary teaching method. We excluded articles that presented multimethod delivery models, in which TBL was just one component of the overall teaching method, if the TBL components were not clearly defined or could not be clearly differentiated from the other delivery methods. Finally, we excluded expert opinions and other commentaries that did not contain original research on TBL programs.

Our literature search yielded 147 potential publications on TBL in undergraduate medical programs (see Figure 1 for our complete search and study selection strategy). Following an initial review of the titles and abstracts for relevancy and removal of duplicate results, we had a total of 44 citations. Two coauthors (A.W.B. and D.M.M.) then independently appraised these 44 full-text articles for relevance. From this appraisal, we excluded 24 articles because the TBL program was inadequately described or we could not differentiate it from the other teaching methods assessed. The same two coauthors (A.W.B. and D.M.M.) then analyzed the remaining 20 articles using Haidet and colleagues'[4] guidelines for reporting TBL activities.

From this full-text analysis, we extracted data related to the implementation context and scope of the TBL program (see Appendix 1), including the program

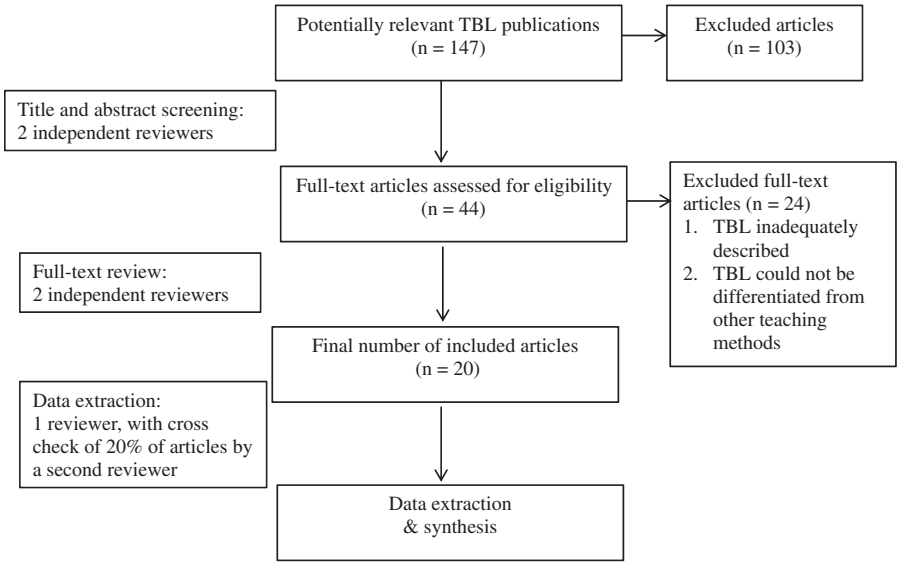

Figure 1 Flowchart of the literature search and study selection process in a systematic review of the literature on team-based learning (TBL) programs in medical education published between 2002 and 2012.

subject, country of implementation, scope of the program (i.e., single session, series, entire course, etc.), class description (i.e., stage of training, class size, etc.), number of learners per team, and staff resource allocation.

We then used the guidelines developed by Haidet and colleagues[4] in critiquing the body of evidence on TBL. We appraised articles by applying these guidelines to determine the extent to which the study applied the seven core TBL design elements: team formation, RA, immediate feedback, sequencing of in-class problem solving, the four S's, incentive structure, and peer review. We rated each of these elements as present and described, present and partially described, present but not described, or not reported, and recorded a summary of the relevant implementation details.

We considered a classic TBL program one that included three phases: (1) advanced preparation, (2) RA, and (3) application exercise.[2] We considered TBL programs to be modified if they did not include one or more of the three phases or if one or more of the phases was significantly different from the implementation approach described by the TBL guide from the Association for Medical Education in Europe.[1]

Results

Of the 20 articles we included in our final review, 14 described a classic TBL program and 6 described modified ones. The studies were conducted in 10 different countries, with seven universities in the United States representing half (10) of the studies. Singapore was the next most commonly represented country, with two studies, both at the National University of Singapore. Other countries represented, with one study each, were Australia, the United Arab Emirates, South Korea, Oman, Japan, India, Austria, and Lebanon. See Appendix 1 for more details about the 20 included articles, such as context, class description, number of learners, and staff resource allocation.

Context of TBL programs

TBL programs were implemented in a wide range of undergraduate medical curricula, including multiple disciplines and content areas, such as the basic sciences, medical ethics, neurology, pharmacology, anatomy, evidence-based medicine, ambulatory care, psychiatry, pathology, and physiology. However, TBL programs were more commonly applied during the preclinical years (14/20) than the clinical years (6/20).

Scope

TBL programs ranged from just two to three sessions of a single course,[5–7] or on specific topics within a course,[8,9] to entire courses of at least eight sessions.[10,11] However, the majority of TBL programs were one and a half to two hours long.

Class and team size

Class sizes ranged from 20 students in a psychiatry clerkship[12] to 240 in a basic sciences clinical application course.[13] The number of students per team ranged from as low as 4 members[14] to up to 12 members.[9]

Appendix 2 summarizes the 20 studies in terms of Haidet and colleagues'[4] reporting guidelines.

Team formation

Random or alphabetical allocations were the most commonly described methods of team formation. Authors described two random allocation methods—the random selection of student numbers[15] and the use of a random list of integers assigned to an alphabetical roster.[16] In addition to applying a random allocation strategy, Nieder and colleagues[17] reported using measures to ensure gender mix, whereas Thomas and Bowen[14] reported using measures to ensure both gender and experience mix.

Other methods included simple team allocation within existing team membership, such as current problem-based learning teams,[13] or carrying over membership from historic teams.[5] Despite recommendations to not allow students to self-select their groups,[4] one article reported using this method.[7]

Readiness assurance

RA was assessed at both the individual student and team level. The majority of the articles (15/20) reported and described the RA process, which largely was in line with recommendations.[1,4] All individual readiness assurance tests (iRATs) and team readiness assurance tests (tRATs) included multiple-choice questions (MCQs), with the same questions used for both tests. Although Willett and colleagues[18] reported using as few as three MCQs, the number typically ranged from 10 to 13. In the few instances where the authors described the time allocation for RA, it varied considerably between 12 and 30 minutes.

Immediate feedback

Eleven articles reported that faculty provided immediate feedback following the tRAT using a class discussion, which also addressed disagreements amongst students and between faculty and students, regarding the correct answer to the tRATs. The remaining articles either did not report or did not provide a description of the immediate feedback design element. Alternative methods of providing immediate feedback included the immediate feedback assessment technique, which involved scratch-off answer sheets,[11,13,14] electronic audience response systems, which displayed results directly on a screen for all students to see,[5,8] and a scanner with print capability to score and return individual and group readiness assessment tests during the session.[19]

Sequencing of in-class problem solving

The majority of articles clearly discussed the sequence of intra- and intergroup discussion but did not provide detail on the length or number of problems. Only one[15] provided a detailed explanation of the sequence, number of problems, and time allocation, along with an example of an application exercise question. Nieder and colleagues[17] discussed intragroup activity only; their program did not include intergroup discussion during the team application of the problem (tAPP).[17] Three articles described the use of group presentations during the application phase.[9,13,20] Abdelkhalek and colleagues[20] claimed that presentation-generated discussion and feedback satisfied the intergroup discussion element.

The four S's

In terms of *significance*, several authors emphasized that the application questions required higher-level thinking and problem-solving skills than the essential knowledge recall questions typically applied during the RA process.[15,16,21] Often, problems were based on complex real-world issues or common clinical scenarios to increase relevance. Next, in all but one case,[9] teams worked on the *same* problem. In addition, MCQs were by and large the method of *specific* choice used for teams to indicate their single-best-fit answer. Finally, the majority of the articles described the use of *simultaneous* reporting. Color-coded and lettered placards were commonly used so teams could simultaneously reveal their responses. In addition to MCQs, one program used true/false questions requiring simultaneous responses.[22] Bick and colleagues[13] reported that, in addition to simultaneous reporting using MCQs, teams were required to submit a written one-page justification for their choice.

Incentive structure

Three articles provided detailed descriptions of incentive structures, including the weighting of grades.[13,22,23] For example, Bick and colleagues[13] described the following weighting structure—iRAT 20%, tRAT 20%, tAPP 40%, and final examination 20%, not including the peer review mark. The majority of authors stated that grades were awarded, but they did not provide a description of the mark distribution. Burgess and colleagues[10] indicated that they used formative and summative assessments but did not detail the grading procedure for the course. Although they awarded points for attendance at TBL activities, Wiener and colleagues[21] reported that they did not follow an incentive structure because it was not in keeping with their educational climate.

Peer review

Ravindranath and colleagues[7] stated that they did not implement a peer review as it would have required a change in the established grading structure, and Chung and colleagues[15] acknowledged that they did not use a peer review either. Several other articles reported evaluating various parameters of peer review, including helpfulness of team members in terms of learning and understanding[19,22,23] and team members' teamwork and interpersonal skills.[23] Although peer review typically took place on the last day of the course, Nieder and colleagues[17] reported a peer review that occurred at three points throughout the course coinciding with major examinations and that included a score out of 10 points plus written comments covering teamwork and communication skills. In the TBL program described by Thomas and Bowen,[14] students completed a peer review online at the end of the rotation, which involved the rating of team members' contributions to discussion by distributing 100 points across the team members and providing narrative feedback.

Discussion

TBL is a relatively new pedagogy in medical education.[24] As a learning tool, it enables a large group of students to take part in small-group learning experiences without a large number of faculty. In addition, students are attracted to the active and collaborative approach of TBL, whereas faculty are interested in its integrated approach to developing students'

professionalism skills, such as leadership, communication, and teamwork.[20] Additionally, with an increasing number of medical students and a decreasing number of teaching staff, the implementation of TBL programs offers resource-saving measures for medical schools. From the studies that we reviewed, we learned that the impact of TBL has been assessed by various outcomes, including student knowledge acquisition, student perception, and faculty perception.

Context of TBL programs

We attribute the dominance of TBL programs in the preclinical years to two factors—preclinical students often are placed in larger groups during this phase of their training, and the resource application of small-group learning could provide the greatest measurable benefit during this period. When faculty used TBL during a clinical rotation or clerkship, it was during scheduled teaching periods, such as when students returned to campus for blocks of teaching[14] or weekly academic half-days.[25] We found no reports of observed bias within the preclinical years of training, with examples of TBL distributed throughout that period.

Scope

We found a large range in the number of TBL sessions (from two to eight). Searle and colleagues[2] suggested that a negative bias might result when exposure to TBL is so minimal (i.e., through only a few sessions) that benefits of the method may not be realized (i.e., increased in-class engagement and application of content).

Class and team size

Wiener and colleagues[21] reported that undersized teams (i.e., two students) scored significantly lower than regular-sized teams (i.e., five to seven students) on RA tests, suggesting that an optimal number of team members to engage students in discussion may exist. According to Michaelsen and colleagues,[26] teams should consist of between five and seven students—small enough to develop process and maximize team dynamics, yet large enough to include sufficient intellectual resources and discussion.

Similar to Haidet and colleagues,[4] we found substantial variability across the articles we reviewed in terms of the application of the seven core design elements and the depth with which they were described.

Team formation

The majority of programs aimed to promote continuity of learning and cohesiveness of teams. The random allocation methods described in the articles we reviewed likely were the most closely aligned with Michaelsen and Richards'[24] ideals for team allocation—that students should be assigned to teams by the facilitator using a transparent process, giving each team a diverse mix of students and ensuring that no preexisting social or friendship-based groupings are formed. Although random and alphabetical allocation methods are likely to prevent teams of friends from self-forming, these methods may not adequately achieve the preferred diversity of learner characteristics. Levine and colleagues[12] and Thomas and Bowen,[14] for example, noted that, in addition to using a random allocation method, they tried to equalize the expertise and gender mix on each team. In contrast, despite Michaelsen and Sweet's[27] warning that such an allocation method could threaten the group's overall development, Ravindranath and colleagues[7] reported that their students self-selected onto teams. In addition, although guidelines[1] recommend that teams "stay together as long as possible," the same authors[7] reformed their teams at the start of each TBL session, which did not allow for the establishment and development of team dynamics.

Readiness assurance

In the articles we reviewed, RA tests typically included questions from the assigned readings to determine students' preparation, comprehension, and readiness for applying the assigned content. As Koles and colleagues[16] acknowledged, the RA process held students individually accountable for their preparation, and, when they failed to prepare, it affected both their individual and their team's learning and performance. In addition, Nieder and colleagues[17] reported that, by using a TBL approach in a gross anatomy and embryology course, faculty spent less time in class covering the basic factual material. We anticipate that, by testing the knowledge of individuals and then the knowledge of the team, students will come to class prepared, motivated by not wanting to let their team down, thus freeing up class time for in-class problem-solving activities.

Immediate feedback

The majority of the articles we reviewed noted that faculty provided immediate feedback to students. Michaelsen and Sweet[27] describe immediate feedback following the tRAT as being inherent to the TBL process to provide students with an understanding of their content knowledge and application ability. In addition, providing immediate feedback encourages competition between both individuals and teams, is key to knowledge acquisition and retention, and affects team development.[27,28]

Sequencing of in-class problem solving

During the problem-solving activities, students had the opportunity to apply their knowledge of course content by working in teams to solve complex, real-life problems. As Parmelee and colleagues[1] noted, students must interpret, analyze, and synthesize information to make a specific choice during the activity, and they must defend their choice to the class if necessary. Although some have described the tAPP as the heart of TBL,[4] this design element was rarely mentioned in detail in the articles we reviewed.

The four S's

The four S's principle should guide the content, structure, and process of the TBL program—the problem needs to be *significant*, all teams need to have the *same* problem to solve, and they need to provide a *specific* choice in their answer, which they and the other teams need to report *simultaneously*. The standard use of MCQs differentiates TBL from other action-based learning techniques, such as case-based learning,[16] that use open-ended questions. Burgess and colleagues,[10] who applied TBL in an anatomy dissection course, did not report the use of two S's—specific choice and simultaneous reporting. We hypothesize that their program did not incorporate these two features because it was lab based and involved hands-on cadaver dissection, rather than a paper-based scenario.

Incentive structure

Assessment has a large effect on students' achievement of course objectives, and, in TBL, it is designed to maximize both individuals' out-of-class preparation and team collaboration.[4] Yet, in many of the articles we reviewed, the authors did not clearly describe the incentive structure. In one, they noted that they had not applied

an incentive structure.[21] Michaelsen and Sweet[27] argued that an effective grading system is necessary to provide rewards for both individual contributions and effective teamwork and to allay students' concerns about grading for group work. Thus, grades should be given for iRAT, tRAT, tAPP, and peer review.[1]

Peer review

Peer review provides an incentive for students to positively contribute to group learning and problem solving.[4] In addition, Parmelee and colleagues[1] recommended that, as part of the TBL process, students contribute to the grades of other students by providing qualitative and quantitative feedback to other team members. However, almost half of the articles did not report on peer review. Having not used peer review in their TBL program, Chung and colleagues[15] suggested that, if they had incorporated it, intra- and intergroup discussion may have improved. Indeed, Michaelsen[29] considered peer assessment to be one of the key components of TBL, because it helps to ensure student accountability. In addition, other articles in the medical education literature report that the practice of giving feedback allows students to develop professional competencies and prepare for their professional lives as clinicians with peer review responsibilities.[30,31]

Limitations

Although we attempted to capture all available and relevant articles, we may have overlooked some as we only included articles written in English and our search strategy may not have been comprehensive. In addition, as the implementation of TBL programs did not gain popularity within medical education until 2001,[1] we have reported on only 10 years of data in this review. Thus, we may have missed earlier descriptions of TBL within medical education. However, it is unlikely that we have missed a substantial number of such publications.

Conclusions

The purpose of our systematic review was to gain a better understanding of the extent and design of TBL programs in medical schools. We used Haidet and colleagues'[4] TBL reporting guidelines in our appraisal of the published literature. Although Parmelee and Michaelsen noted that TBL "works best when all of the components are included in the design and implementation,"[3] our review revealed extensive variations in the design, implementation, and reporting of TBL programs. In addition, Haidet and colleagues[4] argued that the higher the fidelity of the TBL program, the greater the opportunity for faculty to understand, critique, replicate, and compare learning outcomes. Thus, in the future, faculty should adhere to a standardized TBL framework, researching and reporting on their program's outcomes, to better understand the impact and relative merits of each feature of their program.

Funding/Support: None reported.

Other disclosures: None reported.

Ethical approval: Reported as not applicable.

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Appendix 1

Characteristics of the 20 Studies of Team-Based Learning (TBL) Programs in Medical Schools, Identified in a Review of the Literature Published Between 2002 and 2012

First author (year)	Subject	Country of origin	Context	Class description	No. learners / team	Staff resources
Abdelkhalek (2010)[20]	Introduction to medical sciences education	United Arab Emirates	University of Sharjah; the TBL and PBL application phase extended over 6 weeks, each problem was studied over two sessions (2 weeks); one session/ week for 2 hours.	N = 363; students enrolled over 4 semesters; 25–27 students per class	8–9 students	Facilitated by 1 student peer tutor
Bick (2009)[13]	Clinical applications of basic sciences	USA	The University of Texas Medical School at Houston; a course combining the basic sciences with skills learned in the introduction to clinical medicine course; TBL tasks within a 90-minute session; 7 sessions introduced into the first-year curriculum, four in the first semester and three in the second.	N = 240; first-year students	6 students (40 teams)	NR
Borges (2012)[25]	Internal medicine clerkship	USA	Wright State University Boonshoft School of Medicine; internal medicine clerkship is a required 12-week clerkship offered 4 times/year; weekly "academic half days" supplemented by TBL modules.	N = 105	NR	NR
Burgess (2012)[10]	Whole body anatomy by dissection	Australia	The University of Sydney; 34-day, 7-week elective course, maximum possible presence of 272 hours in the dissection room.	N = 42; third-year students	5–6 students (8 teams)	6 demonstrators and 2 supervisors facilitate teaching and invigilate dissection
Chung (2009)[15]	Medical ethics	South Korea	Chonnam National University Medical School; four 2-hour sessions (first session instructional, remaining three sessions applying TBL principles).	N = 160; first-year students	6–7 students (26 teams)	NR
Hunt (2003)[19]	EBM	USA	Baylor College of Medicine; EBM is part of the clinical applications of biomedical science sequence	N = 168/class; second-year students	7–8 students/ team (22 teams)	NR
Inuwa (2012)[23]	Introduction to anatomy	Oman	The College of Medicine & Health Sciences at Sultan Qaboos University; a modified TBL strategy employed during 2 semesters of the academic year; TBL sessions were 2 hours in duration.	N = 170; first-year students	6–7 students	NR
Koles (2005)[16]	Pathology	USA	Wright State University School of Medicine; 8 TBL exercises associated with the corresponding pathology lecture.	N = 83; second-year pathology students	5–6 students (8 teams)	2 full-time pathology faculty facilitated
Levine (2004)[12]	Psychiatry	USA	University of Texas Medical Branch; 6-week psychiatry clerkship rotation; students come together 3 times/ week; eight 1-hour TBL sessions were scheduled 1 to 2 times/week.	N = about 20	4–6 students	5 faculty members developed and administrated TBL activities
Nieder (2005)[17]	Gross anatomy and embryology	USA	Wright Stage University School of Medicine; twelve 2-hour human structure TBL sessions were scheduled into the 9-week time frame of the course.	N = 97; first-year students	5–6 students (18 teams)	3 full-time faculty participated in implementation
Okubo (2012)[5]	Basic science, basic medicine, clinical medicine	Japan	Tokyo Women's School of Medicine; 2 TBL courses held each year; TBL course consisted of 2 to 3 TBL sessions of 105 minutes in duration.	N = about 100; fourth-year students	6–7 team members	2 facilitators—1 chair, 1 provided feedback as a specialist

(*Appendix continues*)

Appendix 1

(Continued)

First author (year)	Subject	Country of origin	Context	Class description	No. learners / team	Staff resources
Ravindranath (2010)[7]	Psychiatry	USA	University of Michigan; 6-week clerkship in psychiatry; hourlong TBL-style modules developed for 3 of 9 lecture topics—mood disorders, anxiety disorders, and consultation-liaison psychiatry; 1 TBL session takes 1 hour.	8 sets of 20–25 students rotating through clerkship in psychiatry	5–6 students (4 teams)	1 facilitator
Shankar (2009)[9]	General embryology	India	Department of Anatomy, St. John's Medical College; 2 of 8 classes conducted using modified TBL method; classes 1 hour in duration.	N = 60	12 students (5 groups)	2 staff
Tai (2008)[6]	Principles in EBM, second year students	Singapore	National University of Singapore; adaption of TBL in a tutorial of the principles of EBM course; delivered to the entire year group over 2 sessions, each lasting 2 hours, involving a class size of about 100 students.	N = 256; second-year students; class size of 100	5 students	Led jointly by 2 facilitators
Tan (2011)[8]	Neurology, third year undergraduate medical students	Singapore	National University of Singapore; 9-week internal medicine posting; 2 topics for TBL—neurological emergencies and neurological localization.	N = 49; third-year students	5–7 students	2 facilitators
Thomas (2011)[14]	Ambulatory medicine clerkship	USA	Johns Hopkins University School of Medicine; required 4-week block clerkship; occurs in community-based primary care offices; students return to the medical school about twice a week, averaging 9 small-group sessions during the clerkship; 3 training problems delivered by TBL.	N = 112; rotated through the study's academic year; second-year students = 5; third-year = 63; fourth-year = 44	4–5 students	1 facilitator
Vasan (2008)[11]	Gross anatomy and embryology	USA	New Jersey Medical School; basic anatomy lectures eliminated and modified TBL introduced; 19-week course divided into 3 units with 40 hours of TBL; 60%–65% course time spent in small-group cadaver dissection.	N = 169–178	8 students	1 faculty member to about 40 students
Wiener (2009)[21]	Functional systems and biological regulation	Austria	Medical University of Vienna; first year curriculum; six 2-hour sessions over a 3-day period as an elective course covering the material of a critical teaching block.	N = 386; first-year students participated in the 8 parallel courses offered	5–7 students	1 facilitator per class
Willet (2011)[18]	Clinical pathophysiology	USA	UMDNJ-Robert Wood Johnson Medical School; instituted in the endocrinology and rheumatology section lasting 5 weeks; intervention targeted 6 case-based sessions, each lasting 1.5 to 2.5 hours.	N = 84; second-year students	7 student (12 teams)	2 facilitators per class
Zgheib (2011)[22]	Pharmacology	Lebanon	American University of Beirut; 3-month internal medicine rotation; six 90-minute, twice-monthly clinical pharmacology sessions; first session didactic instruction followed by 5 TBL sessions.	N = 127; fourth-year students; about 20 students taught at a time	6–7 students (18 teams)	1 facilitator per class

Abbreviations: PBL indicates problem-based learning; EBM, evidence-based medicine; and NR, not reported.

Appendix 2

The Seven Core Design Elements[4] of Team-Based Learning (TBL) Programs in Medical Schools, Identified in a Review of the Literature Published Between 2002 and 2012

First author (year)	Team formation	Readiness assurance	Immediate feedback	Sequencing of in-class problem solving	Four S's	Incentive structure	Peer review
Abdelkhalek (2010)[20]	PND	NR: refer to out of class preparation as readiness assurance	NR	PD: describes sequence of intra- and intergroup discussions; no time distribution specified or number of problems	PD: during application activity, team representatives gave presentations and presenters responded to intergroup questions, followed by faculty wrap-up presentation	PD: formative and summative assessments; triple jump tests and individual student portfolio; final written examination including MCQs and SAQs, weighting not discussed	PND
Bick (2009)[13]	PD: assigned corresponding to gross anatomy tank groups for continuity and cohesiveness of learning within each team	PD: does not provide detail about the content or process	PD: user-friendly scratch off answer sheets provided immediate feedback	PD: describes sequence of intra- and intergroup discussions; does not specify length or number of problem sets	PD: clinical scenario as framework for related problem sets to be solved through group discussions; MCQ options plus 1-page written justification and intergroup presentation	PD: provides details, including weighting (iRAT = 20%, tRAT = 20%, application exercise = 40%, final exam = 20%)	NR
Borges (2012)[25]	NR	PD: iRAT composed of 10 MCQs covering advanced preparation assignment; tRAT composed of same 10 MCQs	PND: immediate feedback received	PND: only states that teams work through challenging cases with whole class discussion and debate on team choices	PND	PD: individual and team scores incorporated into each student's clerkship grade; no weighting described	NR
Burgess (2012)[10]	PD: teams were allocated by facilitator alphabetically	NR	PD: immediate feedback during learning session but not RA as not conducted	NR: only describes dissection schedule for groups; no description of intra- and intergroup activity	NR	PD: indicates that assessments were formative and summative, but does not detail the grading procedure of the course	NR
Chung (2009)[15]	PD: based on random selection of student number or something similar	PD: describes structure and process (i.e., time allocation, closed book, etc.)	PD: iRAT feedback delayed (graded later); tRAT immediate, with answers revealed simultaneously and whole class discussion	PD: describes sequence of problem solving, time dedicated to each part, and number of questions	PD: groups worked on 2 questions of complex real-world problems, such as medical ethics dilemma; paper provides example of question; multichoice options	PD: grades awarded for iRAT, tRAT, final exam, and application exercise, but does not specify weighting or timing	PD: no peer evaluation applied
Hunt (2003)[19]	PND: reports that teams were formed but does not state what process was used to assign members	PD: describes process, content, and example (e.g., RATs content based on reading material assigned in syllabus for given session); RAT questions generally based on clinical scenarios	PD: OMR scanner with print capability to score and return immediate RAT feedback during session	PD: describes sequence of intra- and intergroup discussions; no time distribution specified or number of problems	PD: based on common clinical situations to increase relevance (e.g., case provided); team answers revealed simultaneously using set of colored cards labeled A–E	PD: grading based on RATs, 2 homework assignments, final exam, and peer assessment of individuals' "helping behaviors"; no grades assigned for application-based activities; weighting not described	PD: on the last day, members scored the degree to which each team member was helpful in terms of learning and understanding course content

(*Appendix continues*)

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(Continued)

First author (year)	Team formation	Readiness assurance	Immediate feedback	Sequencing of in-class problem solving	Four S's	Incentive structure	Peer review
Inuwa (2012)[23]	PD: reports that team members were assigned by random sorting but does not detail sorting method; groups were of same gender because of cultural sensitivities	RND	NR	NR	NR	PD: TBL activity accounted for 20% of overall course grade; distributed as 16%, 3%, and 1% for individual quizzes (iRAT), group quizzes (tRAT), and peer evaluation, respectively	PD: at the end of course, each team assessed one another with respect to teamwork and interpersonal skills
Koles (2005)[16]	PD: random number list of integers 1–83 and assigning the randomized sequence of integers to an alphabetical roster	PD: each team permitted to converse freely while achieving team consensus for tRAT but not allowed to consult across team lines or use reference materials	PD: team answers revealed immediately following tRAT and discrepancies discussed	PD: describes sequence of intra- and intergroup activity, number of application exercises, but not relative time distribution	PD: unfolding clinical case scenarios with MCQs embedded in each case; reference materials could be used to choose single-best-fit answer; answers revealed simultaneously with upraised placard	PD: discrepancy process reported; assessment rating not reported	NR
Levine (2004)[12]	PD: team assignment strove to equalize the amount of expertise in each team	PD: RAT consisted of about 12 MCQs derived from prereadings	PD: MCQ provided instantaneous feedback and teacher facilitated discussion during which teams defended their response	PD: describes sequence of intra- and intergroup activity, but no time distribution specified or number of problems	PD: challenging clinically oriented problems written in MCQ format; teams revealed their response simultaneously by holding up lettered card	PD: RATs and application exercises combined to calculate a composite team learning score	NR
Nieder (2005)[17]	PD: students randomly allocated to teams, with a gender mix present	PD: describes process of iRAT, tRAT, and group application to problem; 10 MCQ closed book test used for the iRAT with 12-minute time limit; answers recorded on computer bubble sheets for later grading; same quiz administered in tRAT, with a 20-minute time limit and 25 minutes allocated for RAT questions discussion	PND	PD: only intragroup activity described, no intergroup discussion; time described; number of problems not specified	PD: teams given same clinical cases related today's topic; teams revealed their responses simultaneously using lettered cards	PD: TBL activities comprised 25% of course grade	PD: at 3 points in course, coinciding with major examinations, students required to fill out peer evaluation forms for their team members; evaluation included score out of 10, a second form requiring students to rate their peers and provide written comments in various aspects of teamwork and communication skills

(*Appendix continues*)

Appendix 2

(Continued)

First author (year)	Team formation	Readiness assurance	Immediate feedback	Sequencing of in-class problem solving	Four S's	Incentive structure	Peer review
Okubo (2012)[5]	PD: groups carried over from previously formed PBL teams to maintain familiarity	PD: response analyzer system used for iRAT/tRAT, managing up to 20 question/answers	PD: immediate response provided via response analyzer system, which displayed results directly on screen for all students	PD: intragroup discussion followed by tRAT, followed by intragroup discussion; relative amount of time not discussed; 2–3 cycles during single session	PD: 2–3 cycles of iRAT, intrateam discussion, tRAT, interteam discussion, feedback, and application	PD: assessment consisting of iRAT, tRAT, and peer evaluation	PD: peer evaluation via the Michaelsen subscribed method
Ravindranath (2010)[7]	PD: but self-selected by students	PND: only described that iRAT, tRAT, and application exercise and simultaneous response existed; no description of number of questions or time allocated	NR	NR: traditional TBL format followed	NR	NR	PD: no peer review, as it would have required a change in already-established grade structures
Shankar (2009)[9]	PND: only states randomly distributed	NR	NR	PD: modified phase; describes intergroup presentations and number of case scenarios, not length of cases	PD: worked on different cases	NR	NR
Tai (2008)[6]	PND: we do not know how groups were formed, other than being preassigned	PD: iRAT in MCQ format used, followed by tRAT, using 13 questions; responses to questions recorded using keypads and Turning Point software	PD: immediate feedback given on both iRAT and tRAT	NR: only phase 2 implemented	NR	NR	NR
Tan (2011)[8]	PND: students randomly assigned to teams	PD: students completed iRAT consisting of 4–5 choices using an electronic audience response system, followed by the same test in tRAT, with 3 minutes allowed for team discussion	PD: immediate feedback provided following tRAT	PD: described sequence of intra- and intergroup discussions; 3 minutes for intragroup discussion; does not specify number of problems	PPD: same clinical scenarios used by each team; answers revealed simultaneously	NR	NR
Thomas (2011)[14]	PD: students assigned alphabetically, then shifting for gender mix and experience	PD: 10-item iRAT, same test as teams	PD: used scratch-off immediate feedback (IF-AT) forms	PD: describes sequence of intra- and intergroup activity; 30 minutes for intragroup activity; does not specify number of problems	PD: application of exercise based on clinical scenarios focusing on diagnostic and therapeutic decision making; team answers (MCQ) revealed simultaneously using a set of colored cards labeled A–E	PD: iRAT, tRAT, and peer review accounted for 25% of clerkship mark	PD: completed online at end of rotation; students rated TBL team members' contribution to discussion; 100 points to team members; as well as narrative

(*Appendix continues*)

Appendix 2
(Continued)

First author (year)	Team formation	Readiness assurance	Immediate feedback	Sequencing of in-class problem solving	Four S's	Incentive structure	Peer review
Vasan (2008)[11]	PD: because of diverse backgrounds within class, course coordinators assigned individuals to small groups to ensure balanced teams	PD: team sessions started with individual ungraded MCQ; group MCQ using same assessment questions administered after 90-minute team learning/discussion session	PD: immediate feedback assessment technique (IF-AT)	NR: only phases 1 and 2 conducted; phase 3 not performed	NR	PD: 55% of grade based on clinical vignette MCQs, of which the NBME final contributed 18%, practical exams 30%, and team unit exam grade 15%	PD: collected for internal use only, allowing targeted counseling of consistently low-grade students
Wiener (2009)[21]	PD: students randomly allocated to teams by facilitator	PD: iRAT with 8 MCQs; tRAT	PD: immediate feedback provided following discussion and decision process	PD: describes sequence of intra- and intergroup discussion; number and length of problems not described	PD: answer signaled by showing alphabetic character; 2 additional, more difficult questions emphasizing core concepts in application focused assignments given	PD: author states Michaelsen's format not followed, as it was not in keeping with educational climate; students given points for attendance and contribution	NR
Willett (2011)[18]	PND: students subdivided into groups	PD: 3 MCQs taken individually then by group immediately following	NR	PD: describes sequence of intra- and intergroup discussion; 3–8 cases; length of problems not described	PD: teams worked through 3–8 cases, which evolved on PowerPoint presentations, interspersed with MCQs, responding simultaneously using color-coded cards; in later sessions, teams used audience response system instead of cards	PD: did not contribute to grades; done to maintain grading parity between TBL and SGL students	PND
Zgheib (2011)[22]	NR	PD: 30 minutes spent on RAT (individual and team)	PND	PD: describes sequence of intra- and intergroup discussion; number and length of problems not described	PD: application of the same cases; team answers revealed simultaneously using cards labeled A–E for MCQ and T/F for true/false	PD: 2% attendance; 4% collection of group homework; 3% individual work MCQ and T/F; 1% small-group work MCQ and T/F; 4% group case discussion; 2% group prescription; 5 sessions × 16% = 80% of mark; exam 10%; peer review 10%	PD: at final session, students required to fill out peer evaluation form (10% of grade)

Abbreviations: PD indicates present and described; PND, present not described; NR, not reported; four S's, significant, same, specific, simultaneous; iRAT, individual readiness assurance test; MCQ, multiple-choice question; tRAT, team readiness assurance test; OMR, optical marker reader; SAQ, short-answer question; NBME, National Board of Medical Examiners; SGL, small-group learning.