HOW WE TEACH | Classroom and Laboratory Research Projects

The trilayer approach of teaching physiology, pathophysiology, and pharmacology concepts in a first-year pharmacy course: the TLAT model

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Islam MA, Sabnis G, Farris F. The trilayer approach of teaching physiology, pathophysiology, and pharmacology concepts in a first-year pharmacy course: the TLAT model. Adv Physiol Educ 41: 395–404, 2017; doi:10.1152/advan.00047.2017.—This paper describes the development, implementation, and students’ perceptions of a new trilayer approach of teaching (TLAT). The TLAT model involved blending lecture, in-class group activities, and out-of-class assignments on selected content areas and was implemented initially in a first-year integrated pharmacy course. Course contents were either delivered by traditional lectures or by the TLAT. A survey instrument was distributed by SurveyMonkey to determine students’ perceptions of the TLAT model. Descriptive statistics were used for data analysis. Students’ performance in a total of 225 examination and quiz questions was analyzed to evaluate whether the TLAT model improved students’ performance in a total of 225 examination and quiz questions. We also present the findings of a student survey about their attitudes toward this TLAT model.

METHODS

At the West Coast University School of Pharmacy, there are nine integrated courses in which the concepts of physiology/pathophysiology, medicinal chemistry, pharmacology, and pharmacotherapy are taught in an integrated manner. A three-credit foundational course,

WITH THE RAPID INFLUX OF NEW biomedical knowledge, its contextual understanding and application to clinical reasoning is becoming increasingly crucial for the current generation of learners in health profession education. This requires a paradigm shift from the traditional lecture-based passive mode of teaching to a learner-centered approach of teaching (33, 56). Consequently, active learning strategies are being increasingly utilized by faculty in healthcare education (24, 48) because they are thought to promote higher order learning (41), foster problem-solving abilities (18), and improve the application of learned knowledge to solve complex concepts (21).

There are several reports of improved student performance and satisfaction with pharmacy and medical curricula taught by means of an “engaged lecture” format (21, 29). Pharmacy education literature reports the use of in-class active learning strategies by pharmacy educators to various extents in U.S. colleges and schools of pharmacy (16, 25, 40, 48, 58). In a recent article (17), we reported that U.S. pharmacy programs employ diverse teaching and learning strategies in the delivery of physiology contents to Doctor of Pharmacy (PharmD) students. Commonly employed active learning methods include in-class discussion/recitation, assignment, audio response systems, games, workshop, projects, journal club, problem-based learning, and team-based learning (17). Active learning methodologies such as flipping the classroom (32), team-based learning (19, 20, 22, 28), and simulation-based education (13, 17a) have been reported to improve medical students’ learning outcomes compared with lecture. The integration of various active learning activities including puzzle, board game, video, and debate with lectures had positive effects on medical students’ ability to comprehend physiological concepts in neurology and cardiology (30). The use of short presentation breaks during didactic lectures improves students’ ability to learn physiology (11).

Out-of-class learning activities, such as homework, individual or group assignments, and projects, have been utilized in medical (15, 51), nursing (39), and pharmacy education (43). Studies have shown that assigning homework related to classroom topics positively affects students’ academic performance (6). However, there is limited information on the impact that utilizing blended teaching and learning strategies that integrate lecture, in-class activities, and out-of-class assignments might have on student learning of a complex topic. This article describes the development and implementation of an innovative trilayer approach of teaching (TLAT) to deliver physiology, pathophysiology, and pharmacology topics in an integrated pharmacy course. The TLAT involves instructor-led lecture, engagement of students in in-class activities, and out-of-class homework assignments. The article also describes the impact of the TLAT model on students’ performance on examinations and quizzes. We also present the findings of a student survey about their attitudes toward this TLAT model and their learning experiences.
PHAR 611—Principles of Drug Action, is implemented in the spring semester of the first professional year of the PharmD program before students’ exposure to the integrated courses. The goals of the course are to focus on the physiological, pathophysiological, and physicochemical basis of drug actions. In addition, the course expands on discussion of cellular excitability and electrochemical transmission, physiology of autonomic nervous system, and adrenergic and cholinergic pharmacology (Table 1).

The TLAT model was developed and implemented in the Principles of Drug Action course during the spring 2015 and 2016 semesters. The numbers of students in the spring 2015 and 2016 semesters were 44 and 54, respectively. The class met twice weekly, once for a 2-h and once for a 1-h session. The course contents were delivered either by lecture or by TLAT. Table 2 shows the selected course contents that were taught by TLAT. In addition to PowerPoint lectures, the TLAT model involved student participation in group activities and in both in- and out-of-class learning exercises. This approach involves three layers in teaching selected topics: 1) delivery of materials by the instructor using PowerPoint lecture; 2) engagement of students in the classroom in active learning; and 3) out-of-class individual/group assignments in the same content areas (Fig. 1). The linkages between in-class activities and the out-of-class individual/group assignments are shown in Fig. 2. The 5- to 15-min in-class active learning activities that were integrated during didactic lecture involved instructor-led class discussion (questions and answer session), Think-Pair-Share, and peer teaching on selected topics. The contents covered in these short sessions were incorporated in individual homework assignments, which involved problem-solving and self-study questions. A total of six 30- to 60-min sessions were designed for group discussions on three patient cases and three concept map assignments. To further reinforce learning, students completed the cases and concept maps as homework assignments individually or in groups. All homework was due 1 wk after it was assigned.

Both formative and summative assessment strategies were used to evaluate student learning outcomes. Qualitative and quantitative data were collected from students enrolled in the course over 2 yr (2015–2016) to measure learning outcomes. Students’ knowledge of course contents was evaluated by examinations, quizzes, and out-of-class homework/assignments. Grading rubrics were used to assess individual or group case studies and concept maps (see supplemental material; the supplemental material for this article is available online at the Journal website). A rubric-based peer evaluation was also utilized as an assessment strategy for group case studies. As a part of formative assessment, the instructor provided students with comments and feedback on their in-class activities, homework, case studies, and assignments. Students’ performance in examination or quiz questions from contents that were delivered either by lecture only or by TLAT was analyzed to evaluate whether the TLAT model improved students’ learning.

A survey instrument was developed to determine perceptions of the students of the TLAT model and their learning experiences. An electronic invitation, including the hyperlink to the survey questionnaire, was emailed to the students. The questionnaire contained 13 statements focused on the perceptions of students regarding the teaching strategies employed in the course. The survey instrument was initially sent on at the end of the 2015 and 2016 spring semesters, followed by two subsequent reminders 4 wk apart. A cover letter accompanied the survey, which explained the purpose of the survey, along with the assurance that participation will be voluntary and identity will remain confidential. SurveyMonkey (Portland, OR) was employed to collect responses. The respondents indicated their degree of agreement or disagreement with individual statements using a 5-point Likert scale (range: 1 = strongly disagree to 5 = strongly agree). Survey responses were downloaded into Microsoft Excel. One-way ANOVA followed by Mann-Whitney U-test was performed using SPSS Statistics software (version 22.0; IBM, Armonk, NY) to determine any differences among responses from two cohorts of students. Text-based comments were collated, and thematic analysis of the content was performed by using constant-comparison method (1). Initial coding and theme generation were performed manually by two investigators independently. An iterative review process, which involved another investigator, was utilized to further clarify themes and reach a consensus among investigators. This study was given exempt status by the Institutional Review Board of the West Coast University.

### RESULTS

Qualitative and quantitative data were collected to measure student learning outcomes and assess their attitudes on learning experiences. Students’ knowledge of course content was evaluated by three standardized examinations and four quizzes, and out-of-class assignments/homework. The two midterm examinations and four quizzes counted for 40% and 16% of the
The final examination was comprehensive and cumulative and counted for 30% of the course grade. All examinations included multiple-choice questions, true/false statements, and short-answer questions. Students completed six short-answer problem sets, three patient cases, and three concept maps, which counted for 16% of the course grade. Class average grades for the course were 84.5/110069.6 in 2015 and 81.3/110067.4 in 2016.

Student performance on a total of 225 examination and quiz questions was analyzed to evaluate whether the TLAT model improved student learning. Questions were categorized on the basis of contents, which were delivered by only lecture or by TLAT. The percentage of correct answers for each question was analyzed by Microsoft Excel. Student performance scores for 75 TLAT-based and 150 lecture-based questions were 83.3 ± 10.2 and 79.5 ± 14.0, respectively (P < 0.05, unpaired two-tailed Student’s t-test).

Students highly rated the development, teaching strategies, and implementation of the TLAT model (Table 3). The response rate for this survey was 73%. On the question, “I am clear on how I will use the information presented in this course as a pharmacist,” the response was overwhelmingly positive (98% of the students agreed or strongly agreed). Ninety-five percent of the students agreed or strongly agreed that the course learning objectives and goals were clear. More than 90% of students also agreed/strongly agreed that the course contents were highly challenging, but were also vital for pharmacy practice. A majority of students perceived that the diverse learning strategies in the TLAT model made learning fun and interactive [median response rate (interquartile range): 5 (5–4)] and helped them accommodate their learning style [median response rate (interquartile range): 5 (5–4)]. Moreover, different teaching and

Table 2. Content areas taught by the TLAT model

<table>
<thead>
<tr>
<th>Contents</th>
<th>In-Class Active Learning Activities</th>
<th>Out-of-Class Assignments and Homework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological factors affecting drug action.</td>
<td>Class discussion, think-pair share, peer teaching</td>
<td>Homework: problem-solving and self-study questions</td>
</tr>
<tr>
<td>Membrane transporters.</td>
<td>Class discussion, think-pair share, peer teaching; Group discussion (acetaminophen toxicity)</td>
<td>Homework: problem-solving and self-study questions (on-target and off-target adverse effects); Individual case study (acetaminophen toxicity)</td>
</tr>
<tr>
<td>Physiological factors affecting ADME.</td>
<td>Class discussion, think-pair share, peer teaching; Group discussion (concept map)</td>
<td>Homework: problem-solving and self-study questions (action potentials, mechanisms of arrhythmogenicity); Concept map (catecholamine synthesis, storage and release)</td>
</tr>
<tr>
<td>Pathophysiological basis of drug therapy.</td>
<td>Class discussion, think-pair share, peer teaching; Group discussion (concept maps, cases)</td>
<td>Homework: problem-solving and self-study questions (autonomic nervous system); Concept map: adrenergic pharmacology; Concept map: pharmacology of epinephrine and norepinephrine; Group cases: mushroom poisoning; tyramine toxicity and hypertensive crisis</td>
</tr>
<tr>
<td>Pathophysiology of asthma, gout, lipid abnormalities, hypertension, Parkinson’s disease.</td>
<td>Class discussion, think-pair share, peer teaching; Group discussion (concept maps, cases)</td>
<td>Homework: problem-solving and self-study questions (autonomic nervous system); Concept map: adrenergic pharmacology; Concept map: pharmacology of epinephrine and norepinephrine; Group cases: mushroom poisoning; tyramine toxicity and hypertensive crisis</td>
</tr>
</tbody>
</table>

course grade, respectively. The final examination was comprehensive and cumulative and counted for 30% of the course grade. All examinations included multiple-choice questions, true/false statements, and short-answer questions. Students completed six short-answer problem sets, three patient cases, and three concept maps, which counted for 16% of the course grade. Class average grades for the course were 84.5 ± 9.6 in 2015 and 81.3 ± 7.4 in 2016.

Student performance on a total of 225 examination and quiz questions was analyzed to evaluate whether the TLAT model improved student learning. Questions were categorized on the basis of contents, which were delivered by only lecture or by TLAT. The percentage of correct answers for each question was analyzed by Microsoft Excel. Student performance scores for 75 TLAT-based and 150 lecture-based questions were 83.3 ± 10.2 and 79.5 ± 14.0, respectively (P < 0.05, unpaired two-tailed Student’s t-test).

Students highly rated the development, teaching strategies, and implementation of the TLAT model (Table 3). The response rate for this survey was 73%. On the question, “I am clear on how I will use the information presented in this course as a pharmacist,” the response was overwhelmingly positive (98% of the students agreed or strongly agreed). Ninety-five percent of the students agreed or strongly agreed that the course learning objectives and goals were clear. More than 90% of students also agreed/strongly agreed that the course contents were highly challenging, but were also vital for pharmacy practice. A majority of students perceived that the diverse learning strategies in the TLAT model made learning fun and interactive [median response rate (interquartile range): 5 (5–4)] and helped them accommodate their learning style [median response rate (interquartile range): 5 (5–4)]. Moreover, different teaching and
learning strategies stimulated their active participation in the learning process (Table 3 and Fig. 3).

Survey questions specifically asked students about the impact of in-class activities, solving cases, developing concept maps, and homework/assignments (Table 3 and Figs. 4 and 5). The majority of the students (93%) believed that the in-class group discussion/activities enhanced conceptual understanding of course materials, helped them take responsibility for their own learning, and enhanced their overall learning experiences (Fig. 4). Over 90% of students agreed/strongly agreed that case studies focused on clinically significant learning issues and concepts. Over 80% of respondents felt that solving cases and developing concept maps helped them sharpen creative and critical thinking skills and synthesize complex clinical information. In addition, 90% of the respondents felt that the numerous amount of homework assignments throughout the semester helped them stay up to date and focused with the progress of the course (Fig. 5).

Forty-one open-ended comments from 72 respondents were recorded and subjected to thematic analysis (Table 4). Students’ comments on their learning experiences in the course were overwhelmingly positive. Two major themes emerged from these comments: enriched learning experiences and effective teaching strategies for improved student learning outcomes. The strategy of utilizing diverse teaching and learning activities was well received by students. Students indicated that the in-class active learning sessions and homework assignments were very conducive to learning and achieving course outcomes. Students also commented that the teaching strategies enriched their learning experiences, helped them learn materials, and apply them in practice. Three students indicated that individual assignments were more effective than group assignments. One student found the active learning strategies useless for his/her learning.

DISCUSSION

The overarching goal of the development and implementation of the TLAT model was to foster conceptual learning of physiology, pathophysiology, and pharmacology contents in a student centric interactive learning environment. The TLAT model integrated lecture, in-class active learning activities, and out-of-class assignments to help students see the relevance and meaningfulness of contents in real-life situations. The present study demonstrates that the TLAT method improves students’ performance in the examination, as well as improves their satisfaction and learning experiences. The results of this study suggest that the TLAT model improved students’ learning.

Students taking the course in the 2015 and 2016 spring semesters performed better in the quiz and exam questions from contents that were taught by the TLAT method compared with questions from contents taught by lecture only. However, when the comparison was made in either cohort of students (2015 or 2016), the differences were not statistically significant. Miller et al. (29) reported an 8.6% higher score with engaging lecture compared with traditional lecture. It is noteworthy that the authors compared engaged lecture by one faculty vs. traditional lecture by four different faculty members. It is likely that different teaching styles may have impacted the students’ performances, specifically in traditional lectures. In our study, although three instructors contributed in teaching the course, the principal investigator taught over 70% of the contents utilizing TLAT as well as traditional lectures. Therefore, examination and quiz questions from the principal investigator were included in this study. The smaller difference compared with the findings of Miller et al. may also be due to the teaching style of the instructor.

Despite its passive nature, traditional lecture still remains a key teaching method in professional educational settings (5, 44). A well-organized lecture allows instructors to present information from multiple sources to clarify complex concepts (26, 37). Lectures help students better understand the contents and develop comprehension and skills for outside-of-class activity (29). Indeed, a well-designed lecture may serve as a guiding tool for incorporating active learning activities in the classrooms (7). In the delivery of the Principles of Drug Action course, lecture materials and PowerPoint slides were posted on Blackboard ahead of time for students to review before lecture. The lecture contents in the areas of physiology, pathophysiology, and pharmacology were tailored not to overwhelm students with vast information and unnecessary details. Complex concepts were made simpler for students to comprehend so that they did not have to rely on memorization of facts.

Active learning is an instructional approach that encourages students to accomplish higher order objectives, such as critical analysis, synthesis, and evaluation (6). Some recent studies have documented improved student learning when different active learning methods were integrated in traditional lectures (8, 26). The active learning activities are designed to help reinforce the material presented by lecture. In the present study, we have adopted a number of active learning activities, including class discussions, group discussions, think-pair share, and peer tutoring. For example, in a lecture on pathophysiology of asthma and chronic obstructive pulmonary disease, the physiology of respiratory muscles, the mechanism of muscle contraction and relaxation, and the pathophysiology...
were presented. Then, students were engaged in think-pair
share to identify possible drug targets for the treatment of
asthma or chronic obstructive pulmonary disease. Similarly,
after a lecture on autonomic nervous system, students were
engaged in 5- to 15-min sessions of class discussion on the
physiological roles of sympathetic and parasympathetic ner-
vous systems. During the same session, student volunteers
were asked to share their answers or ideas to the whole class.
In addition, 30- to 60-min sessions of case discussion, problem
solving, and construction of concept maps were incorporated
following respective didactic lecturers for diverse content ar-
eas, as outlined in Table 2. Three cases were developed
involving contents acetaminophen toxicity, cholinergic phys-
ology and pharmacology (mushroom poisoning), and tyramine
toxicity and hypertensive crisis. Each case included a number
of questions/problems, which reflected content knowledge
from physiology, pathophysiology, pharmacology, and their
application in solving the clinical problems. Similarly, students
were engaged in the development of concept maps on the
following: 1) physiology and pharmacology of catecholamine
synthesis, storage, and release; 2) pharmacology of epinephrine
and norepinephrine; and 3) adrenergic receptor subtypes and
their pharmacology. Students were provided with written in-
structions and assessment rubrics. The classroom sessions for
cases and concept mapping were designed to stimulate group
discussions, with the instructor being served as a facilitator. In
several instances, students were provided open-ended ques-
tions to discuss among peers in the classroom settings.

The student survey responses reflected their appreciation of
how the TLAT model encouraged learning. An overwhelming
majority of students perceived that diverse learning strategies
made the learning environment encouraging and interactive
and helped them accommodate their learning style. Moreover,
the students also indicated that active learning strategies stim-
ulated active participation in the learning process and helped
them take responsibility for their own learning. These findings
are consistent with previous studies in professional schools.
Miller et al. (29) has shown that active learning strategies
enhance contextual understanding of complex concepts, facil-
itate student engagement, and promote student comprehension
and application of knowledge. A number of studies have
indicated that active learning can improve students’ compre-
hension of physiology, problem-solving skills, and critical
thinking abilities (2, 3). The use of such strategies was shown
to develop a deeper understanding of physiology concepts (23).

One of the key benefits of active learning methods is the
opportunity of conducting formative assessment of student
progress (38). Gleason et. al. (12) have shown that multiple
2-min breaks during lecture allowed students to work in pairs
and compare their lecture notes, which improved retention of
Lectures with peer-instruction pauses increase student recall and comprehension compared with traditional lectures (57). Peer instruction in a medical course enhanced student learning, increased the ability to solve novel problems, and improved performance on examinations (34). Case-based learning in medical physiology has been reported to foster self-directed learning and develop soft skills (10). In a pharmaceutics course, implementation of “quick thinks” activity into lectures every 15 min and case-based learning enhanced student outcomes, improved problem-solving ability, and fostered critical-thinking ability (35). Similarly, a learner-led, discussion-based, active learning strategy significantly enhanced students’ interest and overall performance in an elective course on emerging infectious diseases (27). Classroom sessions of student-generated test questions following a lecture improved students’ learning experiences in a PharmD elective course (16). In-class case discussions in a Clinical Pharmacokinetics course increased students’ satisfaction as well as performance in the course (7).

One important aspect of our study was to incorporate out-of-class individual or group assignments in the form of case studies, concept mapping, and problem-solving study questions on contents covered during in-class lectures. Following a classroom discussion and exploration of the concepts, students were asked to continue working on the problems outside of class. For the case studies, students were required to provide

Table 3. Students’ perception of blended teaching strategies

<table>
<thead>
<tr>
<th>Survey Questionnaires</th>
<th>Response Rate Median (IQR: 75–25%)*</th>
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<tbody>
<tr>
<td>1. Course learning objectives were clear to me.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>2. I found the course contents highly challenging, but very vital for my success as a future pharmacist.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>3. Diverse teaching and learning strategies in this course made learning fun and interactive.</td>
<td>4.5 (5–4)</td>
</tr>
<tr>
<td>4. Different teaching and learning strategies in this course helped to accommodate my own learning style.</td>
<td>4 (5–3)</td>
</tr>
<tr>
<td>5. In-class group discussion helped me put together my thoughts for conceptual understanding of materials</td>
<td>5 (5–3)</td>
</tr>
<tr>
<td>6. In-class group activities encouraged me to ask questions of my peers as well as instructor for clarification of concepts.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>7. Case studies in this course focused on clinically significant learning issues and concepts.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>8. Solving cases and developing concept map helped refine my creative and critical thinking skills.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>9. Solving cases and developing concept map enabled me to synthesize complex, but clinically meaningful, information.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>10. Numerous homework assignments throughout the course kept me up to date and focused on the progress of the course.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>11. Active learning strategies helped me to take responsibility for my own learning.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>12. The assessment methods (tests, quizzes, case studies, projects/assignments, concept mapping) accurately evaluated the contents of the course.</td>
<td>5 (5–4)</td>
</tr>
<tr>
<td>13. Overall, diverse teaching strategies in this course enhanced my learning experiences.</td>
<td>5 (5–4)</td>
</tr>
</tbody>
</table>

n, No. of respondents. IQR, interquartile range. *Differences in response rates from two cohorts of students were not statistically significant.

Fig. 3. Student perceptions of the overall course. Student perceptions were self-reported on a 5-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. For data analysis, respondents’ scores were combined for 1) strongly agree and agree, and 2) strongly disagree and disagree.

Fig. 3. Student perceptions of the overall course. Student perceptions were self-reported on a 5-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. For data analysis, respondents’ scores were combined for 1) strongly agree and agree, and 2) strongly disagree and disagree.
Active learning strategies helped me taking responsibility of my own learning.

In-class group activities encouraged me to ask questions to my peers as well as instructor for clarification of concepts.

In-class group discussion helped me put together my thoughts for conceptual understanding of materials.

Numerous homework throughout the course helped me keep up-to-date and focused with the progress of the course.

Solving cases and developing concept map enabled me synthesize complex, but clinically meaningful information.

Solving cases and developing concept map helped refine my creative and critical thinking skills.

Case studies in this course focused on clinically significant learning issues and concepts.

Fig. 4. Student perceptions of in-class active learning strategies used in the TLAT model. Student perceptions were self-reported on a 5-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. For data analysis, respondents' scores were combined for 1) strongly agree and agree, and 2) strongly disagree and disagree.

Fig. 5. Student perceptions of out-of-class homework, case studies, and concept mapping used in the TLAT model. Student perceptions were self-reported on a 5-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. For data analysis, respondents' scores were combined for 1) strongly agree and agree, and 2) strongly disagree and disagree.

background information on the cases, identify the clinical problem, and provide a reasonable solution to the problem. Similarly, to complete the concept map, students linked concepts of biochemistry, physiology, medicinal chemistry, and pharmacology to solve clinical problems. Out-of-class assignments were carefully designed to enhance deeper learning through linking new knowledge with existing knowledge and integrating basic science concepts to clinical problems. Literature on the efficacy of homework assignments and academic performance is mixed. In a rigorous and comprehensive meta-analysis, Copper et al. (6) found homework as being beneficial for student achievement in upper grades more than elementary grades in K–12 education. There is limited literature on the influence of homework in professional education. Computer-guided homework and assigned reading were utilized in teaching pathology to undergraduate and graduate allied health professional students (9). An integrated homework assignment on pharmaceutics and pharmacotherapeutics has been found to be an effective means of demonstrating the connection between specific pharmaceutics concepts and practice applications to pharmacy students (47). However, Rehfeldt et al. (36) found that the effects of homework assignments and quiz performance was relatively minor. In our present study, we found that over 90% of the respondents felt that homework assignments were helpful to keep them focused on the course materials. In addition, an overwhelming majority of the students felt that solving cases and developing concept maps outside of class helped them sharpen creative and critical thinking skills and synthesize complex clinical information. The use of case studies promotes application of basic science knowledge to clinical practice and deeper understanding of content (46). Research in medical education suggests that case discussions with appropriate feedback facilitate the development of reflective thinking, deeper conceptual understanding, and clinical reasoning (50). Researchers have recognized concept maps as being an important educational tool in healthcare education. Concept maps have been widely utilized for helping students organize their knowledge structures for conceptual understanding (45, 53–55). The use of concept maps has been shown to increase student performance and satisfaction in learning physiology concepts among first-year medical students (52). Similar observations were made among pharmacy students when the concept map was used as a learning tool (14, 31).

Studies have shown a multitude of challenges and barriers in the implementation of active learning strategies that include faculty buy-in, lack of faculty interest, significant time commitment for preparation of active learning activities, and, finally, balancing the time and depth of content to be covered (42).

Conclusion. In conclusion, it was found that the use of the TLAT model led to a significant improvement in student performance on quizzes and examinations. Moreover, the re-
The results of this study suggest that class lectures with embedded in-class active learning activities and out-of-class homework assignments, when combined, may improve student learning, self-responsibility, and attitudes toward learning in professional schools. This indicates a need for an increased emphasis on in-class active learning activities and out-of-class assignments in the curricular delivery in pharmacy schools. We believe that the TLAT model can be adopted by instructors in similar courses in other professional programs.

**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the author(s).

**AUTHOR CONTRIBUTIONS**

M.A.I. and F.F. conceived and designed research; M.A.I. performed experiments; M.A.I., G.S., and F.F. analyzed data; M.A.I., G.S., and F.F. interpreted results of experiments; M.A.I. and G.S. prepared figures; M.A.I. drafted manuscript; M.A.I., G.S., and F.F. edited and revised manuscript; M.A.I., G.S., and F.F. approved final version of manuscript.

**REFERENCES**


### Table 4. Thematic analysis of students’ open-ended comments

<table>
<thead>
<tr>
<th>Themes</th>
<th>No. of Citations</th>
<th>Representative Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyable learning experience</td>
<td>12</td>
<td>I enjoyed making concept maps and doing in-class activities. The course was interesting and added a lot to my knowledge. I really enjoyed this method of teaching. Thank you Dr. Islam! I hope other teachers can try this method as well. I enjoyed this class very much, and it sparked my interest in pharmacology. The subject was very interesting and even more so when you helped us by using these learning strategies. I also enjoyed all the different styles in teaching, since they made learning fun and made me retain more of the information. I really liked the in-class activity; it gave me an opportunity to evaluate my understanding. The course design was very interesting to learn. I enjoyed the class very much. Thank you. This was one of my favorite classes this semester as it was very interactive and interesting.</td>
</tr>
<tr>
<td>Effective teaching and learning strategies</td>
<td>25</td>
<td>I got to find good study skills for myself. I found my best way to learn and study. It was very helpful at least to me. I got to know how I can study with less time and faster and easier ways, in drug action class. Those in-class activities, concept maps, and homework really helped me to understand the materials in class. Very engaging teaching style, makes me want to come to class and pay attention. Very conducive to learning the outcomes and objectives. We appreciate you helping us apply these skills as a group and individually. I loved it!! It definitely helped me! I really liked the in-class-activity; it gave me an opportunity to evaluate my understanding. The homework and class activities were very effective in the learning process of the students. Overall, this is a great course. It helps me understand the clinical aspects of the cases/concept. The teaching style is easy to understand and very clear. This class, with its variety of teaching strategies, was effective in helping me learn material that I can definitely apply in practice and will not easily forget. I appreciated the in-class assignments as well as homework because they reflected the course material perfectly and were a great study guide for the tests.</td>
</tr>
<tr>
<td>Skeptical about group work</td>
<td>5</td>
<td>The group working in class is very helpful. The group work assignments are helpful as long as the importance of group working means to all the groupmates. I don’t believe making the case studies were useful as a group exercise. They were helpful individually. Group working was not very helpful for my learning. Did not learn well with group case studies, but individual case studies were very helpful!</td>
</tr>
<tr>
<td>PowerPoint lecture was helpful</td>
<td>2</td>
<td>PowerPoints displayed mostly diagrams, which I loved, since I am a visual person. The slides had many pictures, flowcharts, and charts on it, which was also a great help.</td>
</tr>
</tbody>
</table>
Features and uses of high-fidelity medical simulations that lead to effective learning.


West DC, Pomeroy JR, Park JK, Gerstenberger EA, Sandoval J. Critical thinking in graduate medical education: A role for concept...


