DESCRIPTIVE ARTICLE

ASE

Modified Use of Team-Based Learning for Effective Delivery of Medical Gross Anatomy and Embryology

Nagaswami S. Vasan,[1]* David O. DeFouw,[1] Bart K. Holland[2]

[1]*Department of Cell Biology and Molecular Medicine, New Jersey Medical School, Newark, New Jersey*

[2]*Department of Preventive Medicine and Community Health, New Jersey Medical School, Newark, New Jersey*

Team-based learning (TBL) is an instructional strategy that combines independent out-of-class preparation for in-class discussion in small groups. This approach has been successfully adopted by a number of medical educators. This strategy allowed us to eliminate anatomy lectures and incorporate small-group active learning. Although our strategy is a modified use of classical TBL, in the text, we use the standard terminology of TBL for simplicity. We have modified classical TBL to fit our curricular needs and approach. Anatomy lectures were replaced with TBL activities that required pre-class reading of assigned materials, an individual self-assessment quiz, discussion of learning issues derived from the reading assignments, and then the group retaking the same quiz for discussion and deeper learning. Students' performances and their educational experiences in the TBL format were compared with the traditional lecture approach. We offer several in-house unit exams and a final comprehensive subject exam provided by the National Board of Medical Examiners. The students performed better in all exams following the TBL approach compared to traditional lecture-based teaching. Students acknowledged that TBL encouraged them to study regularly, allowed them to actively teach and learn from peers, and this served to improve their own exam performances. We found that a TBL approach in teaching anatomy allowed us to create an active learning environment that helped to improve students' performances. Based on our experience, other preclinical courses are now piloting TBL. Anat Sci Ed 1:3–9, 2008. © 2007 American Association of Anatomists.

Key words: anatomical sciences/medical education; anatomy education; anatomy teaching; team-based learning

In 1984, the Association of American Medical Colleges (AAMC) General Physicians Professional Education (GPEP) Report recommended curriculum change at all traditional medical schools toward problem-based, student-centered learning with an emphasis on integration of basic and clinical sciences (Muller, 1984). Subsequently, the Assessing Change in Medical Education—The Road to Implementation (ACME-TRI) Report (AAMC Report) further defined the need for a system of medical education that fostered students' skills and attitudes that would help them to become lifelong learners. Curricula, especially in the preclinical disciplines, are evolving as a result of this groundwork, and innovative approaches have emerged across the country. Preclinical curricula in medical schools have continued to move away from the teacher-centered and discipline-based curriculum to an integrated clinical application model. The changes involved reduction in lecture hours (learning discrete facts) with more emphasis on teaching concepts and principles.

Team-based learning (TBL) is an instructional strategy originally developed by Dr. Larry Michaelsen, for business courses (Michaelsen et al., 1997), and recently, medical schools have been adopting this strategy (Searle et al., 2003). In the last few years, numerous medical schools adopted TBL in the delivery of basic sciences (Siedel and Richards, 2001; Nieder et al., 2005), clerkships (Hunt et al., 2003; Levine

Parts of this study were presented as poster at the RIME session during the Annual Meeting of AAMC (November 2006) and orally at the Annual Meeting of the American Association of Anatomists (April 2007).

Authors are members of the UMDNJ-Master Educators' Guild.

*Correspondence to: N.S. Vasan, Department of Cell Biology and Molecular Medicine, New Jersey Medical School, Room MSB G-671, 185 South Orange Ave., Newark, NJ 07103.
E-mail: vasanns@umdnj.edu

Received 27 July 2007; Revised 25 September 2007; Accepted 26 September 2007.

Published online 4 December 2007 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/ase.5

et al., 2004), and the residency programs (Haidet et al., 2002, 2004). Since many medical schools are creating integrated and interdisciplinary courses in the preclinical years, TBL is particularly useful because of its emphasis on teamwork, mastery of content, and problem solving skills for clinical application. TBL is an attractive strategy to adopt for medical gross anatomy, because it requires students to learn anatomical facts, from which they develop anatomical concepts for clinical problem solving (Nieder et al., 2005). It also requires consistent preparation and attendance. Compared to passive learning associated with traditional lectures, TBL allows more active student learning (Nieder et al., 2005).

In August 2004, the New Jersey Medical School introduced a comprehensive new 4-year curriculum entitled "The Jubilee Curriculum" in celebration of our 50th anniversary. The concept of the Jubilee Curriculum included an increase in active learning modalities with a concomitant decrease in lecture time. Except the anatomy course, the remaining first-year courses retained much of the pedagogical approach associated with passive, lecture-based learning. In anatomy, laboratory dissection time was minimally reduced, basic anatomy lectures were eliminated, and modified TBL was introduced. TBL enabled the two course coordinators (authors) to set learning objectives, select content and resources, and prepare quizzes and tests. In addition, the course coordinators addressed learners' misconceptions and knowledge deficits during TBL sessions. Hence, a series of organized learning activities were provided to help students build baseline facts into a framework of conceptual interpretation and understanding (Vasan and DeFouw, 2005). This contrasts from Problem-Based Learning (PBL), which is centered on faculty-prepared case studies from which students identify learning issues during small group discussions led by multiple facilitators, who often are not content experts (Vasan and DeFouw, 2007). Moreover with PBL, students individually address knowledge deficits in between the discussion sessions (Vasan and DeFouw, 2007).

This study served to investigate whether the TBL concept could be modified and adopted to the first-year anatomy course during advent of the new 4-year curriculum. We also wanted to understand how "learning issues" as a substitute for lectures would influence learning. We believe that our results have added new dimensions to the existing literature on TBL in that TBL can be modified to fit new curricular needs of a content-rich course and simultaneously improve student performances.

METHODS

For the benefit of the readers, we have summarized the salient features of classical TBL and our modified TBL.

Classic TBL

Members of each team are randomly selected. Course structure involves didactic lectures in a large group format. It has three phases, where Phase 1 involves out-of-class preparation, Phase 2 involves in-class Individual Readiness Assurance Tests (IRAT) and Group Readiness Assurance Tests (GRAT), and Phase 3 involves application exercises that consist of cases in the form of vignettes with a subset of questions related to the case. In Phase 3, all the teams answer each question simultaneously to facilitate interteam discussion.

Modified TBL

Our entering class size of 169–178 includes students in the 7-year BA-MD program (10%), students in MD-MPH program (5–10%), students with postbaccalaureate educations (25–30%), and students with recent 4-year undergraduate degrees (50%). Based upon the diverse backgrounds of the class, the course coordinators assigned individuals to small groups to ensure well-balanced teams. The course structure involves no anatomy lectures, but embryology, and 4–5 clinical correlations are presented through didactic lectures. In Phase 1, we assigned readings from required texts and created "learning issues" based on the readings and cadaver dissections.

In Phase 2, all team encounters started with an *ungraded* MCQ quiz (10 min) that was first taken individually (the quizzes were immediately scored by the staff and the results made available only to the course coordinators). Immediate assessment of quiz performance by individual students allowed us to monitor each student's level of preparation and provide necessary feedback when warranted. The MCQs are in the form of clinical vignettes. Some of these clinical cases will also have 2–3 subsets of questions related to the case. Following the individual quiz, teams discussed the assigned "learning issues" (90 min) that solidified various course concepts for deeper understanding. The course coordinators monitored all the team discussions, provided clarification on issues where students had difficulties, and asked probing questions to expand their thinking and provide feedback when necessary following the discussions. The team as a group retook the same quiz (20 min) and selected one common answer for each question. Immediate Feedback Assessment Technique (IF-AT, Epstein Educational Enterprises) forms are used for the group quizzes. Since the quizzes are case based we did not use Phase 3 (application exercise) of the classical TBL.

The course consists of three graded MCQ unit exams, which are also in the form of clinical vignettes. These are taken individually (scantron scored) and as a team (IF-AT forms). During the team unit exams, teams are allowed to challenge our answers. If a challenge was accepted, the result was applied to the entire class. The comprehensive course final is the anatomy and embryology National Board of Medical Examiners (NBME) subject exam that is taken individually only as required by the NBME guidelines.

Course Structure

The Gross Anatomy course is offered for a 19-week period and was divided into three units—thorax, back, and upper extremity (6 weeks); head and neck (5 weeks); and abdomen, pelvis, perineum, and lower extremity (8 weeks). Approximately 60–65% of course time is spent on cadaver dissection in small groups (four students per cadaver). Attendance in the laboratory is mandatory. Faculty coverage of the laboratory (40–43 tables) is as follows: every 10–11 dissection tables (40–44 students) is covered by a single faculty member, while course coordinators "float" throughout the entire laboratory. In addition, traditional embryology lectures and clinical correlation lectures were presented as per the old curriculum.

In the traditional curriculum, 130 hr was dedicated to laboratory dissection, and the course included 62–65 hr of lecture. In the TBL curriculum, course time was allocated as follows: 105–110 hr for dissection, 17 hr for lectures, and

Table 1.

Analysis of Student Performance (Percent Score and Standard Deviation)

Year	*N*	Unit 1	Unit 2	Unit 3	NBME[a]
2002	169	73 (9.6)	75 (7.5)	71 (8.3)	70 (7.0)
2003	173	70 (7.7)	73 (9.6)	77 (6.9)	64 (8.6)
2004	168	77 (8.7)	81 (8.9)	80 (8.8)	70 (7.3)
2005	178	81 (9.2)	88 (8.1)	85 (7.3)	72 (7.0)
2006	176	84 (8.6)	87 (9.3)	86 (6.5)	78 (6.9)
Group grades[b]					
2005		97	98	97	
2006		100	99	97	

Comparison of class averages in the course unit and NBME subject exams. N = number of students.

Group grades indicate the score achieved by the teams when they retook the same exam as a group. Please note that the NBME did not permit their exam to be taken as a group.

Scores for TBL curriculum (2005 and 2006 combined) were statistically different ($P < 0.05$, using two-tailed t-test) from the traditional curriculum score (2002 and 2003 combined) for each unit and for NBME exam.

[a]Normalized score provided by the NBME. In anatomy, years 2002 and 2003 were lecture-based; 2004 was the year TBL was piloted; and 2005–2006 the years when modified TBL was fully implemented.

[b]The group grades are for descriptive comparison and hence not statistically analyzed, and furthermore, the differences are only negligible.

40 hr for TBL. A total of 169–178 first-year medical students were assigned to teams of eight (combining two adjacent dissecting groups of four students). All teams received a series of assignments and learning issues derived from anatomy textbook readings and the lab dissections (available to readers upon request). Each member of the team prepared the learning issues outside of class prior to team discussions. The learning issues involved basic anatomy and clinical correlations that required application of the underlying anatomical concepts. At least once a week (there were a total of 19 team discussions), the teams discussed the assigned learning issues, sometimes using cadavers, radiographs, skeletons, and other study aids. Because of large space requirements for TBL involving the entire class at one time, the anatomy lab provided an excellent facility for team encounters. The course coordinators circulated among the teams to clarify difficult issues and to ask probing questions to foster student comprehension.

Student Assessment

In the traditional curriculum, 70% of the student's grade was based on didactic MCQs, of which the NBME final contributed 20%, and practical exams accounted for remaining 30%. In the TBL curriculum, 55% of the grade was based on clinical vignette MCQs, of which the NBME final contributed 18%, practical exams contributed 30%, and the team unit exam grade contributed 15%.

Peer Evaluation

We collected peer evaluations among the 23 teams for internal use only. This allowed us to provide proactive counseling to the few students who consistently received low scores from their peers. As expected, these same students invariably received the lowest individual exam grades. Likewise, students who received exemplary scores from their peers were almost always at the top of the individual class grades.

Semistructured Interview

We did not create a formal questionnaire to get student feedback about their experience. As part of continuous course improvement we conduct monthly focus group meetings and invite the students to share their thoughts and provide suggestions to improve the course. It is voluntary, nonthreatening, and truly a sincere effort on the part of course directors. Furthermore, we encouraged narrative comments on the use of TBL in the course. We invited faculty from other departments to witness the TBL process, and to share our experience.

Evaluation of TBL

To evaluate the possible effect of TBL on student performance we compared the unit and NBME subject exam scores between the traditional curriculum years 2002 and 2003 and 2005–2006 when TBL was implemented (Table 1). The NBME provided item analyses of the tests our students took, comparing their performance on each question with other schools in the nation. We categorized the items into eight topic areas (Table 2) and made a comparison analysis between the traditional and TBL curricula, and also between our school and the national scores. The summary of how the class as a whole performed was also evaluated (Table 3). We also collected histology and physiology NBME subject exam scores for subjective comparison during the same period (Table 4).

Statistical Analysis

Data were collected in Microsoft Excel and transformed into SAS data sets (SAS, Cary, NC) for analysis. Two-tailed t-tests

Table 2.

Further Analysis of Student Performances in the NBME Subject Examination

	Traditional curriculum			TBL curriculum			Upward progress
	NJMS	Natl	Diff	NJMS	Natl	Diff	
Back and upper limb (9)[a]	77.8	81.3	−3.5	86.5	81.4	5.1	8.6
Thorax (16)	64.8	76.2	−11	75.3	76.5	−1.2	9.8
Head and neck (24)	61.3	73.7	−13	73.5	73.0	0.5	13.5
Abdomen (27)	74.2	77.7	−3.5	87.7	75.9	11.8	15.3
Pelvis and perineum (20)	71.4	75.8	−4.4	86.9	77.2	9.7	13.1
Lower limb (8)	81.6	82.5	−0.9	88.5	80.4	8.1	9.0
Embryology (21)	61.7	69.7	−8.0	70.8	70.7	0.1	8.1
Radiology (8)	64.9	66.4	−1.5	65.4	63.9	1.5	3.0

Comparison of eight topic areas of NBME item analysis between two curricula.
Seventeen items considered as multiple or intermediate regions were not categorized.
For this analysis, data from 2003 and 2005 represent traditional and TBL curricula, respectively (see Methods). Sign test confirms that the uniform upward progress in 8/8 areas is statistically significant ($P < 0.01$).
[a]Number of items in each topic area (out of a total of 150) is indicated within parenthesis.

were performed at $\alpha = 0.01$, to confirm that changes in score were significant beyond chance fluctuations. A sign test was performed to confirm significant directionality of trends.

RESULTS

We piloted TBL in the anatomy curriculum in year 2004, and this allowed us to reflect and refine the process to develop the modified TBL that was in place for 2005 and 2006. Hence, the student's performances during 2004 year are presented but not included for statistical analysis. The traditional lecture-based curriculum offered in 2002 and 2003 served as the basis for comparison. The class average GPA and MCAT scores for years 2002 and 2003 were 3.47 and 29.12, and for years 2005–2006 were 3.50 and 29.43. This indicates that the entering classes studied are of comparable qualifications. The differences in either GPA or MCAT scores are not substantial and were not in any case subjected to statistical analysis. Because we eliminated anatomy lectures, we made considerable effort to develop "learning issues" for student's self-directed learning. The ungraded quizzes (MCQs) allowed us to closely monitor student preparation for the TBL discussion sessions, and for poor performing students to develop study strategies and other assistance.

Performances in Unit Exams and NBME Subject Examination

In Table 1, we compared the class performances from a lecture-based traditional curriculum (2002 and 2003 combined)

Table 3.

Summary of Class Grades (in Percentage of Students)

Year	*N*	Fail	Pass	High pass	Honors
2002	169	9	38	47	6
2003	173	8	39	42	12
2004	168	8	33	50	9
2005	178	0	16	73	11
2006	176	0	9	60	31

Score range: fail, below 69.4; pass, 69.5–79.4; high pass, 79.5–89.4; honors, above 89.5.
Years 2002 and 2003 are data when the course was taught using lecture-based traditional curriculum; year 2004 when TBL was piloted; years 2005 and 2006 are data when modified TBL was implemented. *N*: number of students in the class.

Table 4.

Comparison of Student Performance in the NBME Subject Exams (Average Score)[a]

Year	Histology	Physiology	Anatomy
2002	74	70	68
2003	70	69	64
2004	67	71	70
2005	70	73	72
2006	69	69	78

[a]The national average score is 70. Both histology and physiology are lecture-based traditional courses. In anatomy, years 2002 and 2003 were lecture-based; 2004 was the year TBL was piloted and 2005–2006 the years when modified TBL was fully implemented.

and the years we implemented the modified TBL curriculum (2005 and 2006 combined). In the unit exams, the class averages in year 2002 and 2003 ranged from 70 to 77. There was a modest improvement in 2004 (averages ranged from 77 to 81) when we piloted the TBL concept. Importantly, when we fully implemented the modified TBL curriculum in 2005 and 2006, the class averages, which ranged from 81 to 87, were significantly greater ($P < 0.01$) than those from years 2002 and 2003. As expected, the group averages in the unit exams were always higher than the individual averages. We further observed that individual students or teams who consistently performed well in the ungraded quizzes performed well as a team or as individuals in the graded unit exams.

For the comprehensive final, we administered the NBME gross anatomy and embryology subject exam. The individual scores in the NBME exam contributed to 18% of the course grade. Table 1 shows the class average scores in the last 5 years. The class averages in the years when TBL was implemented are significantly higher than the previous years when the course followed a lecture-based curriculum. For each unit, and for the NBME exam, differences in results were statistically significant when the TBL curriculum was compared to the traditional curriculum ($P < 0.01$ in each case, using two-tailed *t*-test).

The NBME provided item analyses of the tests our students took for comparing their performance on each question with that of students from other schools in the nation. We categorized the items into eight topic areas and made a comparison analysis between the traditional and TBL curricula (Table 2). As shown in Table 2, under the traditional curriculum, NJMS students performed below the national average in all eight topic areas. With the introduction of TBL, our students outperformed the national average in seven out of eight topic areas. The underperformance in all areas under the traditional curriculum was unlikely due to chance ($P = 0.004$); the performance in TBL curriculum compared to national figures was also statistically significant ($P = 0.031$). The difference between the two curricula was significant as well ($P = 0.0014$), as was the uniformly upward progress in all topic areas ($P = 0.004$). The number of items in each topic area between the years compared did not vary.

Performance Outcomes of the Class

To evaluate the effect of modified TBL on student performance as a whole and how it might have helped the poorly performing students we tabulated grade distributions for the course (Table 3). In 2005 and 2006 following the implementation of TBL, there were no failures in the course. Furthermore, proportions of students receiving a grade of pass decreased with a large increase in the number of students receiving high pass and honors (2006). Before the implementation of TBL, between 81 and 85% of the students received either pass or high pass grades (Table 3).

We subsequently compared the NBME anatomy average score with the average NBME scores in histology and physiology that are taught in the traditional lecture-based format (Table 4). We observed that class average scores varied from year to year both in physiology and histology. However, since the introduction of modified TBL in anatomy, student performances improved in the NBME subject exam.

Evaluation of TBL

Student's narrative comments elicited both positive and negative feedback on TBL. Positive attributes included the ability to cover a vast amount of material in a short time; retention of concepts was aided and stimulated by team discussion, and course coordinators during team discussions helped to immediately clarify misconceptions. Negative attributes of our initial TBL offering included the notion that some team assignments were too long to complete; more practice clinical application questions would have been helpful, and more time for team discussion was needed to ensure correction of mistakes and proper understanding of the tested concepts. Faculty from other departments and the Dean of Education who attended the TBL sessions were impressed by the students' cognitive engagement during the team discussions and showed interest in adopting the TBL concept for their courses.

DISCUSSION

The Jubilee Curriculum (to celebrate our school's 50th anniversary) was adopted in the academic year 2004 after a year of planning. With the introduction of early clinical exposure (preceptorships), in the first year, gross anatomy suffered significant reduction in course time. Furthermore, the mandate of the new curriculum was to reduce lectures (passive learning) and increase small-group active learning. In medical gross anatomy we eliminated anatomy lectures, maintained much of the lab time, and adopted the TBL educational strategy that includes both small group and active learning. We consider that our approach to utilize TBL is unique in that the modification allowed us to remove anatomy lectures and incorporate "learning issues" for students to work as a team in learning anatomy. We were also able to cover the course material despite reduction in curriculum time.

In the last few years, medical schools have been adopting TBL in preclinical courses (Siedel and Richards, 2001; Nieder et al., 2005), clerkships, and resident training (Hunt et al., 2003; Levine et al., 2004). However, in a "high-content" subject such as gross anatomy, we had to overcome initial skepticism and concern about covering the content without lectures and with very limited TBL experience. There are examples of

success using TBL in high-content courses such as organic chemistry (Dinan, 2002), medical gross anatomy (Nieder et al., 2005), and pharmacology (Dunaway, 2005). Gross anatomy is rich in factual content that the students need to recall for application. Hence, we created focused reading assignments from the anatomy textbook and developed learning issues based on the readings and lab dissection. These issues were discussed during TBL encounters that were supervised by the two course coordinators.

During our first attempt to introduce TBL in academic year 2004, we piloted the TBL strategy. Based on student performances, feedback on TBL and our own observations we made required adjustments before fully implementing the modified TBL in later years. We were also encouraged by the positive experiences of Nieder et al. (2005), with their TBL use in medical gross anatomy course. The performance on departmental exams (Table 1) showed that students in the TBL curriculum tended to perform better than the students in the previous year's traditional curriculum. These changes in every case were statistically significant ($P < 0.01$). As described, average GPA and MCAT scores for the reporting classes were similar; therefore, it is likely that TBL contributed to the improved performances. It is possible that TBL improved students' preparedness by encouraging them to keep up with the assignments rather than "cramming" before exams. Furthermore, peer pressure to contribute to team discussions appeared to enhance performance.

It is generally accepted that with peer teaching and group learning methods, such as TBL, the group will outperform the individual. This is clear from Table 1 where the group averages were always higher than the individual averages. Nieder et al. (2005) made a similar observation that group scores were on average 16% higher than the teams' mean individual average. We further examined whether the enhanced performance on the NBME subject exam was an actual reflection of the TBL. While the average NBME scores in the histology and physiology varied from year to year, in anatomy the average score showed yearly improvement since the implementation of TBL (Table 2).

There are a number of factors that might have contributed to the overall improved performances on the unit and NBME subject exam in years 2004–2006 (Tables 1 and 3). These include (1) the inclusion of clinical application exercises in "learning issues" for discussion during team encounters; (2) the improved quality of quiz and unit exam questions written in collaboration with clinical faculty (one of the authors (NSV) also attended NBME item writing workshop); (3) incorporation of high-quality problem solving and clinical reasoning questions obtained from various textbooks, Web sites, etc., into our team discussions; (4) early exposure to preceptorship (as part of Jubilee Curriculum); and (5) student's critical thinking and problem solving ability were likely improved. We are also entertaining the idea that two free afternoons for self-directed learning in the new curriculum might have contributed to students' enhanced learning and performances.

We analyzed the item analyses of the NBME standardized exams to further assess how well students learn anatomy when using the TBL strategy. The items were grouped into eight different topic categories including embryology and radiographic anatomy (Table 3). In our 10–15 years experience with NBME subject exam, we found that the number of items tested in eight of the categories remained fairly constant. Similarly, since the inception of TBL, we maintained a constant number of questions for the various categories in the unit exams. For the sake of convenience, we compared years that are representative of the traditional (year 2003) and TBL (2005) curricula. As noted in Table 3, with the TBL curriculum the class performance showed an upward progress in all eight topic categories. However, the upward progress was uneven, suggesting room for improvement especially in teaching radiographic and thoracic anatomy. It is noteworthy that some of the items categorized in Table 3 as items that overlapped multiple regions involved radiographic anatomy correlating visceral structures, especially, thoracic viscera. We are currently addressing deficiencies in these weaker topics.

Dinan (2002) reported that in undergraduate chemistry courses the use of modified TBL has resulted in significantly higher grades on standardized tests and fewer failures compared to the same course taught by traditional lecture-based means. One of the major benefits of TBL in that context was retention of academically weaker students. We tabulated the anatomy course grades to evaluate the effect of TBL on student performance as a whole and how it might have helped the academically weaker students (Table 4). In 2005 and 2006 following the implementation of TBL curriculum, there were no failures in the course. Furthermore, proportions of students receiving a pass decreased with a significant increase in number of students receiving high pass and honors (2006). Before the implementation of TBL in the anatomy curriculum, between 81 and 85% of the students received pass and high pass grades (Table 4). What made the difference? As suggested by Dinan (2002), we believe that the combined use of reading assignments and quizzes served to elicit more students who studied anatomy on a daily basis. Furthermore, to ensure individual accountability, individual exam grades are weighted more heavily than the group grades (85% to 15%). Using TBL, McInerney (2003) reported enhanced long-term retention and critical thinking in an undergraduate microbial physiology course. Our results also support the concept that providing an opportunity to learn in context with clinical cases and discussing the cases as a team allowed deeper learning, better retention, and improved performances.

The semistructured interviews also gave us valuable information that we applied for improving the TBL sessions. Because the clinical applications seemed to help the student's master basic anatomical concepts for later recall, we plan to continuously expand the use of such applications during team discussions. Because the reading assignments assisted in narrowing the course content to save time, we plan to expand these assignments to include the embryology textbook.

One of the problems encountered in piloting TBL was the excessive number of learning issues for certain team discussions. This prevented complete discussions within those TBL sessions. This, in turn, encouraged students to split the workload in that not all students prepared each learning issue, an unintended consequence of TBL. Another important consideration is the need for close monitoring of team discussions in the initial stages as teams attempt to create cohesive, interactive groups.

CONCLUSIONS

Our initial attempt to incorporate modified TBL in medical gross anatomy was a positive experience. We were able to cover course content and improve student performance

despite reduction in course time allotted by the new curriculum. With continued refinement of "learning issues" and additional clinical application cases for TBL discussion, we would anticipate that students might retain their knowledge of anatomy for application to their clerkship years. We observed that the students were more engaged in their learning as the teams facilitated active learning as well as peer teaching. In year 2006, biochemistry piloted TBL in a small segment of the course while retaining most of the lectures. Encouraged by the outcome, they plan to expand the TBL approach in 2007.

ACKNOWLEDGMENTS

The University IRB approved this study. The first author is a Harvard Macy Scholar 2006, and this project was initiated as part of the Harvard Macy Institute Program for Educators in the Health Professions. The authors thank the project group members Drs. Anne Cuccio, Kathleen Kelley, Nancy Kheck, Anda Kuo, and Venkatesh Lakshman for their assistance in developing this project, and Dr. Alex Stagnaro-Green, Associate Dean for Curriculum and Faculty Development, for guiding us in this study, and critical review of the manuscript. The Department of Cell Biology and Molecular Medicine in part supported this study.

NOTES ON CONTRIBUTORS

NAGASWAMI VASAN, D.V.M., Ph.D. is an associate professor in the Department of Cell Biology and Molecular Medicine at New Jersey Medical School, Newark, New Jersey.

DAVID DEFOUW, Ph.D. is a professor in the Department of Cell Biology and Molecular Medicine at New Jersey Medical School, Newark, New Jersey.

BART HOLLAND, Ph.D. is an associate professor in the Department of Preventive Medicine and Community Health, at New Jersey Medical School, Newark, New Jersey.

LITERATURE CITED

Dinan FJ. 2004. An alternative to lecturing in the sciences. In: Michaelsen LK, Knight AB, Fink LD. (eds.) Team-Based Learning: A Transformative Use of Small Groups in College Teaching. Virginia: Stylus Publishing, LLC. p 97–104.

Dunaway GA. 2005. Adaptation of team learning to an introductory graduate pharmacology course. Teach Learn Med 17:56–62.

Haidet P, O'Malley KJ, Richards BF. 2002. An initial experience with "team learning" in medical education. Acad Med 77:40–44.

Haidet P, Morgan RO, O'Malley KJ, Moran BJ, Richards BF. 2004. A controlled trial of active versus passive learning strategies in a large group setting. Adv Health Sci Educ 9:15–27.

Hunt DP, Haidet P, Coverdale JH, Richards BF. 2003. The effects of using team learning in an evidence-based medicine course for medical students. Teach Learn Med 15:131–139.

Levine RE, O'Boyle M, Haidet P, Lynn DJ, Stone MM, Wolf DV, Paniagua FA. 2004. Transforming a clinical clerkship with team learning. Teach Learn Med 16:270–275.

McInerney MJ. 2003. Team-based learning enhances long-term retention and critical thinking in an undergraduate microbial physiology course. Microbiol Educ J 4:3–12.

Michaelsen LH, Fink RH, Knight A. 1997. Designing effective group activities: Lessons for classroom teaching and faculty development. In: DeZure D. (ed.) To Improve the Academy: Resources for Faculty, Instructional and Organizational Development. Stillwater, OK: New Forum Press. p 373–379.

Muller S. 1984. Physicians for the twenty-first century: Report of the project panel on general professional education of the physician and college preparation for medicine. J Med Educ 59:1–208.

Nieder GL, Parmelle DX, Stolfi A, Hudes PD. 2005. Team-based learning in a medical gross anatomy and embryology course. Clin Anat18:56–63.

Searle NS, Haidet P, Adam Kelly P, Schneider VF, Seidel CL, Richards BF. 2003. Team learning in medical education: Initial experiences at ten institutions. Acad Med 78:555–558.

Siedel CH, Richards BF. 2001. Application of team learning in a medical physiology course. Acad Med 76:533–534.

Vasan NS, DeFouw D. 2005. A successful initial experience with modified team learning strategy in medical gross anatomy course. Med Educ 39:524.

Vasan NS, DeFouw D. 2007. The use of reading assignments and learning issues as an alternative to anatomy lectures in team-based learning curriculum. In: Michaelson LK, Parmelle DX, McMahon KK, Levine RE. (eds.) Team-Based Learning for Health Professions Education. Hemdon, Virginia: Stylus Publishing. p 171–177.