RESEARCH

Redesigning a Pharmacology Course to Promote Active Learning

Daniel R. Kennedy, PhD

Western New England University, College of Pharmacy and Health Sciences, Springfield, Massachusetts
Editorial Board Member, *American Journal of Pharmaceutical Education*, Arlington, Virginia

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Objective. To incorporate active-learning sessions into a lecture-based pharmacology course, assess the impact on student learning and attitudes, and address commonly perceived barriers to implementing active learning.

Methods. Prior to the redesign, the course met twice a week for 75 minutes. As part of the redesign, the two weekly lecture sessions were reduced to 50 minutes each. Additionally, students were assigned to one of three sections that met separately once a week for a 50-minute recitation session in which they applied course concepts to cases, problems, and situations. Data from the two years before the redesign and two years after it were assessed.

Results. Students' average course grade increased 2.5% after the redesign. Average ratings of the course and instructor on student evaluations each increased significantly (around 0.3 points on a 5-point scale).

Conclusion. Student knowledge and performance in a pharmacology course increased when a portion of the time previously devoted to lecture was replaced with an active-learning session. This experience can serve as a blueprint for how to convert a lecture-only course into a hybrid lecture and recitation model.

Keywords: pharmacology, biological sciences, active learning, curriculum, recitations

INTRODUCTION

While lecturing remains the main method of content delivery in pharmacy education, there has been a push over the past decade to implement active learning in the classroom.^{1,2} Thus, active learning has been the subject of many pharmacy education seminars, workshops, and conferences. At its most basic, active learning can be defined as introducing activities into the traditional lecture. However, active learning has become a broad, catchall term that encompasses everything from two-minute activities such as "think-pair-share" or "clickers" to team-based or problem-based learning that replaces the traditional lecture format entirely.³ In a recent meta-analysis of 225 science, technology, engineering, and math (STEM) courses, students' average examination scores improved by 6% after the introduction of active-learning sessions, while students in courses with traditional lectures were 1.5 times more likely to fail the course.⁴ Health care educators have become increasingly interested in using

active-teaching methods to deliver course content, moving away from the lecture models that have dominated health care education over the past century.⁵ While active-learning methodologies, such as team-based or problem-based learning, are now the predominant method of content delivery throughout entire departments and programs at some institutions,⁶⁻⁸ other institutions have only recently explored the challenges of implementing such methods.^{9,10} In light of the benefits of active learning, numerous articles have been published over the past few years to help faculty members add active learning to their courses in a general way^{11,12} or to add specific activities for a given course sequence.¹³⁻¹⁵ Active-learning methods for delivering large amounts of content in elective courses have also been explored.¹⁶⁻¹⁸ However, the use of active methods of delivering content in required pharmaceutical sciences courses is less common, and much of the published work in this area has been in pharmacokinetics. Persky and colleagues examined the impact of converting a large, lecture-based pharmacokinetics course into small groups and implementing games, multimedia modules, and reflective writing.^{19,20} They later conducted an eight-year retrospective study of this course, which ultimately transitioned to a team-based learning format.²¹ Other examples include converting to

Corresponding Author: Daniel R. Kennedy, Department of Pharmaceutical & Administrative Sciences, College of Pharmacy and Health Sciences, Western New England University, 1215 Wilbraham Rd., Springfield, MA 01119. Tel: 413-796-2413. E-mail: dkennedy@wne.edu

a process-oriented guided-inquiry learning (POGIL) format,²² and a problem-based learning format in medicinal chemistry courses,²³ and to a POGIL format in an introductory course in pharmaceutical sciences.²⁴

Despite the available evidence and literature, faculty members, especially those within the pharmaceutical sciences,²⁵ often struggle to implement active learning in their own classes. The challenges and concerns of implementing active learning in the classroom include faculty members' fears that not all course material will be covered, students may miss learning essential material if it is not "handed to them on a slide," ratings on individual course or instructor evaluations may drop, and they will feel resentment or criticism from colleagues for not lecturing.²⁶ A 2013 survey of 218 members of the Biological Sciences Section of the American Association of Colleges of Pharmacy (AACP) found that almost 80% of respondents spent the majority of their time in the classroom lecturing, despite that only 15% preferred lecture-based teaching over other approaches.²⁷ The difference between professors' preference for active content-delivery and what they actually did in the classroom was striking²⁷ and reinforced the idea that significant hurdles remain to incorporating active learning within these subjects. A 2011 study found that faculty members in basic and pharmaceutical sciences were three times less likely than social/administrative sciences or clinical faculty members to use active learning in the classroom.²⁵

This study describes the modifications made to a Principles of Pharmacology course to create a hybrid model of lecturing and recitations. The primary objective of the study was to describe the modifications made in order to help other faculty who are looking for ways to transform their own lecture-based courses. A secondary objective is to demonstrate the change in class performance over a four-year period.

METHODS

Principles of Pharmacology was a foundational course with the purpose of introducing basic pharmacological principles to second-year pharmacy students before they begin the integrated therapeutics courses where they learn individual drug classes. The three-credit course met twice a week for 75 minutes, and approximately 75 students were enrolled in the course each year. The goal of the course was for students to be able to use the drug examples they are provided to prepare them for higher-level critical thinking in later therapeutics courses.

To ensure that the course continued to fulfill the requirements of the college's educational blueprint, the course topics and objectives were not changed as part of the revision, but the methods of instruction were. In

previous years, course content had been delivered in the form of two, 75-minute lectures per week. In 2015, the course was converted to two 50-minute lectures and a separate 50-minute recitation session. This format continued in 2016.

For the recitations, students were divided into three sections of approximately 25 students each. Once divided into sections, the course was arranged so that a topic was introduced in the first lecture session and then expanded upon in the second lecture session. Finally, the knowledge covered in the lecture session was applied in the recitation section to complete the topic. The three recitation sessions, each with a separate group of students, were held on the same day of the week.

Each recitation session of 25 students was divided into semester-long groups of four students. In order to create diverse groups, considerations were given to students' previous academic performance, ethnicity, gender, and personality traits (eg, introvert or extrovert), and comfort level with public speaking. Sessions began with a short quiz which students completed independently and was intended to incentivize them to review lecture material before the recitation. The quiz was followed by a group activity. In the final 10 to 15 minutes, the instructor led a discussion with the entire class on the answers choices on the quiz and the logic behind the correct answer. The activities were designed to encourage students to think critically and explore concepts that were difficult to grasp when delivered in a lecture format. For example, during the early part of the course, students were introduced to drug receptor theory and competitive vs non-competitive binding. In lecture, students often struggled with sketching and even reading a drug response curve on a log scale axis. This concept in lecture generally went smoothly, but when asked to calculate a therapeutic index, the students struggled. This experience was consistent with what McKeachie describes as the "illusion of learning," when students hear an expert describe something that seems simple and makes sense but then they cannot replicate it when asked to do so.²⁸ Thus, the assignment for this section asked the students to sketch a hypothetical set of data to reinforce the difference between log and linear scale (many students try to convert the data, not the axis, to the log scale). Additional questions reinforced the dose response curve of competitive and noncompetitive drug inhibition and explored the use of a therapeutic index, therapeutic window, and onset of undesired effects.

As the course progressed and the students get closer to starting their required therapeutics courses, case studies were developed. Before the session, the students received a pathophysiological based pharmacology lecture on

diabetes medications. The case required them to review the presentation of type II diabetes and the main mechanisms of action of the medications. The purpose of the activity though, was to require the students to critically think about the considerations that go into multidrug therapy: how would the mechanisms of actions of the two drugs work together for maximal effect and, what kind of side effects might be amplified if certain medications are given together. In this assignment, the students were asked to consider the different mechanism of action, effects on HbA1c levels, risk of hypoglycemia and weight, and the other potential side effects of treatment. The purpose was not to have students find a guideline, but to force them to consider why adding sulfonylurea to insulin may not be ideal, or why metformin is considered better than a thiazolidinedione even though thiazolidinedione may be better at reducing HbA1c levels.²⁹

Course assessments consisted of five examinations and a final examination. Quizzes and assignments grades were also compared. The weight of each assessment is shown in Table 1. There were 11 assignments in the course before the course redesign (the lowest graded one was dropped) and 13 after it. A similar number of quizzes were administered; however, instead of being administered after almost every lecture period as before, in the redesigned course they were converted to pre-session individual (in session) quizzes and then a post-session take home quiz to help assess students' readiness for the session and understanding of the session respectively.

For this study, four years of data for the Principles of Pharmacology course was examined: two years (2013 and 2014) during which the traditional lecture format was used with only a few active-learning elements mixed into the content delivery, and two years during which the course was reformatted to include active-learning breakout sessions. The main educational goals for reformatting the course were to improve student comprehension and application. For comparison, the cumulative GPA of each class of students at the end of PY1 for spring 2013-2016, prior to starting the Pharmacology course in the fall of

their PY2. We also examined the average pre-pharmacy GPA for each of these classes before beginning the PharmD program.

Graphpad software (Graphpad Software Inc., San Diego, CA) was used to perform statistical analysis, first the D'Agostine & Pearson omnibus normality test was performed to analyze the normality of the data. Because the data were found to be normal, a two-tailed unpaired *t* test was used to determine significance. This research was submitted to and approved by the Institutional Review Board of Western New England University.

RESULTS

The average course grade prior to reformatting the course (2013 and 2014) was 81.3%, while the average grade after adding the recitation sessions (2015 and 2016) was 83.8%, reflecting a significant increase of 2.5% ($p=.001$; Cohen *d* effect size of 0.4). The Pathophysiology course, a first-year course taught each spring by the same instructor was used as a curricular baseline to allow for comparison between the groups. The average grade in Pathophysiology was an 82.3% for 2013 and 2014 and 83.0% for 2015 and 2016, reflecting no significant change between these class cohorts ($p=.28$). No differences were found in students' prepharmacy GPA or GPA at the end of PY1 between the cohorts of students. Students who took the Pharmacology course before the course redesign had an average prepharmacy GPA of 3.4 and average first year GPA of 3.2 compared to average GPAs of 3.3 and 3.2 for the students who took the Pharmacology after the redesign.

The differences in student performance in each of the four general categories of course assessments is displayed in Table 2. The average score on all course examinations except the final was 76.6% before the course redesign and 79.9% afterwards ($p=.0007$), with a Cohen *D* effect of 0.4. The examination average on the final examination, which was cumulative, was 75.1% before the redesign and 77.0% afterwards. This 1.9% difference approached significance ($p=.087$) and had a Cohen *d* effect of 0.2. Final course grades are displayed in Table 3. The

Table 1. Comparison of Course Assessment Weightings Before and After Redesign of a Pharmacology Course to Include Active Learning

Assessment	Prior to Redesign, No.	Prior to Redesign, %	After Redesign, No.	After Redesign, %
Quizzes	25	15	26 ^b	12
Class Assignments	11 ^a	15	13	13
Examinations	5	45	5	50
Final Examination	1	25	1	25

^a The lowest graded class assignment was dropped

^b These were divided into pre and post quizzes of the recitation session, the lowest 1 pre quiz and lowest 1 post quiz were dropped

Table 2. Comparison of Student Performance Before and After Redesign of a Pharmacology Course to Include Active Learning

Assessment	Average Grade Prior to Redesign, %	Average Grade After Redesign, %
Quizzes	95.2	92.3
Class Assignments	95.2	99.5
Examinations	76.7	79.9
Final Examination	75.1	77.0

percentage of students who earned a final course grade of A or B increased from 59.8% in the two years prior to reformatting the course (2013 and 2014) to 69.0% in the two years after reformatting the course (2015 and 2016) (a 9% increase), demonstrating that the revised format had a noticeable impact on student performance.

The course and instructor evaluations for the course improved after the redesign, averaging a 3.8 out of 5 on the course evaluation beforehand to a 4.1 out of 5 during the first year of the course redesign, and from 3.9 out of 5 to 4.1 out of 5 for the instructor evaluation. The college implemented a new course and instructor evaluation form in the fall of 2016, which was validated for improved reliability and increased from 7 to 18 questions. The evaluation courses increased further to a 4.3 out of 5 for the instructor evaluation and a 4.4 out of 5 for the course evaluation in the second year of the redesign.

When students specifically mentioned the recitations sessions in the course evaluation, the comments were twice as likely to be negative than positive. Some of the complaints were that the material presented in the recitation sessions was too difficult and complex. However, the majority of the students' comments were more general, and referred to how much they learned and were challenged by the course. The comments made during the second year of the recitations were more positive than those in the first year, with a couple of students stating that older students told them how valuable they found the material they learned in the sessions to be once they entered their therapeutics courses.

Table 3. Percent of Students Receiving Course Letter Grades Before and After Redesign of a Pharmacology Course to Include Active Learning

Grade	Prior to Redesign, %	After Redesign, %
A	16.5	20.0
B	43.4	49.0
C	37.5	29.6
F	2.6	1.4

DISCUSSION

In a 2011 study on the use of active learning in US pharmacy education, clinical faculty members and social/administrative science faculty members were more than three times more likely to use active-learning strategies compared with faculty members teaching in departments of pharmaceutical or basic sciences.²⁵ Yet, as the biological sciences survey showed, many faculty members want to use active learning as a method of instruction but still struggle to implement it.²⁷ As the 2016 Accreditation Council for Pharmacy Education Standards advocate for the use of active learning and other content delivery methods that promote self-directed learning,³⁰ faculty members will likely come under increased pressure to incorporate active learning.

This work provides an example of a method to convert a required pharmacology course from a lecture-based course to a mixed format that includes lecture and recitation sessions. This work also explored some of the challenges commonly encountered when implementing active learning. The barriers that faculty members often cite when implementing active learning fall into three main categories: pedagogical issues, student characteristics, and issues impacting the faculty members.³¹ These common challenges include questions about how an instructor can cover the necessary content, concerns about course evaluations, student resistance to non-lecture environments, and increased faculty preparation time.³¹

The active sessions significantly improved learner knowledge as determined by course examinations and overall course grade, which is consistent with findings from past studies.^{3,4,19-22,28,32,33} Pedagogical issues are then more about covering all of the content or that students may miss essential material because it is not "handed to them on a slide" or perhaps even video captured and recorded for instant retrieval.^{26,31} While having time to cover all of the content is often considered a major barrier to faculty members implementing active-learning activities, in the course described, the actual student contact time was not altered in the redesign and no major topics had to be dropped (Table 4). The material taught in the course did require reevaluation, but this was somewhat liberating as it forced faculty members to reflect on what was truly important and relevant to achieving the course objectives. Through this process, it was found that lectures could be more efficient as complex topics such as multidrug therapy could be explored in a more learner-directed manner instead of trying to incorporate the decision-making rationales into a lecture. Multidrug therapy was one topic that seems very obvious to students during lecture, often giving the illusion of learning where a

Table 4. Alterations to Course Topics Before and After Redesign of a Pharmacology Course to Include Active Learning

Order	Topics Prior to Redesign, %	Topics After Redesign, %
Same		
1	Basic Principles of Pharmacology	Basic Principles of Pharmacology
2	Receptor Theory	Receptor Theory
3	Pharmacodynamics & Kinetics	Pharmacodynamics & Kinetics
4	Autonomic Physiology and Pharmacology	Autonomic Physiology and Pharmacology
5	Cholinergics & Cholinergic Blockers	Cholinergics & Cholinergic Blockers
6	Adrenergics & Adrenergic Blockers	Adrenergics & Adrenergic Blockers
7	Biotransformation Principles	Biotransformation Principles
8	Clinical Relevance of Biotransformation	Clinical Relevance of Biotransformation
9	Drug Interactions	Drug Interactions
10	Drugs of Abuse & Herbal Medicine	Drugs of Abuse & Herbal Medicine
11	Multidrug Therapy	Multidrug Therapy
Different		
1	Principles and Mechanisms of Toxicology	Drug Classes & Statins
2		Anti-hypertensives

student felt they understood the concept when they saw it but struggled with on an exam; when the same topic was introduced with an interactive activity, student performance on the assessment was notably stronger. This course redesign demonstrates that active learning can be broadly incorporated into a course without sacrificing course time or content. Although one topic was removed and consolidated into other areas, this was done so that two additional topics could be added: drug classes, which the author determined needed to be a stand-alone topic; and antihypertensives, to further demonstrate multidrug therapy (Table 4).

Student characteristics, eg, students just want the answers or students are not willing to do the necessary preparation to succeed in active-learning environments, are commonly cited as problems to implementing active learning.³¹ Before the course redesign, a quiz was administered during every non-examination class period that was designed to encourage students to review material before the next class. These pre-quizzes, which were used in the recitation sessions, were designed to help ensure students reviewed and prepared for the class session. This was probably the least popular of the course assessments and was commonly mentioned in the course and instructor evaluations. While there was, and still remains, some student resistance to the active learning, the student evaluations actually improved after adding the active-learning sessions compared to evaluations of the class in the years before the recitations were started. Furthermore, whether it was because they knew more what to expect, the instructor's performance improved the second time through, or a combination of both, the student comments were more accepting of the format the second time

through the course. This may not always be the case,²¹ but for those who pursue active learning, the primary objective should be an increase in student knowledge, not satisfaction.

Often the final barrier cited in implementing active learning is faculty issues, eg, that active learning will take more time, both inside and outside of class.^{11,31} There likely will be an increase in time spent outside of class to prepare, especially during the first semester in which active learning is implemented. The methods described here required the instructor to spend two additional hours per week to teach the class. Overall, reformatting the course required approximately an additional 100 hours of instructor time. On average, each of the 15 assignments required three hours to create, and each of the remaining 30 lectures required an average of 30 additional minutes of reformatting and revision in addition to the lecture alterations generally done by the instructor each year. Thus, 45 extra hours to create the assignments, 30 extra hours to revise the lectures, and 30 additional classroom hours because of breaking the class into three sections for the recitations. While the increased time was significant, it was not overwhelming, and issues such as increased workload are something that can potentially be worked out with a supportive and encouraging administration. Nevertheless, it can still be difficult for faculty members to push forward with course redesign. Brazeau describes the situation where faculty members attend numerous workshops and seminars and gather lots of ideas for implementing active learning in the classroom, only to go back to their office and find that the technique they wanted to implement that seemed so easy suddenly becomes an enormous and daunting undertaking.²⁶

According to one study, implementing active learning is even more difficult for seasoned faculty members. Instructors with less than five years of teaching experience were significantly more likely to use active learning than those who had been teaching for 25 years. Also, there was a 3% decrease in the likelihood of using active learning as the instructor's age increased.²⁵

When thinking about converting to non-lecture instructional methods, professors are often advised to go slow and not to try to go from a 100% lecture course to a completely flipped classroom.¹¹ Therefore, taking a course like the one described here and changing a third of it to recitations is one way to make the adaption less overwhelming for the instructor. This approach should be especially beneficial in pharmacology, as the greatest number of respondents to the Biological Sciences survey that wanted to implement alternative techniques to lecture were pharmacologists,²⁷ and limited examples of active content delivery in pharmacology have been published. These modifications should be applicable to various types of curricula, whether it is semester based, trimester based, or modular based. We made the conversion to active learning work within our existing schedule by placing the recitation sections opposite other classes such as laboratories and electives where students were already in smaller sections.

Consistent with the literature on active learning, we found student knowledge significantly increased after the implementation of the recitation sessions into a required pharmacology course. Of the four major types of assessment within the course, only quiz grades decreased, which is likely a result of having a closed-book quiz at the beginning of each recitation session instead of having all take-home quizzes (Table 2). Importantly, grades on the summative assessments and examinations rose significantly, and course grades also improved considerably (Tables 2 and 3). The demonstrated increases do not seem to be due to a variance in the aptitude of the various classes, as incoming class GPAs and overall class performance in the previous academic year (PY1) were not significantly different. With the introduction of the recitation sessions, students were challenged to evaluate, apply, and think critically about course content compared to what students were required to do in prior years. While there is no stand-alone advanced pharmacology course with which to directly compare this course, Persky and Dupuis found that by forcing students to apply knowledge to different situations in a foundational course improved their performance in a clinical pharmacokinetics course.²¹ It is hypothesized that a similar increase in performance in the integrated therapeutics courses may also occur, but too many other variables exist (different in-

structors, course assessment changes, etc) to make a conclusion.

There are a few limitations to this study. The pre-recitation sections of the course taught in 2015 and 2016 were the second and third years that the instructor had taught the course; thus, the improved teaching aptitude that comes with experience may also have played a role in increased student learning and performance. Also, a different instructor taught approximately 15% of the lectures in the pre-recitation sections of the course which could also have positively or negatively influenced student performance. The order in which the course topics were presented was varied from year to year in an attempt to optimize content delivery and, after the recitations were created, to fit the topics into units that ended with the recitation (Table 4). This was sometimes difficult, with fall break causing one recitation to be dropped and Thanksgiving break creating the need to have back-to-back recitation sections. Nevertheless, the author believes adequate adaptation for these challenges were made in the course content order, for example, holding a second recitation on the same topic to account for Thanksgiving break.

CONCLUSION

This work examined the potential educational benefits of creating small group recitation sessions within a three-credit, semester-long pharmacology course. In the two years after the implementation of the recitation sections, average examination scores and overall course grades were significantly increased compared to the two years prior to implementation. This course redesign may serve as a template for faculty members who wish to convert their method of instruction from lecture-based toward more active learning, which is less commonly used by faculty members within the biological and pharmaceutical sciences.

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