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Research paper

Assessment of student learning patterns, performance, and long-term knowledge retention following use of didactic lecture compared to team-based learning ☆

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Abstract

Objective: To assess student learning patterns, performance, and long-term knowledge retention comparing team-based learning (TBL) versus didactic lecture.

Methods: Students were recruited from the Therapeutics 6 course. Primary end points include the following: time spent learning content for each topic, student performance on course examinations, and student performance on follow-up examination five months after course completion.

Results: Students ($n = 35$) spent more time learning topics taught using TBL (mean = 21.12 ± 11.02 hours) compared to didactic lecture (mean = 17.54 ± 7.78 hours) ($p = 0.002$). There was no significant difference in mean score on course examinations (TBL mean = 81.84 ± 8.19; didactic lecture mean = 80.50 ± 7.10; $p = 0.369$) or on the follow-up examination (TBL mean = 63.65 ± 10.14; didactic lecture mean = 65.43 ± 10.11; $p = 0.419$).

Conclusions: Although students used more time learning content for topics taught using TBL compared to those presented by didactic lecture, immediate and long-term exam performances were not significantly different. Educators using TBL should design learning experiences to develop skills that can be strengthened by TBL, including communication, professionalism, team work, and critical thinking. Student preparation time should be considered when implementing TBL within a course or curriculum.

Keywords: Team-based learning; active learning; knowledge retention; pharmacy; education; learning patterns

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Introduction

The Accreditation Council for Pharmacy Education (ACPE) Standards specify the need to develop critical thinking and problem-solving skills through active learning methods in the curriculum of schools/colleges of pharmacy.[1] Existing literature supports the use of team-based learning (TBL) as an active learning method in schools/colleges of pharmacy.[2–10] Benefits of TBL include improved student performance and perceptions compared to lecture-based courses. An analysis of TBL incorporation

has also led to improved student performance on higher-levels of cognition.[3] Advantages of TBL extend beyond student performance on course work and include improvements in professionalism, communication, and team work.[2–8] With improvements in student performance, one may assume a respective corresponding increase in preparation or study time; however, this is currently unknown. Only one published report on TBL in pharmacy education mentions this potential association.[3] As one component of the study, students completed a survey at the conclusion of the course. Of those who responded, 30% felt they spent more time preparing for the course, while 45% did not feel they spent more or less time preparing for the TBL course compared to other courses. This study used a subjective report of learning patterns that was collected at just one time point (conclusion of the course). Prospective assessment of the impact TBL has on student learning patterns warrants additional investigation to determine the potential impact it has on student learning time in a rigorous educational program.

There have been many applications of TBL in health sciences education, but few reports assess long-term knowledge retention. Burgess et al.[11] assessed the impact of TBL in an anatomy by whole-body dissection elective course in 28 medical students. The authors compared student performance between end-of-course and one-month post-course examinations. The authors found a significant improvement between pre-course and post-course performances ($p < 0.001$), but no difference between end-of-course and post-course performances ($p = 0.55$). The primary limitation of this study is the time frame between end-of-course and post-course examinations may have been too short to assess knowledge retention. Warrier et al.[12] assessed student knowledge retention following implementation of TBL in six educational sessions of a required pediatric clerkship in the third medical year. Knowledge was assessed via fourth-year medical student high-stakes objective structured clinical examination (OSCE) scores, which occurred between one and ten months following completion of the clerkship. Student performance was compared to a control group of students who completed the clerkship prior to TBL implementation. Student performance improved following implementation of TBL ($p = 0.011$). The primary limitation of this study was that the authors did not assess change in knowledge over time by comparing student performance in an OSCE at the end of the clerkship vs. the high-stakes OSCE at a later time. Another study assessed the influence of knowledge acquired using TBL in a foundational pharmacokinetics course on the performance in a subsequent course (clinical pharmacokinetics).[3] The authors compared student performance on examinations of the clinical pharmacokinetics course based on pedagogy used in the foundational pharmacokinetics course (TBL vs. lecture). Overall course grades increased from 86.6% with the lectures to 90.7% with TBL (effect size, $d = 0.73$). The results of this study may signify that when foundational pharmacokinetic concepts are learned using TBL, subsequent use of the knowledge for clinical application improves. The primary limitation of this study was that it indirectly measured knowledge by comparing pedagogy used in a prerequisite course to student performance in the subsequent course. Collectively, these studies imply TBL improves long-term knowledge retention. However, due to the study limitations, additional investigation is needed.

The purpose of this study was to assess student learning patterns, performance, and long-term knowledge retention comparing material learned using TBL versus didactic lecture.

Methods

Team-based learning was introduced into the curriculum at the University of Tennessee College of Pharmacy in 2008 where it was first incorporated into an elective course on the Knoxville campus.[2] Since that time, TBL has been incorporated into various elective and required courses in the second and third professional years. Most recently, TBL was incorporated into the required Therapeutics 6 course, a required course in the third professional year, Fall 2011, with 128 students enrolled. This course is the final course in the Therapeutics course sequence and is taught in the semester prior to students beginning advanced pharmacy practice experiences. The course follows the core elements of TBL except for implementation of peer evaluations.[13] Peer evaluations were not incorporated into the course structure because of the limited number of team interactions in the course.

Students were recruited from those enrolled in the Fall 2012 offering of the Therapeutics 6 course. The course included 21 topics, four (17%) of which were taught using TBL (headache disorders, insomnia, intensive care unit sedation/spinal cord injury, and tobacco cessation). The course spanned seven weeks, and one TBL session was included weekly in weeks three through six. Each of the TBL sessions was designed by a different faculty member who had prior experience using TBL ($n = 3$) or received mentoring when creating materials and facilitating the class session ($n = 1$). The didactic lecture topics included for comparison were each also taught by different faculty members who did not facilitate a TBL session. All examination questions were written by the faculty member who developed the class materials. The course was taught using live, simultaneous, videoconferencing to students located on two campuses. Class sessions are recorded, and students have access for online viewing after class. Enrollment in the study via informed consent was voluntary, and students were provided modest compensation for study participation. Although the students had been exposed to the TBL method in a required course in the previous semester, TBL is not a component of any other courses in the Therapeutics series. The study was deemed exempt by

the University of Tennessee Graduate School of Medicine Institutional Review Board.

Study end points

The primary end points include the following: (1) total time spent learning for each pedagogy, (2) student performance on course examinations, and (3) student performance on follow-up examination administered five months after the completion of the course to assess retention of knowledge. Knowledge retention was assessed five months after course completion as this time frame was considered long enough for students to not retain direct recall of the examination questions. The time frame also allowed for administration of the examination before multiple students would be lost to follow-up while on advanced pharmacy practice experiences, some of which are international experiences. Secondary end points include time spent learning using different learning/study methods, impact of time from end of course to follow-up examination and pedagogy on knowledge retention, and comparison of student performance based on item difficulty and pedagogy.

Documentation of learning patterns

Study participants were required to document time spent studying each topic (in minutes) within the course using logs provided. In addition to the total time spent learning, study participants recorded the study method used (e.g., reviewing required/suggested readings, reviewing lecture notes, creating study guide/outline/notecards/tables, discussing material within a study group, one-on-one tutoring session, group tutoring session, in-class time, watching/reviewing recorded class session, and completing practice examination questions) for each topic in the course. To improve the accuracy of the reported learning time, study participants submitted weekly reports of learning patterns.

Student performance

Student performance was assessed using course examination scores for the topics included in the analysis. The course examination structure included mid-term and final examinations. The course was delivered over a seven-week period. The mid-term examination assessed 11 topics (26 classroom hours), and the final examination assessed ten topics (24 classroom hours). The topics included in the analysis, method of teaching, classroom time, and numbers of examination questions are listed in Table 1. Final course grades were not assessed for the purpose of this study.

Knowledge retention assessment

The follow-up examination to assess long-term knowledge retention was administered five months after the conclusion of the course. Students were instructed to not study for the follow-up examination. The examination included eight topics that were addressed in the Therapeutics 6 course [four topics taught using TBL (headache disorders, insomnia, intensive care unit sedation/spinal cord injury, and tobacco cessation) and four topics taught using lectures that were matched for allotted in-class time and difficulty based on complexity of the disease state and corresponding pharmacotherapy (anxiety disorders, attention-deficit hyperactivity disorder, traumatic brain injury, and drug and alcohol abuse)]. The multiple-choice questions on the follow-up examination were the same questions that were included on the course examinations. During the five-month interval, students began advanced pharmacy practice experiences (APPEs) and may have also been enrolled in elective courses. The APPEs and elective courses that were identified as potential confounding factors include psychiatry, pediatrics, critical care, ambulatory care, and community pharmacy.

Statistical analysis

Descriptive statistics were used to assess the demographic characteristics of the study participants. Time spent on various learning methods were compared using paired t-tests; however, learning methods to which fewer than ten students responded were excluded from any comparison. Item difficulty and discrimination indices were computed for each TBL and didactic lecture topic pair by using the

Table 1
Characteristics of educational topics included in the study

Topic	Pedagogy	Classroom time (hours)	Number of examination questions
Anxiety disorders	Didactic lecture	2	9
Attention-deficit hyperactivity disorder	Didactic lecture	2	7
Drug and alcohol abuse	Didactic lecture	3	6
Headache disorders	TBL	2	6
Insomnia	TBL	2	7
Intensive care unit sedation and spinal cord injury	TBL	2	7
Tobacco cessation	TBL	3	7
Traumatic brain injury	Didactic lecture	2	5

TBL = team-based learning.

Table 2
Demographic characteristics of study participants

Characteristic	Frequency (%) or mean (SD) ($n = 35$)
Age, years	26.29 (3.23)
Female gender	20 (57.1%)
Race/ethnicity	
Caucasian	28 (80.0%)
Asian	4 (11.4%)
Black	3 (8.6%)
Incoming grade point average[a]	3.14 (0.41)

[a] Cumulative grade point average from the end of the semester prior to enrollment in the course.

proportion of correct responses and biserial correlations, respectively.[14] The average item difficulty for each of the set of topic questions was calculated as the proportion of individuals answering correctly. A low proportion of correct responses indicated a difficult item while a high proportion meant the item was somewhat easier. Items were also categorized as recall or application as a descriptive measure of item complexity. Topics varied with respect to the number of questions, so each set of topic questions was scaled to a 100-point total score to standardize the comparisons between TBL and didactic lecture topics. Both performance between TBL and didactic lecture topics and knowledge retention from course to five-month follow-up were compared using paired t-test analysis. The changes in test scores from course to follow-up as well as the interaction between time and pedagogy were assessed using a 2 × 2 within-subjects analysis of variance. All statistical analyses were conducted using SPSS v.21 (IBM Inc., Chicago IL) and were two-sided. An alpha value of $p < 0.05$ was considered statistically significant.

Results

There were 128 students enrolled in the course. Overall, 35 students (27.3%) opted to participate in the study. The mean age was 26.29 years and 57.1% were female. Baseline demographics of the students enrolled are included in Table 2. Data presented represents outcomes of the students enrolled in the study and is not meant to be representative of the entire class.

Student learning patterns

Table 3 describes the study outcomes related to student learning patterns. Overall, students spent more time learning topics taught using TBL (mean = 21.12 hours, SD = 11.02) compared to didactic lecture (mean = 17.54, SD = 7.87) ($p = 0.002$). For topics taught using TBL, students spent more time on required or suggested readings (TBL mean = 4.86 hours, SD = 3.41; didactic lecture mean = 1.35 hours, SD = 1.11; $p = 0.001$) and more time in class (TBL mean = 7.27 hours, SD = 2.13; didactic lecture mean = 4.23 hours, SD = 2.64; $p < 0.001$). Students spent more time watching recorded class sessions for topics taught using didactic lectures (TBL mean = 1.76 hours, SD = 1.34; didactic lecture mean = 5.71 hours, SD = 2.99; $p < 0.001$). None of the study participants reported time spent in individual or group tutoring sessions, nor did they spend time completing practice examination questions.

Student performance and knowledge retention

The average item difficulty across the TBL and didactic lecture topics was similar on the course examinations (TBL mean = 0.59, SD = 0.04; didactic lecture mean = 0.62, SD = 0.10) and on the retention test (TBL mean = 0.59, SD = 0.09; didactic lecture mean = 0.63, SD = 0.09). Although the didactic lecture items appeared slightly easier, all values fell within the average level of difficulty.[14] There was a significant difference in item complexity. Topics taught using TBL included significantly more application questions than topics taught using didactic lecture ($p = 0.014$) (Table 4).

Table 5 lists student performance on each topic during the course and on the follow-up examinations. When

Table 3
Comparison of study time by learning method and pedagogy

Learning method[a]	Study time, hours (SD)		Difference[b] (95% CI)	p Value[c]
	TBL	Didactic lecture		
Required/suggested reading	4.86 (3.41)	1.35 (1.11)	3.51 (1.86 to 5.15)	0.001
Reviewing class notes	5.91 (4.77)	6.73 (5.14)	−0.82 (−1.85 to 0.2)	0.111
Creating study guides	3.31 (2.63)	3.73 (2.78)	−0.42 (−1.9 to 1.07)	0.554
In-class time	7.27 (2.13)	4.23 (2.64)	3.04 (1.85 to 4.51)	<0.001
Watching recorded class sessions	1.76 (1.34)	5.71 (2.99)	−3.95 (−5.0 to −2.91)	<0.001
Total time	21.12 (11.02)	17.54 (7.78)	3.58 (1.45 to 5.73)	0.002

TBL = team-based learning.

[a] Study methods with fewer than 10 student responses were excluded from analysis.

[b] The difference was calculated by the time studying for topics taught using TBL minus time studying for topics taught using didactic lecture.

[c] Pedagogies compared using paired t-test analysis.

Table 4
Comparison of item complexity by pedagogy

Item classification	TBL	Didactic lecture	*p* Value[a]
Recall of knowledge	12	21	0.117
Application of knowledge	18	6	0.014

TBL = team-based learning.
[a] Compared using Chi-square goodness-of-fit test.

comparing student performance without accounting for confounding factors, there was no significant difference in mean score when the questions were administered on course examinations (TBL mean = 81.84, SD = 8.19; didactic lecture mean = 80.50, SD = 7.10; $p = 0.369$) or on the follow-up examination (TBL mean = 63.65, SD = 10.14; didactic lecture mean = 65.43, SD = 10.11; $p = 0.419$). None of the elective courses or advanced pharmacy practice experiences were found to result in a statistically significant difference on topics that would most likely be influenced by the learning experience.

Overall, student performance declined on the knowledge retention examination. Table 6 displays the impact of time and pedagogy on student performance. Knowledge retention was not impacted by pedagogy but was negatively impacted by time from when students completed the course to when they took the knowledge retention examination.

Table 7 displays student performance based on item complexity and pedagogy. Student performance on recall of knowledge versus application of knowledge items did not differ on course examinations or on the knowledge retention examination.

Discussion

To our knowledge, this is the first study to prospectively assess the impact of TBL compared to didactic lecture on the three outcomes of learning patterns, in-class performance, and knowledge retention in pharmacy education. Our findings indicate that learning patterns differed significantly between pedagogies. Students spent more time overall learning for the TBL topics compared to didactic lecture. For the TBL topics, students spent more time reviewing required readings and attending class. For didactic lectures, students spent more time watching the recorded class sessions. These differences were expected, based on the structure of TBL requiring pre-class preparation and classroom attendance being low for didactic lectures, as the video recordings of class sessions are available online to students. In contrast, a prior study retrospectively assessed student perceptions on class preparation and found that 45% of students felt they did not spend more or less time compared to other courses.[3] Our findings have the ability to influence a course director's view of TBL in that it requires extra effort from students, so use of TBL should be carefully planned and spaced appropriately throughout the

Table 5
Student performance on examinations based on topic and learning method[a]

Topic and learning method		Course examination			Knowledge retention examination		
TBL	Didactic lecture	TBL, mean (SD)	Didactic lecture, mean (SD)	*p* Value (95% CI)	TBL, mean (SD)	Didactic lecture, mean (SD)	*p* Value (95% CI)
Headache disorders	Anxiety disorders	78.78 (16.39)	82 (8.68)	0.32 (−3.27 to 9.72)	58.01 (21.11)	78.28 (13.49)	<0.001 (12.23 to 28.32)
Tobacco cessation	Drug and alcohol abuse	79.59 (12.63)	79.59 (12.63)	0.757 (−8.43 to 6.19)	62.5 (18.49)	58.01 (21.11)	0.200 (−2.81 to 12.87)
Insomnia	ADHD	86.07 (11.65)	73.57 (17.87)	<0.001 (6.61 to 18.39)	76.52 (16.16)	67.53 (16.08)	<0.001 (−22.12 to −8.16)
ICU sedation/spinal cord injury	Traumatic brain injury	81.79 (12.26)	86.67 (14.46)	0.109 (−10.91 to 1.15)	57.58 (17.67)	62.5 (18.49)	0.484 (−5.68 to 11.74)
Total TBL	Total didactic lecture	81.84 (8.19)	80.50 (7.10)	0.369 (−1.69 to 4.45)	63.65 (10.14)	65.43 (10.11)	0.419 (−6.21 to 2.65)

ADHD = attention-deficit hyperactivity disorder; ICU = intensive care unit; TBL = team-based learning.
[a] Student scores were scaled to a 100-point total score.

Table 6
Student performance assessing the interaction between change over time and pedagogy[a]

Topic and pedagogy		Course examination		Knowledge retention examination		p Value (Partial η^2)	
TBL	Didactic lecture	TBL, mean (SD)	Didactic lecture, mean (SD)	TBL, mean (SD)	Didactic lecture, mean (SD)	Time[b]	Time[b] and pedagogy
Headache disorders	Anxiety disorders	78.78 (16.39)	82 (8.68)	58.01 (21.11)	78.28 (13.49)	<0.001 (0.43)	0.001 (0.30)
Tobacco cessation	Drug and alcohol abuse	86.07 (11.65)	73.57 (17.87)	76.52 (16.16)	67.53 (16.08)	<0.001 (0.55)	0.106 (0.08)
Insomnia	ADHD	79.59 (12.63)	79.59 (12.63)	62.5 (18.49)	58.01 (21.11)	<0.001 (0.48)	0.470 (0.02)
ICU sedation/spinal cord injury	Traumatic brain injury	81.79 (12.26)	86.67 (14.46)	57.58 (17.67)	62.5 (18.49)	<0.001 (0.72)	0.060 (0.101)
Total TBL	Total didactic lecture	81.84 (8.19)	80.50 (7.10)	63.65 (10.14)	65.43 (10.11)	<0.001 (0.86)	0.220 (0.047)

ADHD = attention-deficit hyperactivity disorder, ICU = intensive care unit, TBL = team-based learning

[a] Student scores were scaled to a 100-point total score.

[b] The change in the outcome variable over the time from when the students finished the course to when they took the knowledge retention examination.

course to allow students adequate time to prepare for class. At this time, it is unknown if learning patterns become more efficient following increased exposure to TBL. Future studies should assess impact of varying amounts of exposure to TBL and time devoted to learning in and out of the classroom.

The structure of TBL holds students accountable to practice knowledge acquisition through pre-class reading that is guided by learning objectives. This activity can extend to developing skills for life-long learning, as acquiring knowledge through reading is an essential method of learning once in practice. Students who participated in this study spent significantly more time reviewing required/suggested readings on the TBL topics compared to topics learned using didactic lecture. Increased practice of knowledge acquisition from reading may prove useful as a practicing pharmacist. Future studies should assess if this type of learning improves knowledge acquisition once the student enters professional practice.

Student performance on course assessments and knowledge retention did not differ between pedagogies. However, differences in certain topic pairs were observed. This may support the idea that some topics are better suited to learn using TBL while others are better suited for didactic lecture. One possibility for the lack of overall observed difference was the assessment method used. Multiple-choice examinations are a traditional assessment method for knowledge; however, TBL has potential to strengthen communication, professionalism, team work, critical thinking, and problem solving in addition to knowledge. Using multiple-choice assessments may not be the best method to discriminate knowledge and skills learned using TBL as these skills are not easily assessed on multiple-choice examinations. There were significantly more high complexity items assessing application of knowledge for topics taught using TBL. However, student performance did not differ when accounting for item complexity (recall of knowledge vs. application of knowledge). This finding differs from a recent report of use of TBL in a Therapeutics course sequence that used multiple-choice and essay questions for assessments.[15] The authors compared student performance on content taught using TBL and didactic lecture. Results of this report indicated that students taught using didactic lecture performed better on multiple-choice questions that assessed recall, and students performed equally on multiple-choice questions that assessed application of knowledge and essay

Table 7
Student performance on examinations based on item complexity

	Course examinations			Knowledge retention examination		
	TBL, mean (%)	Didactic lecture, mean (%)	p Value[a]	TBL, mean (%)	Didactic lecture, mean (%)	p Value[a]
Recall of knowledge	29.5 (84.29)	28.9 (82.89)	0.997	21.33 (60.95)	21.48 (61.36)	1.0
Application of knowledge	27.94 (79.84)	28.33 (80.95)	0.913	21 (60)	21.67 (61.9)	0.999

TBL = team-based learning

[a] Compared using two-way analysis of variance.

questions. Future research on the impact of TBL on student performance should focus on discriminating performance based on item complexity and development of objective structured clinical examination assessment methods or other assessment methods that measure the skills developed through TBL learning strategies.

Another possibility for lack of observed difference in student performance, and limitations of the study, include the small sample size and few number of team interactions. Student enrollment in the study was optional, which resulted in a smaller sample size compared to existing published reports of TBL in pharmacy education. Prior, large, retrospective studies that compared student performance between didactic lecture and TBL have reported conflicting results showing either improvement in scores using TBL[3,4] or no observed difference.[5,6] Students only had four TBL sessions for team interaction. This short duration of time working together may not have permitted enough development for students to learn effectively from one another.

Another limitation of the study was the use of different content topics in each pedagogy. The course is taught synchronously at only one point in the curriculum which did not allow for comparison of the same topics taught using different pedagogies. To attempt to control for this, the topics included in the analysis were matched for allotted in-class time and the authors' assessment of difficulty based on complexity of the disease state and corresponding pharmacotherapy. The average item difficulty for each pair of topics was also assessed via proportion-correct values prior to any analysis.

Conclusion

Students used more time learning content for topics taught using TBL compared to didactic lecture. Students spent significantly more time reviewing required/suggested readings and attending class sessions for topics taught using TBL. Performance on course examinations and knowledge retention examinations was not significantly different. Faculty considering implementation of TBL should design materials to emphasize the skills strengthened through TBL, such as communication, professionalism, team work, critical thinking, and problem solving in addition to knowledge. Because TBL requires extra student effort prior to class, implementation should be carefully planned with student preparation time taken into consideration.

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