INSTRUCTIONAL DESIGN AND ASSESSMENT

An Active-Learning Assignment Requiring Pharmacy Students to Write Medicinal Chemistry Examination Questions

Srikanth Kolluru, PhD

Texas A & M Health Science Center, Rangel College of Pharmacy, Kingsville, TX

Submitted February 13, 2012; accepted March 17, 2012; published August 10, 2012.

Objectives. To implement and assess the effectiveness of an assignment requiring doctor of pharmacy (PharmD) students to write examination questions for the medicinal chemistry sections of a pharmacotherapeutics course.

Design. Students were divided into groups of 5-6 and given detailed instructions and grading rubrics for writing multiple-choice examination questions on medicinal chemistry topics. The compiled student-written questions for each examination were provided to the entire class as a study aid. Approximately 5% of the student-written questions were used in course examinations.

Assessment. Student appreciation of and performance in the medicinal chemistry portion of the course was significantly better than that of the previous year's class. Also, students' responses on a qualitative survey instrument indicated that the assignment provided students' guidance on which concepts to focus on, helped them retain knowledge better, and fostered personal exploration of the content, which led to better performance on examinations.

Conclusion. Adding an active-learning assignment in which students write examination questions for the medicinal chemistry portion of a pharmacotherapeutics course was an effective means of increasing students engagement in the class and knowledge of the course material.

Keywords: examination, active learning, medicinal chemistry

INTRODUCTION

Actively engaging millennial students in the classroom and involving them in a course beyond the classroom has been a challenge to the teaching community, including pharmacy educators. The Accreditation Council for Pharmacy Education (ACPE) guidelines 10.2 and 11.2 emphasize the need for pharmacy faculty members and preceptors to incorporate newer active-learning strategies to improve the critical-thinking and problem-solving skills of these students.¹ Active learning has been a buzz word since the 1980s and there is a plethora of literature published on this topic.²⁻⁷

Over time, pharmacy colleges and schools across the country have developed several active-learning strategies to engage students in the classroom, such as think-pair-share, classroom discussions, minute papers, student debates, and class games.⁸ Active learning is superior to passive learning, but student engagement in the learning process is still lacking in many of the implemented active-learning

strategies.⁹ "Learning by teaching" is one of the successful teaching strategies that was introduced in some German schools to better engage students in the active-learning process. In this approach, learners perform teaching-related activities. This guided active-learning process is an efficient learning strategy that improves student investment in the course.¹⁰

In this study, we followed a "learning by teaching" approach that involved students writing multiple-choice examination questions, a task usually performed by the instructor. The major objectives of this study were to increase student appreciation for medicinal chemistry; provide an additional study platform to improve student learning; and engage students in teaching-related activities.

DESIGN

At the Texas A & M Health Science Center College of Pharmacy, there is no separate medicinal chemistry course that relates directly to disease states. Instead, all disease states are taught in 8 integrated pharmacotherapy courses. In each of these integrated courses, physiology, pharmacology, medicinal chemistry, and pharmacotherapy are taught sequentially for a given disease. The active-learning exercise presented in this paper was instituted in

Corresponding Author: Srikanth Kolluru, PhD, Assistant Professor, Texas A & M Health Science Center, Rangel College of Pharmacy, 1010 West Avenue B, MSC 131, Kingsville, TX 78363. Tel: 361-593-3034. Fax: 361-593-4303. E-mail: kolluru@pharmacy.tamhsc.edu

the medicinal chemistry component of the Integrated Pharmacotherapy VI course during fall 2011. This is a 5-credit-hour course with 15 hours assigned to the medicinal chemistry component. Topics covered included anti-inflammatory drugs, asthma, chronic obstructive pulmonary disease, allergic rhinitis, benign prostatic hyperplasia, erectile dysfunction, urinary incontinence, arthritis and gout, and peptic ulcer disease.

All students enrolled in the Integrated Pharmacotherapy VI course in fall 2011 were divided randomly in to 15 groups (5 to 6 students per group) at the beginning of the semester and each group was assigned 1 lecture for which to construct multiple-choice examination questions. All students were provided detailed instructions for constructing the examination questions (Appendix 1). To construct more meaningful questions, students were encouraged to make notes and consider the most-stressed points in class. Each group was asked to write 5 or 6 examination questions depending on the number of students in the group. After constructing the questions, the students had to match each question with 1 or more of the provided learning objectives and justify all right and wrong answer choices for the question. Each group member was responsible for evaluating all of the group's questions for accuracy and completeness. The students submitted the completed assignment using Blackboard (Blackboard Inc., Washington, DC) for a group grade. Students were required to write questions and submit their assignment within 48 hours of their assigned lecture.

Accuracy and completeness of the student-submitted questions as well as feedback for all choices were graded based on the rubric provided in Table 1. Points were deducted for any missing or wrong information. None of the questions submitted by the students was discarded;

instead, faculty members provided any additional and/or missing information to make each question a useful study tool for students. Although some of the questions required significant modification and faculty comments, all questions were graded as this was a learning activity.

Before each examination, faculty members provided copies of each group's corrected student-written questions and related faculty feedback to the entire class as a study guide. This was a guided assignment, with all rubrics and instructions provided to students at the beginning of the course. Once students submitted their questions with explanations for correct and wrong choices, the assignment was graded and all questions and feedback were supplied to the entire class. About 5% of student-written questions were used in each examination to motivate all students to become involved in this exercise, making it a good learning activity. Student performance on examinations was significantly improved with this activity when compared with previous year's students who had not participated in this exercise. Students also expressed that this exercise helped them improve their learning, study habits and examination preparation.

EVALUATION AND ASSESSMENT

Course Examinations

The medicinal chemistry questions written by the students counted about 5% of the total grade for the examination. The medicinal chemistry portion of the course was assessed through 4 examinations, each of which covered 1 or more diseases depending on the amount of content. Approximately 4-5 medicinal chemistry lectures were covered in each examination. A student group number was attached to the questions that were used in the examinations to give the students authorship. All student questions were weighted a half point on examinations, whereas faculty-written questions were weighted 1 point. The point value of student questions was intentionally kept low to encourage students to read all the questions sent back to them more thoroughly. The intent was that after students read these questions and the faculty feedback on right and wrong answer choices, they would have a better understanding of the subject material and perform better on these questions on the examination as well as questions written by faculty members.

All examinations included questions from each of the disciplines (pathophysiology, pharmacology, medicinal chemistry, and therapeutics) covered in the Integrated Pharmacotherapy VI course. All examinations during fall 2011 and fall 2010 used only multiple-choice questions. To make meaningful comparisons and assess student learning, student performance on the medicinal chemistry portion of each examination in fall 2011 and 2010 was

Table 1. Demographics of Pharmacy Students Enrolled in the Fall 2011 and Fall 2010 Classes

	Fall 2011	Fall 2010
Class size	79	89
Average age, yrs	24	23
Age range, yrs	18-44	18-35
GPA	3.3	3.4
Gender, %		
Male	52	53
Female	48	47
Ethnicity, %		
Asian	34	37
Black	6	2
Hispanic	25	28
White	33	31
Other	2	2

separated from that for the rest of the examination. The performance of fall 2011 students was then compared with that of fall 2010 students who did not complete the question-writing assignment. The remainder of the course was delivered similarly for both years, followed similar syllabi, and had the same learning objectives. A similar number of medicinal chemistry questions were used in each of the 4 examinations administered in fall 2010 and fall 2011. Examination 1 covered peptic ulcer disease; examination 2 covered arthritis and gout; examination 3 covered asthma, chronic obstructive pulmonary disease and allergic rhinitis; and examination 4 covered benign prostatic hyperplasia, erectile dysfunction and urinary incontinence. The student demographics for fall 2010 and 2011 were similar (Table 2). Students' scores on student-written questions in 2011 were not included in data analysis so that a true comparison of performance between classes could be made.

The mean examination scores of students who completed the course in fall 2011 were approximately 10% higher than those of students who completed the course in fall 2010 (Figure 1). As determined by student *t* test, the average course grade of students in the fall 2011 course was significantly higher than that of students in the fall 2010 course ($p = 0.002$).

Students' perceptions of the usefulness of this learning activity were also assessed using a specially developed survey instrument.¹¹ A rating scale of 1 to 5 was used, with 1 indicating the least amount of agreement and 5 indicating the greatest amount of agreement with the survey statements (Table 3). The survey instrument also included an open-response item to find out in what other ways this active learning assignment had helped their learning and to give them an opportunity to provide

suggestions to improve this activity. The survey was conducted after all groups submitted their assignments and all examinations were completed. Students were asked to read a consent information form before participating in the survey and could indicate that they were not interested in participating in the study.

Eighty-eight percent of the fall 2011 class participated in the survey. Students perceived that the "learning by teaching" exercise helped to improve their learning in several ways. The mean responses to all survey statements were 4.5 or higher, indicating that this activity was well-received by students.

The majority of students agreed that "learning by teaching" was a novel idea, that the instructions given were easy to follow, that writing questions was a reasonable faculty expectation of the students, and that the faculty comments provided useful information. They strongly recommended that the exercise be included in the course in the future as well as in other courses in the curriculum.

The majority of the students (over 85%) felt that this exercise was helpful in preparing for examinations, provided guidance on concepts that they needed to focus on, helped retain knowledge better, and fostered personal exploration of the content, which eventually led to better performance on examinations. This is also evident from the significantly higher examination scores compared with the previous year's class.

Students indicated that the process of writing examination questions, required them to explore the content more deeply and therefore learn the material better. The exercise also provided good reinforcement of the material covered in class. Several students indicated in the comments section of the survey that while medicinal chemistry

Table 2. Grading Rubric for Student-Written Examination Questions^a

Criteria	Excellent (8)	Good (6)	Poor (4)
Completeness of the question	1. Followed directions provided 2. Matches the question with objectives provided 3. Identifies which portion of the lecture the question was derived. 4. Have single best answer and all other distractors are completely wrong	Followed half or more of the instruction provided under "excellent" column but not all.	Missed most of the directions in writing the questions
	Usable (2)	Not usable (0)	
Usability	1. Question does not ask minute details 2. Includes options of similar length 3. Feedback provided for correct answer 4. Usable for a quiz or an exam	1. Includes minutes details and no feedback provided 2. Not usable	N/A

^a Student-written questions were graded on a 10-point scale. Completeness was worth a maximum of 8 points and usability was worth a maximum of 2 points.

Figure 1. Student performance in medicinal chemistry component of all examinations in the Integrated Pharmacotherapy VI course during fall 2010 and fall 2011.

was their weakness, this exercise helped them to better understand the concepts and improve their grades.

Students felt that the concepts that were harder to understand were made easier through the faculty explanations provided for each question. It also motivated them to study the material, as they knew that some of

the questions would appear on examinations. One student commented that writing and reviewing questions provided her an opportunity to look at the material as a professor would in preparation for the examination.

Some students indicated how difficult it was to construct relevant questions and plausible but incorrect answers as well as the correct answer. Overall students indicated that this activity was a great learning tool that created interest in the course, helped them to better understand and retain subject material, and eventually perform better in the examinations.

DISCUSSION

Course outcomes and student performance improved as a result of a student-generated examination question assignment. Multiple-choice questions may not always adequately assess all levels of cognitive learning unlike open response questions. However, assessing large classes with open-response questions is challenging as these examinations take an enormous amount of faculty time to grade. Multiple-choice questions can be used to promote

Table 3. Student Survey on Learning After Experiencing Student-Written Medicinal Chemistry Examination Questions Assignment

Statement	Students Choosing This Response, No. (%) ^a						Mean
	1	2	3	4	5	UA	
I like the idea of writing exam questions by the students	1 (1.4)	1 (1.4)	0	6 (8.5)	62 (87.3)	1	4.8
I would recommend this activity again in the future	2 (2.8)	0	1 (1.4)	4 (5.6)	64 (90.1)	0	4.8
Writing exam questions by the students is a reasonable expectation by the faculty	0	2 (2.8)	4 (5.6)	14 (19.7)	51 (71.8)	0	4.6
Writing exam questions by the students with 24-48 hours of lecture delivery was a reasonable expectation	0	1 (1.4)	3 (4.2)	10 (14.1)	55 (77.5)	2	4.7
Instructions given were easy to follow	0	2 (2.8)	4 (5.6)	15 (21.1)	50 (70.4)	0	4.6
Comments provided by the faculty were helpful in understanding the material better	0	1 (1.4)	5 (7.0)	12 (16.9)	53 (74.6)	0	4.6
Explanations on right/wrong answers for each question helped me understand material better	0	1 (1.4)	9 (12.7)	14 (19.7)	47 (66.2)	0	4.5
I am able to score better due to the student written questions and at the same time I did learn the material	1 (1.4)	1 (1.4)	0	6 (8.5)	63 (88.7)	0	4.8
Writing exam questions by the students is helpful in preparing for the exams	1 (1.4)	0	0	10 (14.1)	60 (84.5)	0	4.8
Writing exam questions by the students provides me guidance about the concepts that I need to focus	1 (1.4)	1 (1.4)	2 (2.8)	10 (14.1)	57 (80.3)	0	4.7
Writing exam questions by the students helps me to retain the knowledge from comprehensive material better	2 (2.8)	1 (1.4)	5 (7.0)	15 (21.1)	47 (66.2)	1	4.5
Writing exam questions by the students is a meaningful learning activity	1 (1.4)	1 (1.4)	2 (2.8)	18 (25.4)	49 (69.0)	0	4.6
Writing exam questions by the students fostered personal exploration of content	0	0	6 (8.5)	20 (28.2)	45 (63.4)	0	4.5

Abbreviations: UA = unanswered.

^a Responses were based on a 1-5 rating scale, on which 1 was least agreeable and 5 was strongly agreeable. The number under the rating column indicates the number of students who picked that option and the number within the parentheses is the corresponding percentage of students.

active learning and higher-order thinking when they are written effectively.¹¹⁻¹⁶ In the current study, detailed instructions were given to students for writing effective multiple-choice questions (Appendix 1).

The current study demonstrates a strategy to use multiple-choice questions to improve student learning. Approximately 85%-90% of the students agreed or strongly agreed (rating scale 4 and 5 combined) that this activity was well designed, well delivered, useful for learning, and resulted in better performance on the examinations. The assignment component of this activity counted less than 1% of the course grade. Although the assignment was low stakes, the students participated in this activity because of its usefulness. All students received the corrected assignment with detailed feedback to all answer choices. Explanations provided for each question for correct and wrong answers provided further insight into how the correct answer was the best choice. Students were motivated to participate because they saw the usefulness of this instrument in the learning process and in performance on the examinations.

All students were informed that they could take notes on the concepts presented during class and provide ideas for constructing quality questions to the assigned group. As a result, student engagement in the classroom improved. This process encouraged active learning, which is heavily emphasized by ACPE, and is an appropriate learning method for millennial students.

Students were informed that if they did not write questions that followed the instructions provided for constructing effective multiple-choice questions, their questions might not be included on the examination. Adherence to the guidelines resulted in a significant number of high-quality questions written by the students. One of the challenges faced by the faculty member was to create examination questions different from the student-written questions. Most of the concepts were covered in the student-written questions and in their explanations, and as a result, studying the questions and answers written by their peers made it easier for them to correctly answer the faculty-written questions on the same topic. When students wrote a question on any concept, it forced other students to focus on that material and the question itself served as a starting point toward understanding the concept. In addition, this exercise provided an additional platform and a good starting point for students to begin their study for the examinations. At the same time, students were more involved with the course content and understood the material better, which was reflected in their survey responses.

Medicinal chemistry is, in general, viewed by pharmacy students as a difficult subject to understand. It is a challenge for faculty members to show students

the importance of basic sciences in pharmacy education;¹⁷ hence, there is a general lack of interest in basic science courses among pharmacy students. Faculty members are always looking for effective ways to better engage students in the subject and improve their understanding.¹⁸⁻²⁰ This activity encouraged students to study and understand the material better than an assignment requiring memorization of facts. Although only 15 medicinal chemistry lectures were used for this active-learning exercise, it provided interesting data regarding student performance and was well supported by students. Students were able to learn the medicinal chemistry material better through a combination of studying the lecture material with student-written examination questions. The student-written questions also served as a practice examination.

On average, it took 30-45 minutes to grade every 5 questions submitted by the students. However, it was worth the effort especially after seeing student perceptions of this activity and their examination performance, in terms of how it helped in learning the material better. It also engaged students with the course much deeper and made them feel like they were well-connected with the course content. Expanding the exercise to encompass all course content might benefit students even more. It could be challenging to administer such an exercise in integrated courses taught by multiple instructors, as the feedback provided by different faculty members might vary significantly. Coordinating faculty members from different disciplines could also be challenging. Nevertheless, it would be possible to implement this assignment in a multi-instructor taught course by providing detailed instructions to the faculty members. To further improve the effectiveness of this activity, the order of the answer choices for the student-written questions should be scrambled to prevent memorization as mentioned by a few students in the survey responses. Submitting questions within 48 hours after the lecture delivery was challenging for a few students.

CONCLUSION

An exercise that required students to write examination questions was effective not only as a graded group assignment, but also as a tool to encourage classroom engagement and as a study aid for examinations. Writing the questions provided an ideal platform for "learning by teaching" where students assumed the role of an instructor. The questions generated through this assignment helped students in several ways such as serving as a study guide for examinations, leading them to understand difficult material better, reinforcing concepts learned in class, etc. Many students felt that this exercise was a novel idea and recommended implementing it in other courses. The

assignment also led students to be engaged more actively in class as they were listening to identify possible concepts for which to write quality questions. This activity could also be used in other courses across the pharmacy curriculum.

ACKNOWLEDGEMENT

The author thanks Dr. Thomas L. Lemke, Professor Emeritus, University of Houston, for editing this manuscript.

REFERENCES

1. Accreditation Council for Pharmacy Education. Accreditation Standards. https://www.acpe-accredit.org/pdf/S2007Guidelines2.0_ChangesIdentifiedInRed.pdf. Accessed May 20, 2012.
2. Ernst H, Colthorpe K, Expanding voluntary active-learning opportunities for pharmacy students in a respiratory physiology module. *Am J Pharm Educ*. 2008;72(2):Article 28.
3. Timpe EM, Motl SE, Eichner SF, Weekly active-learning Activities in a drug information and literature evaluation course. *Am J Pharm Educ*. 2006;70(3):Article 52.
4. Karimi R, Arendt CS, Cawley P, et al. Learning bridge: curricular integration of didactic and experiential education. *Am J Pharm Educ*. 2010;74(3):Article 48.
5. Devraj R, Butler LM, Gupchup GV, Poirier TI. Active-learning strategies to develop health literacy knowledge and skills, *Am J Pharm Educ*. 2010;74(8):Article 137.
6. Sibbald D. Virtual interactive case tool for asynchronous learning: PBL students develop online resource for non-prescription drugs. *Am J Pharm Educ*. 2003;67(1):Article 19.
7. Dupuis RE, Persky AM, Use of case-based learning in a clinical pharmacokinetics course. *Am J Pharm Educ*. 2008;72(2):Article 29.
8. Stewart DW, Brown SD, Clavier CW, Wyatt J. Active-learning processes used in US pharmacy education. *Am J Pharm Educ*. 2011;75(4):Article 68.
9. Anita H, Sanjeev K, Surekharani C, Manjul R, Shailaja P. Active learning by play dough modeling in the medical profession, *Adv Physiol Educ*. 2011;35(2):241-243.
10. Martin JP, Oebel G. Lernen durch Lehren: Paradigmenwechsel in der Didaktik? In: *Deutschunterricht in Japan*; 2007. Zeitschrift des Japanischen Lehrerverbandes. http://www.developingteachers.com/articles_tchtraining/koblenzpf_jody.htm. Accessed May 20, 2012.
11. Pittenger AL, Lounsbery JL. Student-generated questions to assess learning in an online orientation to pharmacy course. *Am J Pharm Educ*. 2011;75(5):Article 94.
12. Nicol D. E-assessment by design: using multiple-choice tests to good effect. *J Furth High Educ*. 2007;31(1):53-64.
13. Fellenz MR. Using assessment to support higher level learning: the multiple choice item development assignment. *Assess Eval High Educ*. 2004;29(6):703-719.
14. Woodford K, Bancroft P. *Multiple Choice Questions Not Considered Harmful*. Conferences in Research and Practice in Information Technology. Vol. 42. Alison Young and Denise Tolhurst, Eds. <http://crpit.com/confpapers/CRPITV42Woodford.pdf>. Accessed May 20, 2012.
15. Teaching large classes at VCU. Resource guide: testing and assessment: multiple choice exams. http://www.vcu.edu/cte/resources/tlc/4_2_multiple_choice_exams.htm. Accessed May 20, 2012.
16. Faculty Resources quick tips, Park University. <http://captain.park.edu/facultydevelopment/multiple-choice.htm>. Accessed May, 20, 2012.
17. Alsharif NZ, Galt KA. Evaluation of an instructional model to teach clinically relevant medicinal chemistry in a campus and a distance pathway. *Am J Pharm Educ*. 2008;72(2):Article 31.
18. Roche VF. Utilizing chemical knowledge in rational therapeutic decision-making. *Am J Pharm Educ*. 1985;49:154-157.
19. Dimmock JR. Problem solving learning: applications in medicinal chemistry. *Am J Pharm Educ*. 2000;64(1):44-49.
20. Webster AA, Riggs RM. A quantitative assessment of a medicinal chemistry problem-based learning sequence. *Am J Pharm Educ*. 2005;70(4):Article 89.

Appendix 1. Student instructions for writing multiple-choice questions.

1. Questions should be derived from one or more of the learning objectives presented in the class.
2. All questions needed to be written in a multiple choice format with 4-5 choices on the assigned topic.
3. Single best answer is always better in writing good questions.
4. If you CANNOT create five choices with four distractors for a given question, you can go one less, than throwing in a choice which might not distract anybody.
5. Avoid the following types of questions in the exams (most competitive exams try to stay away from such questions)
 - a. Avoid True/False questions (when the answer is unknown to the student it gives the student a 50% of the chance to getting it right leading to poor question discrimination).
 - b. Avoid K-type questions (Examples given below)

Which of the following are muscle relaxants:

 1. Atracurium
 2. Vecuronium
 3. Mivacurium
 4. Valium

A. Choices 1,2 and 3 are correct.
B. Choices 1 and 3 are correct.
C. Choices 2 and 4 are correct.

- D. Only choice 4 is correct.
- E. All choices are correct.

Which of the following are muscle relaxants:

- A. Atracurium
- B. Vecuronium
- C. Mivacurium
- D. Choices 1 and 3 are correct
- E. All choices are correct.

6. Avoid “All the above” or “none of the above” choices (using these foils, it only takes student to know two of the choices to be either right or wrong to get the answer right)
7. Try to avoid questions like the following
 - a. Which of the following statements is correct or wrong (false)?
In using this kind of statements in the questions “which is NOT” directed in testing particular concept, is unfair for the students to know whole chapter to answer one question), instead covert your question as following.
 - b. Which of the following statements in relation to **mechanism of action of Morphine** is correct?
The above question makes more sense than the previous because it tests the particular concept in the topic and what they know not what they don’t know.
8. SAR and metabolism should accompany structures. Free chemistry software can be downloaded from the following Web site (http://www.chem.orst.edu/courses/ch361-464/ch361/free_chemistry_drawing_software.htm). You can also download chem draw software for two week free trial.
9. Here is an example of med chem question based on SAR
Replacing with which of the following substituents at both R₂ and R₃ (general structure provided below) would result in an inactive muscarinic antagonist?

- a. Phenyl
 - b. Naphthyl**
 - c. Cyclohexyl
 - d. Cyclopentyl
10. Not all medicinal chemistry questions necessarily accompany structures. At least half of the questions submitted by each group must accompany structures if not all.
 11. You will have 0.75% of course grade assigned to this assignment.
 12. While working in groups, make sure all questions are sufficiently different and usable on the exams.
 13. It is also groups responsibility to check each other’s questions and make sure everyone understands what others wrote and be able to explain
 14. One student written question from each group will be used on the exams. Include your group number next to each question
 15. You are required to submit your questions 48 hours after your assigned lecture is delivered