Active learning in a Year 2 pathology curriculum

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PURPOSE Team-based learning (TBL) has been successfully used in non-medical curricula, but its effectiveness in medical education has not been studied extensively. We evaluated the impact of TBL on the academic performance of Year 2 medical students at Wright State University by comparing this active learning strategy against a traditional method of case-based group discussion (CBGD).

METHODS A prospective crossover design assigned 83 Year 2 medical students to either CBGD or TBL for 8 pathology modules in the systems-based curriculum. The effectiveness of both learning methods was assessed by performance on pathology-based examination questions contained in end-of-course examinations. The highest and lowest academic quartiles of students were evaluated separately. Students' opinions of both methods were surveyed.

RESULTS No significant differences in whole group performance on pathology-based examination questions were observed as a consequence of experiencing TBL versus CBGD. However, students in the lowest academic quartile showed better examination performance after experiencing TBL than CBGD in 4 of 8 modules ($P = 0.035$). Students perceived that the contributions of peers to learning were more helpful during TBL than CBGD ($P = 0.003$).

CONCLUSION This study demonstrates that TBL and CBGD are equally effective active learning strategies when employed in a systems-based preclinical pathology curriculum, but students with lower academic performance may benefit more from TBL than CBGD.

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INTRODUCTION

Undergraduate medical education in the pre-clinical sciences remains challenged to find teaching strategies that actively engage students in the learning process. Large classes, compromised faculty time for teaching and an ever-expanding knowledge base have influenced many educators to favour the lecture as the standard teaching format. Medical students often prefer lectures because finely honed lectures seem to simplify complex topics, providing a sense of security that the lecture has provided 'just what I need to know' for passing examinations. Students adept at memorising faculty-prescribed lecture content may not feel as comfortable with active learning activities that require reasoning and the application of knowledge to solve problems. Moreover, some faculty believe that essential clinical reasoning skills are mainly learned by observing experienced doctors in the wards and clinics, rather than by being taught during classroom activities. Pre-clinical students often feel overwhelmed or burned out by the amount of information they must acquire through individual study,[1] sometimes resulting in sceptical or prejudicial attitudes toward active learning exercises that require large investments of time in exchange for questionable gains in factual knowledge.

Multiple methods purport to increase students' engagement in the learning process. Laboratory exercises, which require students to generate, organise and interpret data while formulating conclusions, have been part of many curricula.[2,3]

Overview

What is already known on this subject

Team-based learning (TBL) has been used extensively in higher education in the USA since the 1980s. The application of TBL in medical education has been explored since 2000 in multiple US medical schools.

What this study adds

This study demonstrates equivalent academic performance among medical students experiencing TBL versus case-based group discussion (CBGD) in a Year 2 pathology curriculum, and suggests that students with lower academic performance may benefit more from TBL than from CBGD.

Suggestions for further research

Further investigation is needed regarding the impact of TBL on academic performance, the potential benefits of TBL for students with below average academic performance, and the influence of TBL on professional development.

Problem-based learning (PBL) requires students to independently investigate multiple sources of information in preparation for group problem-solving discussions.[4,5] Working within small groups and personal feedback from faculty tutors are documented benefits of PBL.[6] Computer-based, self-instructional activities certainly have great potential for engaging students in active learning exercises.[7–9] Team-based learning (TBL) has been used successfully in non-medical curricula for over 20 years, and resembles PBL by providing small group experience with faculty guidance.[10–12] However, TBL has only recently been proposed as an instructional strategy in medical education.[13–15]

As part of an ongoing plan to integrate more active learning strategies into the pre-clinical curriculum, Wright State University School of Medicine (WSUSOM) has introduced TBL into the Year 1 anatomy course[16] and throughout the pathology component of the Year 2 systems-based curriculum.

Prior to this prospective study, pathology instruction in Year 2 consisted of 81 hours of lecture time and 19 hours of case-based group discussion (CBGD), distributed across all courses. Case-based group discussion exercises, as implemented in our curriculum, consisted of a pathologist and 15–20 students discussing a clinical case that included history and physical examination, imaging studies, laboratory test data, gross and microscopic morphology of disease, and a brief summary of hospital courses, with open-ended questions embedded throughout the exercise. Team-based learning exercises consisted of similar clinical case content and morphology of pathologic processes, but were organised around several multiple-choice questions (MCQs), inserted at critical points in the development of the case, requiring groups of 5–6 students to make consensus judgements about the interpretation of data, with a single pathologist facilitating discussion among 8 teams of students. A primary goal of this study was to compare the effectiveness of TBL with CBGD as an active learning strategy. Our outcome measure for effectiveness was the comparison of how students assigned to either strategy performed on pathology questions administered in end-of-course examinations. A related outcome measurement was to determine if TBL or CBGD improved learning for any subgroups of students. A secondary goal was to assess the subjective experiences of students participating in both learning strategies. Our objective was to determine whether significant differences in end-of-course examination performance would be observed as a consequence of the active learning strategy experienced.

METHOD

A prospective crossover design compared the effectiveness of the 2 methods, both of which potentially enhance active student participation in the learning process: case-based group discussion and team-based learning. The salient features of these 2 methods are compared in Table 1. After approval of the research protocol by the university's institutional review board and informed consent from students had been gained, the study was accomplished during academic year 2002–03 at WSUSOM. An overview of the study protocol is illustrated in Fig. 1. Sixteen teams were generated by using a random number list of integers 1–83 and assigning the randomised sequence of integers to an alphabetical roster of Year 2 medical students. Students matched with numbers 1–5 formed team 1, numbers 6–10 formed team 2, etc. Teams 1–8 were designated 'green'; teams 9–16 were

Table 1 Comparison of case-based group discussion versus team-based learning

Feature	Case-based group discussion	Team-based learning
Sources of teaching during the live learning event	Faculty primary; students secondary	Students primary; faculty secondary
Question format within exercises	Open-ended or fill-in-the-blank	Multiple-choice
Nature of primary social interaction	Teacher-centred	Peer-centred
Faculty understanding of students' knowledge and problem-solving skills	Acquired if and when students volunteer personal opinions	Acquired inevitably as students are required to reveal answers and explain supporting rationales for their answers
Opportunity for students to 'loaf' or disengage from learning	Easily done, with no penalty for 'loafing'	Difficult, because peers usually notice and disapprove
Opportunity for faculty to identify misunderstandings and resolve misunderstandings	Unpredictable; depends on the willingness of students to verbalise their understanding	Predictable; students' misunderstandings are revealed by public answers, with opportunity for on-the-spot resolution

designated 'gold'. Initially, 13 teams had 5 members and 3 teams had 6 members each. Team membership was not altered during the period of study (August 2002 through May 2003). Differences between the green and gold teams for gender and mean age were assessed with a chi-square test and 2-sample *t*-test, respectively.

Two full-time pathology faculty (authors SN and PK), each with over 20 years of experience in medical education, delivered 8 pathology lectures and created the corresponding CBGD and TBL exercises that reinforced the learning objectives of the lectures. Lectures on genetic, immune, muscle and parathyroid diseases were delivered by SN; lectures on neoplasia, vascular, breast and liver diseases were taught by PK. Green teams were assigned to CBGD and gold teams to TBL for immune, neoplastic, cardiovascular and parathyroid (INCP) disease modules. All teams were assigned to the opposite active learning method for genetic, muscle, breast and liver (GMBL) disease modules. This crossover design insured that all 16 teams experienced 4 modules of each active learning method. All CBGD exercises were designed and prepared by SN, while PK created all TBL exercises. Individual readiness assessment tests (IRATs) were standardised to contain 10 MCQs. The IRAT questions were written by the non-lecturing author to minimise lecturer bias in teaching toward the test. For example, the IRAT on genetic diseases was written by PK, while SN delivered that lecture.

The CBGD exercises contained numerous open-ended questions embedded within each presentation to stimulate interactive discussion. Faculty leaders were asked to encourage student responses to each question before explaining the preferred answer(s). Each case was taught by only 1 faculty member, maximising consistency of content and emphasis. Because each CBGD module consisted of 2 or 3 separate cases, SN was joined by 1 or 2 additional pathology faculty in each of the 8 CBGD modules.

Team-based learning application exercises consisted of unfolding clinical case scenarios with MCQs embedded within each case. Upon completion of the IRAT by all students, only those 8 teams assigned to TBL completed the group readiness assessment test (GRAT). The GRAT consisted of the same 10 questions used in the IRAT. Each team was permitted to freely converse while achieving team consensus for all 10 questions, but teams were not allowed to consult across team lines or use reference materials. After completion of the GRAT by all teams, the answer key was revealed and students verbalised any questions or objections. If any student argued persuasively against the designated answer, the faculty leader invited that student to submit a formal written challenge supported by references from textbooks or current literature. After review of any challenges, the answer key was adjusted as necessary.

The brief discussion of GRAT answers was followed by 2 consecutive TBL application exercises, during which teams worked independently to achieve consensus answers. Application exercise questions were designed to be more challenging than the IRAT questions, requiring problem-solving skills beyond the simple recall of relevant information. Accordingly, all teams were permitted to use reference materials while achieving consensus. Each team was required to choose a single best answer for each question. All teams simultaneously revealed their

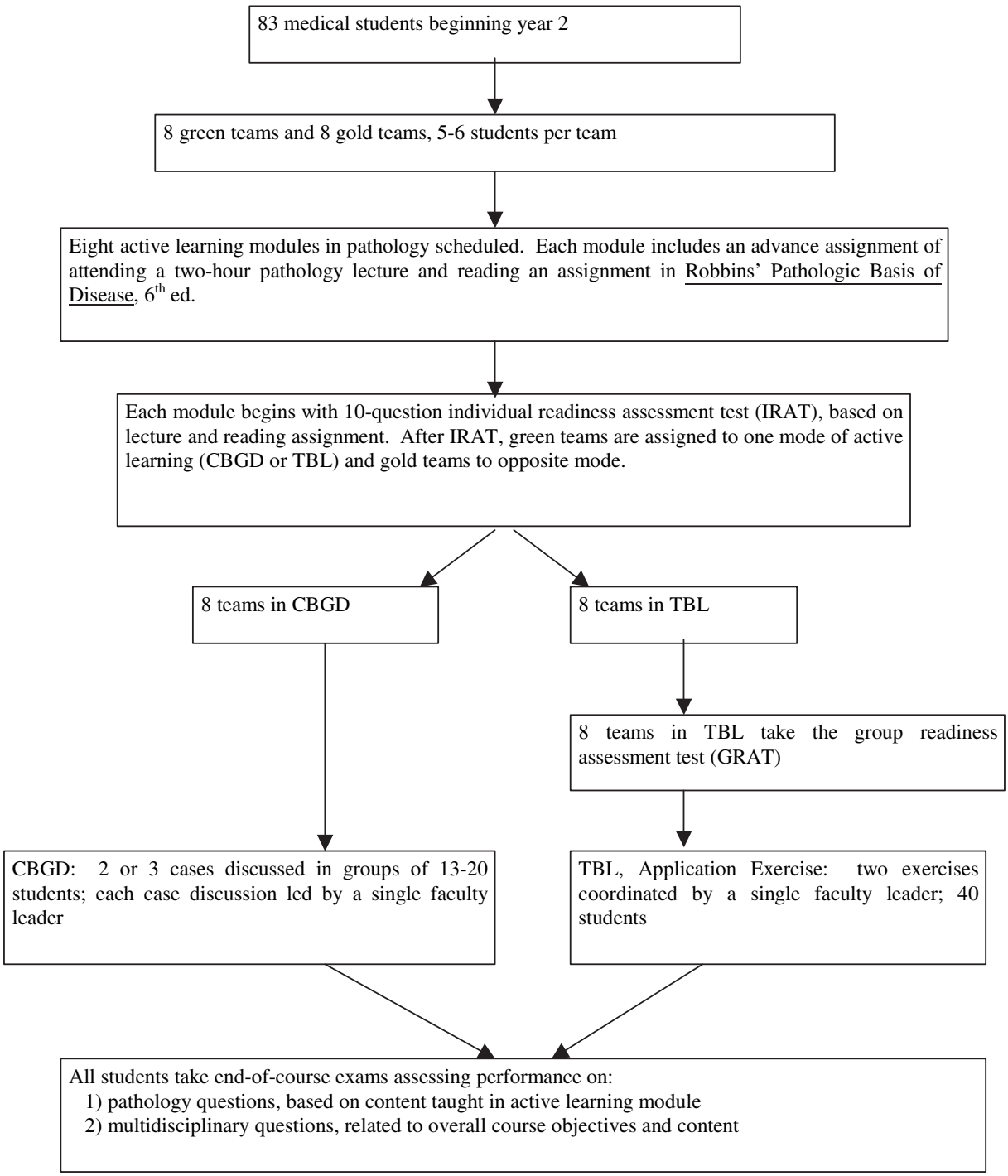

Figure 1 Study protocol.

answers with an upraised placard upon signal from the faculty leader. If all 8 teams indicated the same correct answer, the exercise progressed toward the next question with minimal discussion. If answers lacked unanimity, students were asked to explain their answers to the entire group. Faculty-coordinated discussion ensued until resolution of important educational issues was achieved.

SN and PK consulted while designing each module, making reasonable attempts to insure that CBGD and TBL exercises covered similar factual content. Many images, charts, tables and texts were duplicated within both presentations. Noteworthy differences between the learning methods, as configured for this study, include question format (open-ended in CBGD versus multiple-choice in TBL) and group

dynamics (individual students volunteering their answers in CBGD versus teams arriving at consensus answers in TBL).

All end-of-course examination questions were retrospectively analysed by 1 of us (PK) and assigned into 1 of 2 categories:

1 directly related to content taught within a specific pathology lecture-CBGD–TBL module, or
2 essentially unrelated to a specific pathology lecture-CBGD–TBL module.

End-of-course examinations consisted entirely of objective MCQs and occurred within 1–3 weeks after the active learning events. Each student's performance (number of correct answers/number of questions) was determined for:

1 all examination questions;
2 pathology examination questions related to content taught in INCP modules;
3 pathology examination questions related to content taught in GMBL modules;
4 IRATs in all 8 modules;
5 IRATs in INCP modules, and
6 IRATs in GMBL modules.

Scores for each outcome were compared between green and gold teams with 2-sample *t*-tests.

Performance on the entire spectrum of end-of-course examination questions was then used to stratify the class into 4 quartiles of academic achievement; further analyses were conducted on the differences between IRAT and end-of-course examination scores for students in the lowest and highest quartiles. For both the lowest and highest quartile students, 2-way analysis of variance (ANOVA) with repeated measures on the 'treatment' factor was performed separately on grouped modules of INCP pathology versus grouped modules of GMBL pathology. For each analysis of INCP modules, the group effect (green teams experiencing CBGD versus gold teams experiencing TBL), treatment effect (IRAT scores versus end-of-course examination scores), and the interaction between the group and treatment effect were assessed. The same analyses were conducted on GMBL modules, where the group effect was green (TBL) versus gold (CBGD) teams. As the outcome of interest was the interaction between group and treatment effects, only the interaction *P*-values are presented in the results. For all analyses, *P*-values < 0.05 were considered statistically significant.

Student opinions in response to 7 survey statements were obtained after 5 active learning sessions in January 2003, and after completion of all 8 sessions in May 2003 (see Appendix). Fifty-nine of 80 students completed the survey in both January and May; survey data from these 59 students only were analysed. Informed consent included permission to publish aggregate survey data, but not individual responses. Each survey statement was rated by students on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) for both the CBGD and TBL methods. Differences in students' responses were assessed with paired *t*-tests.

RESULTS

Of the 83 Year 2 medical students who began the study in August 2003, 80 students completed all 8 learning modules. Three could not participate in all events due to health or academic issues and were eliminated from the database. Demographic features are summarised in Table 2. Gender distribution and mean ages were similar among both green and gold teams.

The academic performances of students in green and gold teams were similar, as reflected by mean scores on end-of-course examinations encompassing physiology, pathology, pharmacology and clinical applications. Analysis of the subset of end-of-course examination questions based on pathology content in the 8 active learning modules also revealed no differences between the green and gold teams (Table 2).

Individual readiness assessment test (IRAT) scores reflected students' comprehension of pathology content within the assigned reading and lectures immediately before participating in an active learning event. Table 2 shows similar mean IRAT scores for students in green and gold teams during all 8 learning modules, for the 4 IRATs assessing knowledge in INCP diseases and for the 4 IRATs covering GMBL diseases.

Differences in academic performance emerged when analysing only lowest quartile students who experienced the CBGD method versus the TBL method during INCP active learning modules. If one considers the IRAT score as a measure of short-term knowledge, then scores on end-of-course pathology-related examination questions reflect longer retention of that knowledge.

Table 2 Performance of study population on examination questions

Item	All ($n = 80$)	Green teams ($n = 39$)	Gold teams ($n = 41$)	*P*-value
Demographics				
Mean age (SD)	27 (4)	27 (4)	27 (3)	0.97*
Range	23–43	23–43	24–35	
Female (%)	49 (61.2)	23 (59.0)	26 (63.4)	0.68†
Male (%)	31 (38.8)	16 (41.0)	15 (36.6)	
End-of-course exam scores (6 exams)				
Mean, all exam questions (SD)	80.3% (5.6)	79.9% (5.4)	80.6% (5.8)	0.60*
Range	66.1–92.3%	66.1–88.4%	68.2–92.3%	
Mean, pathology questions, INCP (SD)	80.9% (8.1)	81.2% (8.4)	80.7% (7.9)	0.79*
Range	64.7–95.1%	67.1–94.4%	64.7–95.1%	
Mean, pathology questions, GMBL (SD)	86.8% (8.3)	85.9% (8.7)	87.6% (7.9)	0.36*
Range	59.4–100.0%	59.4–100.0%	72.6–100.0%	
IRAT scores				
Mean, all 8 modules (SD)	86.4% (5.3)	86.4% (4.9)	86.4% (5.7)	0.99*
Range	75.0–97.5%	78.8–96.3%	75.0–97.5%	
Mean, INCP (SD)	82.3% (7.3)	82.7% (6.8)	81.9% (7.8)	0.63*
Range	65.0–97.5%	67.5–97.5%	65.0–97.5%	
Mean, GMBL (SD)	90.5% (6.1)	90.1% (6.0)	90.9% (6.2)	0.56*
Range	75.0–100.0%	75.0–100.0%	77.5–100.0%	

INCP = immune, neoplastic, cardiovascular, parathyroid disease modules.
GMBL = genetic, muscle, breast, liver disease modules.
* 2-sample *t*-test.
† Chi-square test.

Table 3 compares the change in scores between IRATs and end-of-course examinations during INCP modules. Lowest quartile students demonstrated less deterioration of scores between these 2 assessments after experiencing a TBL session than after a CBGD session ($P = 0.035$). However, the method of active learning did not significantly affect the change in scores from IRAT to end-of-course examinations among highest quartile students ($P = 0.067$). During GMBL active learning modules, differences between IRAT scores and end-of-course examination scores were not associated with the mode of active learning. This lack of association prevailed among both lowest and highest quartiles of students (Table 4).

Students' subjective impressions of both learning strategies were obtained after 5 modules (January 2003) and upon completion of all 8 modules (May

Table 3 Performance of lowest and highest academic quartile students in INCP modules, IRAT versus end-of-course examination questions in pathology

Group	*n*	Mean IRAT score (SD)	Mean score pathology exam questions (SD)	*P*-value
Lowest quartile, green teams experiencing CBGD	9	81.9% (6.0)	72.6% (4.2)	
Lowest quartile, gold teams experiencing TBL	12	76.8% (7.6)	75.3% (6.9)	0.035*
Highest quartile, green teams experiencing CBGD	8	86.2% (6.4)	91.1% (3.0)	
Highest quartile, gold teams experiencing TBL	12	88.5% (5.3)	87.0% (6.8)	0.067*

INCP = immune, neoplastic, cardiovascular, parathyroid disease modules.
* Interaction, 2-way ANOVA.

Table 4 Performance of lowest and highest academic quartile students in GMBL modules, IRAT versus end-of-course examination questions in pathology

Group	*n*	Mean IRAT score (SD)	Mean score pathology exam questions (SD)	*P*-value
Lowest quartile, green teams experiencing TBL	9	87.2% (6.8)	74.7% (7.5)	
Lowest quartile, gold teams experiencing CBGD	12	87.9% (6.5)	80.4% (5.0)	0.058*
Highest quartile, green teams experiencing TBL	8	95.3% (3.1)	93.7% (3.5)	
Highest quartile, gold teams experiencing CBGD	12	93.5% (6.3)	94.2% (5.3)	0.462*

GMBL = genetic, muscle, breast, liver disease modules.
* Interaction, 2-way ANOVA.

2003). The same survey instrument was used at both times (Appendix).

At the end of the study in May 2003, the overall level of satisfaction with TBL was not significantly different from that with CBGD, based on responses to all 7 survey questions (Table 5). However, analysis of survey statement 4 revealed that students perceived the contributions of peers to be more helpful for learning during TBL events than during CBGD sessions ($P = 0.003$).

DISCUSSION AND CONCLUSIONS

This prospective comparison of 2 educational strategies measures an objective outcome: students' performance on examination questions. Performance on MCQs was impacted by numerous faculty-related variables, including bias in question content, question format, language style and timing of the examination in relation to course schedule. Student-related variables were also legion: amount of sleep; concurrent emotional or physical stressors; examination room configuration and temperature; and time of day, to name only a few. Given these admitted shortcomings, performance on MCQs remains a flawed but acceptable method of assessing learning outcomes in both individuals and groups.

The 80 students completing this study experienced 8 contact hours of each active learning method, distributed across 4 separate learning modules. Because individual readiness assessment test (IRAT) scores comprised 5–15% of the final grade in courses which contained active learning events, students were externally motivated to prepare for each module. Results demonstrate no significant differences between green and gold teams in terms of gender, age, quality of preparation as reflected by IRAT

Table 5 Student opinions (n = 59) after all 8 active learning modules; May 2003

Survey question	Case-based group discussion mean (SD)	Team-based learning mean (SD)	Team-based learning–case discussion mean difference (SD)	*P*-value*
1	5.80 (1.23)	5.81 (1.28)	0.02 (0.86)	0.880
2	5.64 (1.45)	5.85 (1.42)	0.20 (1.08)	0.153
3	5.44 (1.41)	5.71 (1.43)	0.27 (1.14)	0.073
4	5.02 (1.53)	5.61 (1.51)	0.59 (1.45)	0.003
5	6.08 (1.29)	5.98 (1.31)	− 0.10 (0.92)	0.401
6	5.25 (1.45)	5.34 (1.54)	0.08 (1.04)	0.533
7	5.20 (1.45)	5.34 (1.54)	0.14 (1.07)	0.336
Mean, all 7 questions	5.49 (1.22)	5.66 (1.31)	0.17 (0.89)	0.143

* Paired *t*-test.

scores, or overall academic performance on end-of-course examinations (Table 2). While it is impossible to insure equivalent faculty performance within both strategies of active learning, the 2 authors of all learning exercises resembled each other in terms of gender (male), age (50 and 52 years), teaching experience (20–25 years), and reputation as effective teachers.

Notwithstanding our deliberate attempts to create equivalent content in all active learning exercises, CBGD and TBL are fundamentally different strategies, as illustrated in Table 1. Students participating in CBGD exercises realise the quality of such exercises depends not only on case content, but quite substantially on the skills of the faculty discussion leader. Learners often attempt to choose favourite teachers during sessions staffed by several faculty, even when they have been assigned to a particular person.[17] This popularity factor was eliminated from our study because each faculty was assigned to discuss only 1 case for all students assigned to CBGD. As case discussion exercises were written by only 1 author (SN) in a visually attractive format, the skills of each faculty leader became an important variable affecting the learning atmosphere. Free text comments on student surveys showed that students attributed the variable quality of CBGD exercises to perceived differences in faculty leaders' skills and enthusiasm, rather than to differences in the conceptual content of exercises. Their perception underscores a common problem for educators using group discussion exercises, namely, the difficulty of standardising faculty effectiveness for all groups of students.

In comparison, the quality of a TBL exercise depends more heavily on the design and content of the exercise itself than on the charisma of the faculty leader. For example, if most questions in a TBL application exercise are easily answered by student teams, with unanimous agreement among teams, it will be difficult for even a skilled faculty leader to generate spirited discussion. On the other hand, an application exercise with challenging content and difficult questions will probably generate vigorous debate within student teams and produce non-unanimous opinions as to correct answers. Such well designed application exercises require students to compare variations in understanding among peers, identify personal and team deficits in knowledge, practise reasoning skills, and develop confidence in defending their team's opinion before the scrutiny of peers and faculty. Authors of excellent application exercises create questions which extend students' knowledge into zones of judgement, reason and discrimination among viable options.[18] As a well designed application exercise unfolds, the faculty leader's role is more like that of a referee between teams than that of a quarterback leading the team. Energy is generated primarily through peer interactions instead of by faculty prodding.

End-of-course examination questions related to pathology were either written or edited by the same 2 authors who wrote the IRAT questions; all examination questions were in multiple-choice format. Performance on pathology-related examination questions by green team students after experiencing case-based group discussions was not significantly different from that of gold team students after experiencing team-based learning (INCP modules, Table 2). Similarly, there were no significant differences between green and gold team students' examination performance when the learning methods were reversed (GMBL modules, Table 2). Thus, when learning was measured by performance on end-of-course examination questions directly related to content in pathology modules, the method of active learning (CBGD versus TBL) did not affect the academic performance of the class as a whole. Because TBL has an inherent potential for student-to-student mentoring, we were interested in knowing whether the academic performance of lowest quartile students was affected by these 2 learning methods. Analysing the examination performance of students in the lowest and highest academic quartiles disclosed an important finding. Among students in the lowest academic quartile, our data demonstrated less deterioration of knowledge after active learning with TBL than with CBGD. This finding is evidenced by the change in the mean scores of lowest quartile students between IRAT (first measurement of knowledge) and end-of-course examination questions related to pathology (second measurement of knowledge). These differences in retention of knowledge were statistically significant for lowest quartile students while they learned pathology-based content in immune, neoplastic, cardiovascular and parathyroid diseases (Table 3). However, similar significant differences in knowledge retention were not demonstrated for lowest quartile students learning about genetic, muscle, breast and liver diseases (Table 4). Possible explanations for these asymmetric results among lowest quartile students include differences between learning modules regarding the difficulty of IRAT questions, difficulty of end-of-course examination questions related to pathology, or course content itself. It is not surprising that students in the highest academic quartile showed no

differences in knowledge retention related to method of learning (Tables 3 and 4).

Acquaintance with theoretical and practical benefits of TBL permits a rational interpretation of these findings. When a large group of students prepares for a learning event, there is inevitably a wide range of preparation intensity, as reflected in our study by mean IRAT scores ranging from 75% to 97.5% (Table 2). When gathered into learning teams during a TBL session, poorly prepared students benefit first from the stronger preparation of their peers while taking the GRAT, during which individual knowledge is freely exchanged within teams. As team discussions during the application exercise lead to consensus choices on MCQs, better students continue to inform and enhance the understanding of poorer students. It is likely that below-average students experience more change in their fund of knowledge during the TBL session than academically superior students. These interpretations of the learning process in TBL are not directly applicable to students experiencing CBGD, because in the CBGD method, a much greater portion of content clarification and reinforcement derives from the faculty leader's skills, rather than from peer influences. One might postulate that the vigorous give-and-take among students during TBL, as they clarify and adjust their individual knowledge base through team discussions, results in better retention of that knowledge, particularly for students whose academic performance is below average. In comparison to some other methods of active learning, TBL requires productive peer interaction to achieve correct answers on GRAT and application exercise questions. Learning how to work constructively with peers during the pre-clinical curriculum may aid in developing teamwork skills which enhance student ability to participate effectively within patient care teams during the clinical years. The improvement of such teamwork skills is a vital part of every doctor's professional growth.

This 10-month study allowed for longitudinal observation of student attitudes and behaviour. In CBGD exercises, attendance was high (usually over 90%) and students enjoyed the relaxed atmosphere. Aggressive learners tended to participate by answering questions, while timid or self-conscious students were more reticent to answer and ask questions. Small groups of students, typically high academic achievers, often stayed after the CBGD sessions were completed to continue learning with faculty. Regarding TBL, the first sessions in August met with some scepticism and even boycotting of the application exercises after the graded portion of the event had been completed. Some teams did not work up to their potential on TBL application exercise questions, perhaps because our study design mandated that application exercises should not be graded, as students experiencing CBGD had no corresponding exercise which could be graded. (All students are now being graded on their team's performance during TBL application exercises at WSUSOM. Predictably, students approach application exercises much more seriously.) As the year progressed, a more appreciative attitude developed toward TBL sessions, with greater than 90% attendance at the ungraded application exercises during the last 5 months of the study. Students began to enjoy the challenge of interpreting morphologic, clinical and diagnostic test data to arrive at a diagnosis. The incorporation of data from current literature into TBL exercises allowed students to improve their observational and interpretive skills. Importantly, team representatives often defended their consensus opinion persuasively to the other teams during open discussions, resulting in effective peer-to-peer teaching without correctional intervention by faculty.[19]

The secondary goal of this investigation was to document student opinions of the experience. These data are somewhat compromised in that only 59 of 80 potential participants completed both opinion surveys (January and May). While 3 of the 7 survey items generated significant differences between CBGD and TBL after 5 learning events in January, only statement 4 showed a persistent capacity to discriminate between the 2 methods after all 8 learning events had been completed (Table 5). Not surprisingly, students rated TBL higher than CBGD when evaluating the statement 'the contributions of my peers have helped me learn during these activities'. After only 4 2-hour experiences with TBL during an entire academic year, students recognised that the combined brainpower of peers is a useful educational resource.

Based on this investigation, we offer several conclusions and recommendations.

1 Both CBGD and TBL are equally effective active learning methods, which, when implemented by skilled faculty in a pre-clinical medical curriculum, result in no significant differences in overall student performance on examination questions based on learning modules in which these methods are used. While our study focused on pathology-related content, it may be reasonable to

assume this observation extends to other medical science disciplines. As this study did not include a control group that experienced neither CBGD nor TBL, we cannot comment on whether these 2 learning methods actually improve academic performance.

2 Case-based group discussion exercises were conducted with no more than 20 students per faculty leader, while TBL exercises were attended by 40 students (8 teams of 5) with 1 faculty leader. While this study does not address ideal student : faculty ratios for these learning methods, the ratios used in our study resulted in adequate learning. With increasing budget constraints and strained faculty resources in medical schools, the option of TBL, with its relatively high student : faculty ratio, may be attractive.[20]

3 The TBL method may selectively benefit students with lower academic achievement more than higher achievers, evidenced in this study by better retention of knowledge among lowest quartile students between an active learning event and the end-of-course examination. Additional studies, utilising larger amounts of data, are needed to confirm this observation.

4 Students recognise the valuable contribution of their peers during TBL events. We observe that harnessing the resources of well prepared students to benefit their peers is among the most attractive features of TBL. Of course, a well designed and executed learning module, comprised of an advance assignment, readiness assessment test and challenging application exercise, remains the responsibility of faculty alone. When skilled teachers and well prepared students meet within a TBL exercise, effective and enjoyable learning is almost inevitable.

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APPENDIX

Student opinion survey after 8 active learning sessions in pathology, Class of 2005, Green Teams

Name _____

	Case discussions							**Team learning**						
	Immunology (Nelson, Gibbs, Kramer) Neoplasia (Nelson, Mirkin, Parmelee) Cardiovascular (Nelson, Bacheller, Powell) Parathyroid, Thyroid (Nelson, Misick)							**Genetics (Koles) Muscle (Koles) Breast (Koles) Liver (Koles)**						
	Strongly disagree						**Strongly agree**	**Strongly disagree**						**Strongly agree**
1 These activities have improved my understanding of pathology	1	2	3	4	5	6	7	1	2	3	4	5	6	7
2 I have been challenged to apply factual knowledge in solving clinical problems during these activities	1	2	3	4	5	6	7	1	2	3	4	5	6	7
3 I have been actively engaged in critical thinking during these activities	1	2	3	4	5	6	7	1	2	3	4	5	6	7
4 The contributions of my peers (other students in my group) have helped me learn during these activities	1	2	3	4	5	6	7	1	2	3	4	5	6	7
5 The contributions of faculty have helped me learn during these activities	1	2	3	4	5	6	7	1	2	3	4	5	6	7
6 These activities have been a productive use of my time	1	2	3	4	5	6	7	1	2	3	4	5	6	7
7 I feel these activities are enjoyable	1	2	3	4	5	6	7	1	2	3	4	5	6	7