Development and Evaluation of a Quasi Problem-Based, Objective-Driven Learning Strategy in Introductory and Clinical Pharmacokinetics Courses

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ABSTRACT. A teaching strategy that combines some aspects of traditional instruction with problem-based learning was developed and applied to basic and clinical pharmacokinetics courses. After a brief introduction to each topic by the instructor, the students utilize problems as the main tool in the learning process. Additionally, the method is outcome-based in that students are responsible for achieving outcomes and specific objectives for each topic. Student evaluations of the method in both large and small class sizes were strongly positive. Additionally, a comparison of grades during the recent years suggests a significant improvement in pharmacokinetics learning with implementation of the new strategy. The method offers some advantages over the traditional didactic lectures while being less resource-intensive than most problem-based learning strategies. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworthpressinc.com]*

KEYWORDS. Problem-based learning, basic pharmacokinetics, clinical pharmacokinetics, ability-based outcome, computer-assisted learning

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The author would like to thank both B.S. and Pharm.D. students who were subjected to this new format, provided feedback, and patiently worked with the author to create a more effective learning environment.

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INTRODUCTION

The effectiveness of traditional instruction in a didactic setting has been scrutinized during the past decade (1,2). It has been suggested that with traditional lectures, students assume a passive role in their learning, resulting in minimal retention of content over time. Conversely, when students are actively engaged in learning, the retention of knowledge and skills is reportedly extended (3). Active learning may involve a number of different strategies such as group discussions inside and outside the classroom and the use of cases, scenarios, or problems as the means of acquiring knowledge, skills, and attitudes.

One active learning strategy is the problem-based learning (PBL) model which has been used at the McMaster University in medical education (4). The problem-based model has also been applied in pharmacy education (5-14). The McMaster model (4) is a radical departure from the traditional didactic lecture method in that students are divided into small groups and presented with a set of therapeutic problems which they need to address. Each group has a tutor/facilitator, usually a faculty member. Thus, PBL is more resource intensive than traditional lecturing (15). Additionally, it requires a significant change in the attitude of faculty who may feel uncomfortable with the departure from the controlled setting of a lecture.

It appears that traditional teaching and PBL may represent two extreme instructional strategies. Therefore, alternative methods which combine some aspects of these extremes may be more practical and effective, given current staffing and financial resources available to colleges of pharmacy. The intent of this article is to report on the development and evaluation of such a strategy for instruction in basic and clinical pharmacokinetics.

DESCRIPTION OF THE NEW FORMAT

Outcomes and Objectives

General ability-based outcomes were developed for the pharmacokinetics courses during a recent curriculum development process. These general outcomes were used as guidelines to develop topic areas with more specific outcomes and objectives. The specific objectives were presented to students in the form of specific questions. Students were responsible for achieving the stated outcomes and objectives for each topic. Examples of outcomes and objectives for the topic of constant intravenous infusion are presented in Appendix A.

Quasi Problem-Based Strategy

One or more scenarios were developed to address outcomes and objectives for each topic; an example problem for the topic of constant infusion is presented in Appendix B. Additionally, handouts were prepared and distributed which contained the information necessary to address the questions posed in the objectives and/or to direct students to other reading materials for solutions. The handouts and reading materials contained all the information that would normally be transmitted to students in a lecture, including explanation of concepts with examples. An example handout for the topic of dosage regimen design and modification is published elsewhere (16). For each topic, which on average would be covered over two to three lecture hours, a short (10-15 minute) introduction was given by the instructor at the end of a class period. The students were given the set of outcomes/objectives, problem(s), and handout(s) before leaving the class. They were then asked to solve the problem(s) after reviewing the reading materials outside the class and to come prepared to the next class for discussion of the problem. Although no formal groups were formed by the instructor, the students were instructed that they may work on the problem(s) with their classmates. During the next class time, the concepts and objectives were addressed through discussion of the solution to the problem(s). In these sessions, the instructor would ask for student volunteers to answer the questions posed in the problem (see Appendix B). This would normally lead to more questions and/or clarifications by other students and more elaboration of important concepts by the instructor. After the completion of the topic, students were given similar problems for practice and as graded homework.

Computer-Assisted Instruction

Computers were used extensively to facilitate learning. The details of computer-assisted generation and grading of pharmacokinetics practices and assignments were reported recently (17). Briefly, the practice problems and assignments were generated using the spreadsheet program EXCEL®, which can be used in both Windows-based and Macintosh computers. Each program can generate an unlimited number of practices/assignments having similar structure, but with different data. Automatic grading of the submitted assignments was also accomplished using a macro developed for the same program. Whereas the generation and use of practices were voluntary, the use of assignments were mandatory in both courses. Additionally, students were free to use manual graphs, calculators, and/or computers for solving the assignments.

Courses and Students

The new approach was applied to a basic pharmacokinetics course (Pharmacy 160) required in a five-year B.S. program. The course was offered to fourth-year pharmacy students during the fall semester. Pharmacy 160 is a 3-credit-hour, introductory course with three 50-minute classes scheduled per week and an enrollment of 150 students. Additionally, the new strategy was applied to one of two modules of a required clinical pharmacokinetics course (Pharmacy 211). Thirty-seven students were enrolled in the course which was offered to Pharm.D. students during the first seven weeks of the spring semester. Pharmacy 211 is also a 3-credit-hour course, with a single 3-hour class per week. Both courses were offered in a single section format, *i.e.*, all the students in the class were subjected to the same teaching strategy.

DESCRIPTION OF THE TRADITIONAL FORMAT

The instruction of pharmacokinetics before the implementation of the new strategy was based on traditional didactic methods in which class time was primarily devoted to presentation of material, followed by limited application examples. Although general outcomes for the course and topics also existed under this format, they had been developed without the current emphasis on the ''ability-based'' outcomes. Additionally, specific objectives, such as those developed for the new strategy (see Appendix A) were lacking. With regard to practice problems, students were provided with one or two problems for each topic, along with solutions in the traditional format. However, take-home problems were not graded. The use of computers at that time was limited primarily to demonstration of concepts during the class.

EVALUATION OF THE LEARNING STRATEGY

At the end of the semester (Pharmacy 160) or the module (Pharmacy 211), an evaluation form containing both quantitative (Likert Scale) and qualitative questions was distributed to students, who were informed by the instructor of the intent of the survey.

The differences between the Pharm.D. and B.S. students in their responses to the questions were tested using a two-tailed unpaired t-test at a Bonferonni-adjusted significance level of 0.0026 (0.05 divided by the number of comparisons). The students' responses to the questions were anonymous, with a response rate of 135 of 150 for Pharmacy 160 and 31 of 37 for Pharmacy 211.

The results of the quantitative questions are presented in Table 1 for both

TABLE 1. Student Response to Quantitative Statements.[a]

Question	B.S. *n* = 135	Pharm.D. *n* = 31	*P*
1. I have been exposed previously to a problem-based learning style in other courses.	2.39 ± 1.19	1.87 ± 0.86	0.023
2. I regularly worked through the practice problems before they were discussed in class.	2.86 ± 1.22	1.37 ± 0.67	<0.0001[b]
3. The reading material provided to students before each topic (handouts, examples, textbooks chapters) were sufficient for understanding the topic.	1.81 ± 0.94	1.67 ± 0.80	0.444
4. I was able to answer and understand most of the questions posed in the problems before they were discussed in class.	2.49 ± 0.85	2.13 ± 0.73	0.031
5. I was able to answer and understand most of the questions posed in the problems after they were discussed in class.	1.42 ± 0.66	1.27 ± 0.45	0.231
6. The objectives of each topic listed in the handouts were specific enough that I could easily understand what the instructor wanted us to learn.	1.64 ± 0.77	1.70 ± 0.75	0.695
7. Based on the material and instructions provided by the instructor, I knew exactly what the expectations of the instructor were in this course.	1.69 ± 0.88	1.47 ± 0.63	0.190
8. The objectives for each topic helped me learn pharmacokinetics better.	1.86 ± 0.88	1.90 ± 1.03	0.825
9. The exams were consistent with the objectives for the topics.	1.61 ± 0.81	1.87 ± 0.87	0.114
10. The objectives helped me do better in the exams.	2.01 ± 0.92	2.30 ± 0.79	0.107
11. The reading material, practice problems, assignments, and exams consistently reinforced the same material.	1.48 ± 0.62	1.87 ± 0.86	0.004
12. The brief overview of each topic before starting the problem was beneficial.	1.68 ± 0.88	1.30 ± 0.54	0.022
13. The practical applications and examples made me see better the "bigger picture."	1.72 ± 0.77	1.57 ± 0.86	0.34
14. Enough time was spent in class for discussion of each problem.	1.69 ± 0.90	1.67 ± 0.84	0.910

TABLE 1 (continued)

Question	B.S. *n* = 135	Pharm.D. *n* = 31	*P*
15. I spent more time working on this course than any other 3-credit-hour pharmacy course.	2.34 ± 1.20	2.70 ± 1.1	0.128
16. Compared with what I learned, the time that I spent for this class was worth it.	1.93 ± 0.95	1.70 ± 0.75	0.210
17. There should be positive reinforcement for people to come to class prepared.	1.97 ± 0.91	1.87 ± 0.94	0.584
18. Overall, I believe that the objective and problem-based format used in this course (as opposed to traditional lecturing) helped me learn better.	1.63 ± 0.83	1.40 ± 0.86	0.169
19. I wish more pharmacy courses were problem based.	2.22 ± 1.04	1.72 ± 0.70	0.012

[a] The scale was 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, and 5 = strongly disagree.
[b] Significant difference between B.S. and Pharm.D. students (at a significance level of < 0.05/19 or 0.0026).

B.S. (Pharmacy 160) and Pharm.D. (Pharmacy 211) students. The students response to the new format was very favorable. Overall, a majority of students (strongly) agreed that the objective-driven, problem-based format used was appropriate for learning basic (B.S. students) and clinical (Pharm.D. students) pharmacokinetics. Additionally, except for question 2, there were no statistically significant differences between the Pharm.D. and B.S. students in their responses to the questions. However, as the responses to question 2 indicate, Pharm.D. students were more prepared before attending the class discussion of the topics.

Most prevalent responses of students to three qualitative questions regarding the format of the course are presented in Table 2 for both B.S. and Pharm.D. students.

To test student performance, the outcomes/objectives of each topic were used to design formal examinations which primarily dealt with application of the concepts and problem-solving skills instead of memorization of facts. The impact of the new instruction strategy on student learning of pharmacokinetics was then determined by comparing the grades of students in the formal examinations during the last available four years for Pharmacy 160 (see Tables 3 and 4); the exam format, the type of questions, and grading scale were similar for all years. The comparisons were made using unpaired t-test with Bonferonni-adjusted significance p value of 0.0083 for a total of

TABLE 2. Student Response to Qualitative Statements.

Question	B.S.	Pharm.D.
1. What was your most favorite aspect of the course format?	The class was interactive. No lecture style; we are smart enough to read the handouts. The objectives. I learned a lot working the problems. The handouts, practice problems, assignments, quizzes, and exams all seemed to flow into each other, helping my understanding. Discussion of practice problems in class.	Using examples to learn. I liked the fact that learning was up to me by preparing in advance. I learned so much from the problems. By completing problems before lecture, I felt I could ask better questions. Hands-on problem solving and constant reinforcement. Great format for learning. At home, I made mistakes. In class, I learned how to fix them and avoid them in the future.
2. What was your least favorite aspect of the course format?	I taught myself kinetics. Some students were not prepared for the class. If I had not done the problems or had figured them all out, the class was boring. Having to always be prepared.	Not able to cover all the material in the syllabus. If I had a problem with a practice problem, there was little time to explain it in class. The class seemed rushed some of the time.
3. How can the format of this course be improved?	A little more instruction time and a little less going over the problems. Make working on the practice problems before class mandatory. More order.	More handouts to eliminate the textbook. Rewards for those who come to class prepared. It is hard to hold a discussion when some in the group have not done their work.

six comparisons (0.05/6). As demonstrated in Table 4, there were no significant differences among the performance of students before the implementation of the new strategy. However, the students' grades after the implementation of the new format were significantly higher than those of previous years. Similar comparisons for Pharmacy 211 could not be made, because the division of course into two modules only occurred in the last two years, along with redistribution of topics between the modules.

DISCUSSION AND CONCLUSION

Over the past several years, the profession of pharmacy has been shifting towards provision of pharmaceutical care, with concomitant changes in phar-

TABLE 3. Examination Grades[a] (%) in Pharmacy 160 (B.S. Program) for Recent Years.

Year (Format)[b]	*n*	Grade (Mean ± SD)
1992 (Traditional)	112	75.9 ± 10.8
1993 (Traditional)	120	76.2 ± 11.2
1995 (Traditional)	134	74.8 ± 12.5
1996 (New)	150	82.6 ± 10.1

[a] For consistency among years, grades are reported only for formal examinations, excluding assignments or quizzes.
[b] Data for 1994 are not reported because the course was not offered by the author.

TABLE 4. Statistical Comparison of Examination Grades in Pharmacy 160 (B.S. Program) for Recent Years.

Comparison	*P*	Significance[a]
1996 vs. 1995	1.69×10^{-8}	Yes
1996 vs. 1993	1.45×10^{-6}	Yes
1996 vs. 1992	4.99×10^{-7}	Yes
1995 vs. 1993	0.3503	No
1995 vs. 1992	0.4656	No
1993 vs. 1992	0.8359	No

[a] Significant difference at a significance level of < 0.056/6 or 0.0083.

macy education. The Commission to Implement Change in Pharmaceutical Education has advocated self-learning abilities and habits and problem solving skills as necessary outcomes of pharmacy education in this new era (18). However, teaching pharmacokinetics has traditionally involved didactic lectures on concepts followed by some examples to provide application of the concepts. This means that instruction mostly emphasizes knowledge rather than abilities such as problem-solving skills. On the other hand, practicing pharmacists are expected to apply knowledge to day-to-day problems, requiring previous hands-on experience with similar situations. Too often, students fail to recognize the relevance and importance of the concepts until these are presented in the form of specific examples and applications. Therefore, it may be beneficial to attempt teaching in the opposite direction, *i.e.*, starting with a problem and working towards learning the concepts, which is the basis of problem-based learning (15).

The McMaster PBL (4) involves resource-intensive small group (usually

five students) discussions with faculty members as tutors/facilitators. To circumvent the problem of faculty/tutor resources, some pharmacy faculty have utilized unsupervised groups in PBL courses (7,8,19). Although less resource-intensive, the latter approach adds its own unique concerns and problems (19) to the shortcomings of the supervised groups (15). For example, it was reported (19) recently that issues like workload equity and attendance are among the dissatisfactions of the students with this particular format. In the present report, a modified version of PBL was applied to the entire class for both a very large class size of 150 students and a relatively small class size of 37 students without forming supervised or unsupervised groups. Also, the method was different from the McMaster PBL in that the students were encouraged to study the concepts in reading materials before attempting to solve the problems. However, in-class discussions were based on the developed problems, rather than the concepts. Additionally, the instructor's expectations of the students were communicated to them through specific outcomes and objectives for each topic. Despite some shortcomings (Table 2), the students' evaluation of this strategy was mostly positive (Tables 1 and 2). The majority of the students agreed or strongly agreed that the problem and outcome-based format enhanced their learning of pharmacokinetics. Furthermore, a comparison of the grades for the last four years (Tables 3 and 4) indicate that the student performance was improved with the new strategy. Nevertheless, the results also point to some areas which need improvement.

One of the major points noted by the instructor during the test semesters and confirmed by the results of both quantitative and qualitative questions is the issue of student preparation before attending each class. This is also a major differentiating point between the B.S. and Pharm.D. students as noted by the answer to question 2 in Table 1; a greater number of Pharm.D. students were well prepared for each class, compared with the B.S. students. This was somehow expected because of higher faculty expectations of the Pharm.D. students and more exposure of the Pharm.D. students to active learning methods in our program. Additionally, the very large class size of B.S. students prohibited the assignment of extrinsic rewards (*e.g.*, participation points) during the class time. Therefore, compliance with the instructions regarding pre-class preparation was not monitored for Pharmacy 160. One possible remedy for this may be administration of short quizzes before the discussion of each problem in the classroom. These quizzes may be given small bonus points as incentives. Nevertheless, the lack of preparation was cited (Table 2) by both B.S. and Pharm.D. students as one of the least favorite aspects of the format and should be dealt with in future modifications for these courses.

Although not quantitatively evaluated, student participation in the discussion during the class period for both courses was substantially higher than

that in previous years when a didactic lecture format was used. However, student participation in Pharmacy 160 was generally much less than that in Pharmacy 211 during the new format. The lack of participation was troublesome to the instructor, because it was perceived to be due to a lack of preparation. Therefore, it resulted in spending more time on a topic. However, in addition to lack of preparation, a significantly larger class size of Pharmacy 160 has likely contributed to this distinction. This is in agreement with a recent report (12) demonstrating that only 20 percent of the class participated in the discussion in a large class size of 160 students with a format similar to that used in this study. Other factors such as shyness and domination by a few students could also reportedly (19) contribute to lack of student participation. It has been suggested (7) that calling on students by use of a random list may help student participation in the discussion. This strategy may be used in future implementations of our pharmacokinetics courses.

It has been reported (15) that in PBL, breadth of content is sacrificed to some degree for the depth of knowledge. Our current experience with Pharmacy 160 and Pharmacy 211 is in agreement with this shortcoming; with the new format there was not enough time to cover all the topics in the course syllabi which had been designed based on the instructor's experience with didactic format. This shortcoming was also noted by the students as one of the least favorite aspects of the new format (Table 2). It has been argued (7) that with the rapid rate of expansion of knowledge, there is no way that faculty can teach all the topics in their area. Therefore, teaching students general problem-solving and self-learning skills may serve the students better than trying to transfer the knowledge in a passive manner. Because the exams were designed to test the students' ability in the areas covered during the semester or module, the reduced content coverage did not have a detrimental effect on the test scores. However, the effects of reduced coverage in a problem-based format on the pharmacy students' performance in practice settings remain to be investigated.

In conclusion, a new format combining some aspects of didactic and problem-based learning was used for teaching pharmacokinetics to B.S. and Pharm.D. students in relatively large and small class-size settings, respectively. The method offers some advantages over the traditional didactic lectures while being less ambitious and resource-intensive than most problem-based learning strategies.

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APPENDIX A

Expected Outcomes for the Topic of Constant IV Infusion (Basic Pharmacokinetics Course; B.S. Program)

1. Predict the effects of changes in the major pharmacokinetic parameters and infusion rate on the steady-state plasma concentration (plateau) and the time to reach plateau after constant IV infusion.
2. Estimate patient-specific pharmacokinetic parameters from the infusion and postinfusion plasma concentration-time data.
3. Design dosage regimens (infusion rate and bolus dose) based on the available pharmacokinetic parameters (population or patient-specific data) and therapeutic goals (desired plasma concentrations).

Specific Objectives for the Topic of Constant IV Infusion (Basic Pharmacokinetics Course; B.S. Program)

- *General Concepts*

    1. What are the applications of IV infusion (what are its advantages and disadvantages)?
    2. Why does the plasma concentration rise after the start of IV infusion?
    3. Why does the plasma concentration reach a plateau (C_{SS}) some time after the start of infusion?
    4. What determines the magnitude of C_{SS}?
    5. What determines the time to reach C_{SS}?
    6. When is it necessary to administer a bolus dose along with the IV infusion?
    7. What is the effect of a change in the infusion rate constant on the plasma concentration-time curve?

- *Estimation of Kinetic Parameters from IV Infusion Data*

    8. How can C_{SS} be estimated after constant IV infusion of drugs?
    9. How can the half-life be estimated from the data during the infusion?
    10. How can the half-life be estimated from the postinfusion data?
    11. How can the clearance be estimated from the infusion data?
    12. How can the volume of distribution be estimated from the infusion data?

- *Use of Individualized or Population Kinetic Parameters for Design of Dosage Regimens*

    13. How can an infusion rate be estimated to achieve a target C_{SS}?
    14. How can C_{SS} be estimated from a known infusion rate?
    15. How long does it take to reach steady state without administering a bolus dose?
    16. How can a bolus dose be estimated to immediately achieve a target C_{SS} which is maintained by the simultaneous administration of an infusion?

APPENDIX B

Example Problem for the Topic of Constant IV Infusion
(Basic Pharmacokinetics Course; B.S. Program)

An asthmatic patient is administered 40 mg/hr of theophylline (in the form of aminophylline) as an IV infusion, with no bolus dose. The following plasma concentration-time data were obtained based on theophylline measurements.

Time (hr)	Plasma C (μg/mL)	Time (hr)	Plasma C (μg/mL)
0	0.00	24	9.00
3	2.88	48	9.60
12	7.27	72	9.40

1. Plot the plasma concentration-time data on a linear graph.
2. Why did the plasma concentration rise after the start of IV infusion?
3. Why did the plasma concentration reach a plateau (C_{SS}) some time after the start of infusion?
4. What is the steady-state concentration of theophylline?
5. What is the clearance of theophylline?
6. What is the elimination half-life of theophylline?
7. What is the volume of distribution of the drug?
8. How long did it take to reach the plateau (number of half lives and hours)?
9. If an immediate achievement of C_{SS} had been desired, what bolus dose should have been administered?
10. After 72 hours of aminophylline therapy, the condition of the patient did not improve. The infusion was discontinued and two postinfusion plasma samples were drawn:

Time (hr)	C (μg/mL)
84	2.25
96	0.520

11. Plot the postinfusion concentrations (including the concentration at the end of the infusion) versus time on a semilog graph. What information can be obtained from the slope of this line?
12. The therapeutic range of theophylline in asthma is between 5-15 mg/L. Please determine a new infusion rate to achieve a plasma concentration of 15 mg/L in this patient (assume no drug is left in the body when the new infusion is started).
13. How long would it take to reach the new steady-state level (number of half lives and hours)?
14. Estimate a bolus dose to achieve this new C_{SS} immediately.
15. If instead of your recommended infusion rate calculated in 12, theophylline is infused at a rate of 90 mg/h, what is the expected C_{SS}?