Teaching Pharmacokinetics Using a Student-Centered, Modified Mastery-Based Approach

Carolyn C. Brackett and Richard H. Reuning

College of Pharmacy, The Ohio State University 500 W. 12th Avenue, Columbus OH 43210-1291

Evidence from clinical clerkships and pharmacy practice suggests that pharmacy students have great difficulty learning to apply pharmacokinetic principles to patient care. It is hypothesized that the problem is one of contextual transfer of learning. An undergraduate pharmacokinetics course was redesigned to teach the process of contextual transfer using active learning strategies. A modified mastery grading system was adopted to encourage consistent, long-term learning. Five years of course assessment data indicate that the instructional and assessment methods result in an enhanced process for learning application of pharmacokinetics. Evidence from student assessments and from the practice environment suggests that students who complete our course do begin to overcome the barriers of contextual transfer. Descriptions of specific instructional strategies and supporting data are presented.

INTRODUCTION

We have observed that most pharmacy students have considerable difficulty applying pharmacokinetics to patient care, and further, that this limitation is also prevalent among practicing pharmacists. In order to apply pharmacokinetics to patient care, the student or pharmacist must be able to transfer a learned process from one context to another; in other words, from the classroom to the patient-care setting. Angelo(1) states that “Research on learning to transfer generally is depressing. Most learning is highly context-bound, and few students become skilled at applying what they’ve learned in one context, to another similar context. In fact, many students cannot recognize things they’ve already learned if the context is shifted at all.” The essential, transferable process in application of pharmacokinetics is the ability to reason and solve problems in a bidirectional fashion. By this we mean that the student must be able to work from an observed event, such as a dose-related adverse drug reaction, backward to the relevant pharmacokinetic principles in order to understand and solve the problem. Conversely, effective individualization of an effective dosing regimen necessitates that one begin with principles and reason forward to a solution.

We teach an elective third quarter of clinical pharmacokinetics to undergraduate pharmacy students. The course is taught annually and enrollment is usually 30-35 students. The apparent lack of learning to transfer we observed has occurred despite a history of more than 30 years of pharmacokinetics teaching experience, and a 15 year experience with the current course. One might ask then, whether the cause of this problem is: (i) not enough instruction; (ii) the wrong kind of instruction; (iii) student attitudes that inhibit learning to transfer; (iv) inadequate student ability; or (v) some combination of these explanations. Our own sense when we initiated this experiment was that reasons (ii) and (iii) above were the primary culprits. Pharmacokinetics is commonly perceived and taught as a mathematics- and physiology-based discipline. Our past instructional approach was quite traditional in most aspects, including an approach to problem solving which was directed primarily from principle to application. In other words, we taught the mathematical and physiologic principles, gave example applications, and expected that students would be able to use the principles when caring for patients. This is precisely the “instructional model” referred to by Barr and Tagg(2) wherein teachers teach the principles and the students are responsible for the transition to application. In order to add a dimension of reality to our teaching, we frequently tested students’ “understanding” of our teaching with case-based examination questions. The difficulty of contextual transfer was evident even on these contrived examination questions and thus became the issue which prompted the introspection relative to our teaching efficacy. The subsequent discussions and analysis led us to embark on a path of radical and wholesale change. Although we did not benefit at the time from the cogent thinking of Barr and Tagg(2) in their recent article on the “learning paradigm”, our conclusions were very similar. Even in the absence of their descriptions, we were attempting to shift from the “instruction paradigm” to the “learning paradigm.”

The working hypothesis which emerged from our deliberations was that mastery and successful bidirectional problem-solving in pharmacokinetics could be accomplished only by the creation of a substantially different environment(3). Reflection on this hypothesis led to the emergence of three evaluable learning objectives which we feel encompass the mastery and bidirectional application of pharmacokinetics:

1. Students must identify drug-related problems which involve pharmacokinetic principles.

Further, students must solve drug-related problems which involve pharmacokinetic principles by:

2. working from an observed outcome of drug therapy, for instance a side effect or therapeutic failure, backward from the outcome to the contributory principles, and/or

3. working from a relevant principle, for instance decreased drug clearance, forward to the desired outcome of a modified dosage regimen.
This paper will illustrate the revisions we made in our teaching, learning, and evaluation strategies. The educational principles involved are previously established ones, but we will demonstrate how we applied them in our own classroom. The methods we used, strengths and weaknesses of each approach, and our evaluations will be described in the hope that some may be transferable to other teachers and areas of study.

METHODS AND RATIONALE

The strategies and methods we have developed or adapted for use in our course can be divided into three general categories: those which involve: (i) active learning; (ii) the evaluative tools, and (iii) a set of ancillary contributors.

Active Learning

Without undertaking an exhaustive discussion of active learning, we feel that, in Barr and Tagg’s words “...students must be active discoverers and constructors of their own knowledge.” The methods we use in class can be divided into either “instructor-centered” learning or “student-centered” learning(2). Approximately 30 percent of our course is taught in a modified lecture format. While these modified lectures are certainly more instructor-entered than student-centered, we attempt to create an active learning environment even within these more traditional sessions. For example, prior to a formal classroom session, we provide the students with a detailed set of photocopied notes. The notes contain the majority of factual information to be presented during the class so that the students’ attention is not consumed by capturing data. Information is presented to the class in small divisions or discrete subtopics, which are immediately followed by a set of questions demonstrating application of the information to a patient. These application questions are present on the students’ printed copies but the answers are not. After lecturing for 3-5 minutes, the applications are discussed aloud between the instructor and students who volunteer in class, or in a “think-pair-share” format(4). We have found that this manner of presentation serves several purposes. First, students are not left to establish connectivity to patient care by themselves. By immediately discussing the application of each principle, the process of contextual shifting is demonstrated repeatedly. Secondly, the energy shifts(4) generated by alternating listening and answering questions keeps students in an active rather than passive frame of learning. They recognize misunderstandings and ask questions more readily when discussion time is built into the class, and when the atmosphere focuses on application rather than listening and recording.

A variation on this which also helps the students learn contextual transfer involves our use of specific drugs or drug classes as pharmacokinetic models. For instance, we use the aminoglycoside antibiotics as a platform for teaching the pharmacokinetics of intermittent infusions. The pharmacodynamics, absorption, distribution, metabolism, elimination, serum drug concentration monitoring, and dosage individualization of the aminoglycosides are each presented as 3-5 minute lectures followed, as described earlier, by applications to patient care. Students then identify other drugs or drug classes that conform to the same kinetic model and thus, might be managed with a similar thought process. This too demonstrates the process of contextual transfer, both to the care of a patient and to understanding the disposition of drugs which for example, obey first-order kinetics and are administered by intermittent infusion.

We schedule frequent cooperative learning exercises which strengthen the “observation-back-to-principle” portion of the problem-solving process. At the beginning of the course students are randomly assigned to groups of four or five students and these groups are reconfigured once during the quarter. Groups are given a patient case to solve and the instructors serve as reference sources and facilitators. Sometimes the cases illustrate previously presented material, but often represent new areas. Students must identify and clarify their own understanding of the principles or models which best explain the issues in the case. They then submit for grading a solution based on these principles. These are usually written but are sometimes verbally presented to the class by the groups. All group members receive the same grade, thus maximizing incentive to collaborate. Exercises such as these ask students to work in both backward and forward directions, relative to principles, and also give them experience in contextual transfer.

Another case-based exercise which has worked exceptionally well for us is an extended assignment which figures strongly into the students’ course grades. Students identify a practicing pharmacist who can explain the details of a specific patient to them. This patient must have experienced a drug-related problem involving some aspect of pharmacokinetics, and the pharmacist must have intervened actively. The students explore the pharmacist’s thought process in depth and then later work through the problem on their own. When they compare their solution to the pharmacist’s, they often note significant differences. After the written projects have been submitted, selected projects are summarized and presented in class so that students can experience the wide variety of pharmacokinetics applications seen by their peers. This demonstrates that many of the common problems that pharmacists encounter each day have a pharmacokinetics component. One of our course objectives is that students learn to identify pharmacokinetics problems in patient care. This exercise, more than any other, helps to accomplish this objective. It also allows students to see how pharmacists approach such problems. We have found that students are quick to adopt the explanations of more experienced pharmacists because they do not trust their own ability to apply (transfer) what they have learned. The pharmacist case study exercise offers students the opportunity to examine their own thought processes side by side with those of the pharmacists. By receiving feedback on the strengths and weaknesses of their own approaches, students are encouraged to evaluate and then trust their own assessments and strategies.

The teaching/learning strategies described herein are not as time efficient as a traditional lecture. It was clear at the outset that material would need to be eliminated from the course as it existed previously. We approached this task with the essential problem-solving processes and pharmacokinetic models in mind, and deleted topics that were repetitive in either sense. After this paring was complete, about 15 percent of material had been deleted from the original syllabus and while this choice was difficult, the remaining material clearly supported the learning objectives we had established.

Assessment

Students in a traditional teaching/learning environment develop a complex set of performance-oriented studying tactics that are fundamentally detrimental to long-term retention
4. Understand and apply the concepts and variables important for solving pharmacotherapy problems requiring application of principles, basic concepts, and fundamental equations of pharmacokinetics. This means solving patient problems by starting with the principle(s) and working from principles to applications, (objectives 1 & 3)

<table>
<thead>
<tr>
<th>Question</th>
<th>Before Pharmacy 712</th>
<th>After Pharmacy 712</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify and solve patient pharmacotherapy problems requiring application of principles, basic concepts, and fundamental equations of pharmacokinetics. This means solving patient problems by starting with the principle(s) and working from principles to applications, (objectives 1 &amp; 3)</td>
<td>4.46</td>
<td>2.49*</td>
</tr>
<tr>
<td>2. Identify and solve patient pharmacotherapy problems characterized by altered therapeutic response, pharmacokinetics or pharmacodynamics due to concurrent disease, environmental variables (e.g., diet, smoking), or concurrent drug therapy. In this case, you are thinking from application to principles, (objectives 1 &amp; 2)</td>
<td>4.66</td>
<td>2.40*</td>
</tr>
<tr>
<td>3. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to the specific drugs covered in class, (objective 1)</td>
<td>4.91</td>
<td>2.40*</td>
</tr>
<tr>
<td>4. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to drugs not covered in class, (objectives 1-3)</td>
<td>5.00</td>
<td>2.80*</td>
</tr>
</tbody>
</table>

}\footnotesize{3}\footnotesize{(N = 35)}

1. Identify and solve patient pharmacotherapy problems requiring application of principles, basic concepts, and fundamental equations of pharmacokinetics. This means solving patient problems by starting with the principle(s) and working from principles to applications, (objectives 1 & 3)

2. Identify and solve patient pharmacotherapy problems characterized by altered therapeutic response, pharmacokinetics or pharmacodynamics due to concurrent disease, environmental variables (e.g., diet, smoking), or concurrent drug therapy. In this case, you are thinking from application to principles, (objectives 1 & 2)

3. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to the specific drugs covered in class, (objective 1)

4. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to drugs not covered in class, (objectives 1-3)

\textit{Mean} and \textit{SD}

\textit{Table I. Degree of achievement of course objectives}^{3}\footnotesize{(N = 35)}

\textit{Question} \hspace{1cm} \textit{Before Pharmacy 712}^{4}\footnotesize{\textit{c}} \hspace{1cm} \textit{After Pharmacy 712}^{4}\footnotesize{\textit{c}}

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify and solve patient pharmacotherapy problems requiring application of principles, basic concepts, and fundamental equations of pharmacokinetics. This means solving patient problems by starting with the principle(s) and working from principles to applications, (objectives 1 &amp; 3)</td>
<td>4.46</td>
<td>1.17</td>
<td>2.49*</td>
<td>1.20</td>
</tr>
<tr>
<td>2. Identify and solve patient pharmacotherapy problems characterized by altered therapeutic response, pharmacokinetics or pharmacodynamics due to concurrent disease, environmental variables (e.g., diet, smoking), or concurrent drug therapy. In this case, you are thinking from application to principles, (objectives 1 &amp; 2)</td>
<td>4.66</td>
<td>1.15</td>
<td>2.40*</td>
<td>1.14</td>
</tr>
<tr>
<td>3. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to the specific drugs covered in class, (objective 1)</td>
<td>4.91</td>
<td>1.22</td>
<td>2.40*</td>
<td>1.33</td>
</tr>
<tr>
<td>4. Understand and apply the concepts and variables important for identifying and solving pharmacokinetic/pharmacodynamic patient problems related to drugs not covered in class, (objectives 1-3)</td>
<td>5.00</td>
<td>1.37</td>
<td>2.80*</td>
<td>1.18</td>
</tr>
</tbody>
</table>

\footnotesize{Data are from class taught during Spring, 1998.}

\footnotesize{INSTRUCTIONS TO STUDENTS:} The number “1” on the scale represents the highest that could be expected of a B.S. Pharmacy graduate - to have confidence in your ability to recognize drug therapy problems that involve pharmacokinetics, to gather and interpret the needed data, propose alternative solutions to the pharmacokinetic patient therapy problem, and monitor for therapy outcomes. The number “7” represents your level of competence when you first entered the College of Pharmacy. The number “4” would mean that you think you are about 50 percent of the way towards the description for number “1.”

\footnotesize{Pharmacy 712 is the clinical pharmacokinetics course described in this paper. Both “before” and “after” responses were obtained at the end of the course.}

\footnotesize{Unpaired t-test comparing “before” Pharmacy 712 with “after” Pharmacy 712.}

and application of knowledge. Many of these tactics are related to the “two midterms and a final” method of assessment, so common in the traditional classroom. Alley(3) states that “Assessment is far too undervalued as a potentially active tool of quality student-centered learning. More than merely an instrument for measuring student mastery, it can and should be woven into the basic fabric of the teaching and learning process so that it both reflects and enhances learning.” We agree with this philosophy and used our course objectives to develop four expectations of a grading system which we feel characterize Alley’s description. First, the method of student assessment must decrease examination anxiety and “ cramming”, which yields temporary command of large amounts of very context-bound information. Second, it must assess students’ mastery of bidirectional problem solving as well as their abilities to transfer to other contexts. Third, it should serve as an instructional tool as well as an instrument of evaluation. Finally, assessment should yield a fair evaluation of multiple dimensions of learning such as researching information, formulating hypotheses, designing a course of action, performing accurate calculations, and assessing therapeutic outcomes.

Our first and greatest departure from a traditional grading system was the implementation of a modified mastery-based approach to student assessment. Students must receive no less than a “B-” on each homework, case, project, and examination, or they must resubmit the work. If the item is a homework, quiz, or project, resubmission of the original assignment is permitted. When we schedule major examinations, a “retake” date is also scheduled whereupon a completely different test is administered to students who received less than “B-”. Satisfactory resubmissions receive a grade of “B-”, and in the rare case where the resubmitted grade is also less than “B-”, the actual grade or score attained on the second attempt is recorded. This is intended to disallow any advantage over students who perform well on their first attempt. We apply this strategy to all graded material and have, in the last six years, had four students obtain final course grades of less than “B-”. Thus, in contrast to a true mastery-based approach to learning we do not permit unlimited attempts due to our concern that student dedication may actually decline when unlimited examination opportunities are available. We feel that this modified mastery-based approach to assessment fulfills the first and third expectations of an assessment process. Our students report decreased levels of test anxiety since there is an opportunity to recover from a poor performance. Retaking examinations or resubmitting cases is sufficiently time consuming for the student, however, to serve as a deterrent to suboptimal initial effort. More important though, is the provision for additional learning which results from restudying material which was obviously not mastered adequately on the first attempt. Having to restudy material for a grade prompts a more intensive effort than merely reviewing an exam after it is returned with an unacceptable grade.

We assess students’ mastery of material at frequent intervals and by a variety of methods which target different dimensions of learning. In addition to decreasing test anxiety, one of the intents is also to diminish the arithmetic prominence of any single project or examination. In other words, each of the two midterm examinations contributes only 20 percent to students’ final grades, while the cumulative quizzes and homework contribute 20 percent and so forth. By administering a frequent and varied assortment of assessments, the phenomenon of minimal effort between examinations is diminished and students...
find that they must exert a very consistent effort in order to maintain their performance. Frequent, short-answer quizzes serve to support this ongoing currency of understanding. Students know they must master material consistently or else risk poor performance on the next week’s quiz. Although each quiz grade contributes only about one percent to the final grade, our intent is to provide real incentive to do well. Perhaps more importantly, however, the quizzes allow us to assess students’ learning that is not context specific - our second expectation of a good assessment system. We test this with quiz questions which are sometimes contextually different from the way in which the material was initially presented and discussed. This gives students practice with contextual transfer, and also lets us keep a watchful eye on the emergence of this ability.

In addition to quizzes, students complete a variety of projects which serve as assessment tools. We use both in-class and take-home examinations. The take-home examinations are essay case-study examinations and involve library work and a depth of problem solving that is not possible on an in-class examination. Students also receive grades for in and out of class group projects, as well as the quizzes and pharmacist case study. This variety of assessments serves all four of the expectations we have of an assessment system: decreased anxiety, assessment of mastery, use as a teaching tool, and appraisal of various dimensions of learning. The assessment tools expose students to questions and situations which reflect a wide variety of contexts. They must practice and demonstrate their understanding, working both from principles to solutions, and from observable events back to principles. As Angelo succinctly states: “Learning to transfer, to apply previous knowledge and skills to new contexts, requires a great deal of practice” and, “...if you value transfer, teach transfer.”(1) As nearly as possible, we expose students to real life situations and accommodate a broad range of learning styles. This, coupled with the feedback we give and the chance to repeat projects if the first attempt goes wide of the mark, gives students both security and direction as they develop confidence in their assessments and decision making.

Ancillary Contributors

There is a set of factors which we feel contribute to our students’ learning, but cannot be categorized readily as either teaching tools or assessment strategies. The first is the balance of experiences contributed by the two instructors. One of us (RHR) has taught for 30 years as a laboratory-based scientist trained in pharmaceutics and pharmacokinetics. The other (CCB) is a PharmD with six years of teaching and practice experience in internal medicine. The differences in our thought processes are quite pronounced. We find that the basic scientist reasons and teaches in an a priori, “principles-to-application” manner, emphasizing exactitude. The clinician, on the other hand, operates from a strongly a posteriori, or “observations-to-principles,” position. Far from working at cross purposes however, this combination of approaches has strengthened our teaching efficacy beyond all expectation. We are able to present subjects with a depth and dimension that neither instructor could provide alone. We feel that this observation is noteworthy because basic science and clinically oriented courses are often sequenced and taught independently of each other, hence the potential vigor of the combined contributions may not be achieved. The recent interest in case-based teaching of basic science courses may reflect this.(5)

Because we approach subject material from different perspectives and use a wide variety of teaching and learning designs, we feel that the course facilitates a wide range of student learning styles and preferences. We expect that our students will succeed, and communicate this to them at the beginning of and throughout the quarter. This expectation is also implicit in the modified mastery-based grading system we use. But in addition to the opportunity to master material, we feel that the expectation that students will succeed, beyond the customary bell shaped grade distribution, reassures and motivates them to learn well.

Finally, in transitioning from an instructor-centered to a student-centered classroom, we could not help but note the contribution of encouragement to our students’ learning. A student-centered classroom increases instructors’ vulnerability; but the students’ roles change as well. Barr and Tagg describe how “The Learning Paradigm shifts what the institution takes responsibility for: from quality instruction (lecturing, talking) to student learning. Students, the co-producers of learning, can and must, of course, take responsibility for their own learning. Hence, responsibility is a win-win game wherein two agents take responsibility for the same outcome even though neither is in complete control of all the variables.” This change in the instructor-student relationship coupled with the expectations of mastery-based assessment places students in an unfamiliar learning environment. For our students, facilitation of this transition is enhanced by an environment of deliberate encouragement. Encouragement, broadly, suggests acknowledgement of students’ efforts, perspectives, and challenges. Parker Palmer(6) describes discussions with teachers about teaching. He strives to establish an environment where “Everyone can feel both honored and challenged in his or her own teaching style.” Encouragement helps establish this environment for the students with varying learning styles as well.

EVALUATION OF TEACHING AND LEARNING

We have used extensive student assessments of teaching and learning for five years to better understand students’ reactions to our teaching methods, thus guiding course modifications. During the last class session students complete a 39-item assessment of perceptions about the learning materials, cooperative learning exercises, active learning strategies, and grading system. As part of this assessment, students also evaluate their own pre- and post-course achievement of course objectives, and also their self-perceived ability to apply pharmacokinetics to patient care. Anchored five- and seven-point scales are used for measurement. Space is designated at regular intervals for written comments and we find that students take liberal advantage of this opportunity. Results of questions from the 1998 surveys which specifically address the three learning objectives (see above) are presented in Table I. We present 1998 data only because responses to the same survey instrument from years 1993-1998 are virtually superimposable. In all cases, students’ responses indicate a statistically significant improvement in mastery of learning objectives during the course. The results of questions on teaching/active learning strategies are presented in Table II. Students respond very positively to introspective class presentations, in-class problem solving, and the modified mastery grading system. The students’ response to in-class cooperative problem solving is consistently less positive.

DISCUSSION

The best measure of successful teaching methods is a demonstrable increase in student learning. Learning, particularly
The course surveys and students’ comments further demonstrate appreciation of the interactive learning environment, the ABI grading system, and enthusiasm for the course in general. The comments reveal that subject material students previously perceived as very intimidating now seems useful and non-threatening. The ABI grading system, together with small group discussions).

In both free-text comments and scaled responses, students indicated a very strong preference for the use of cases and practice-centered examples of pharmacokinetics applications. The utility in our use of cases is two-fold: first, the students identify with the role of a practitioner and second, the practice-centered method enables us to teach them the process of contextual transfer. It is essential however, that the patient-centered “from-application-back-to-principle” not be the only direction taught, and the great strength of a basic science faculty member’s orientation is the demonstration of the “from-principles-forward-to-application” process.

The course surveys and students’ comments further demonstrate appreciation of the interactive learning environment, the ABI grading system, and enthusiasm for the course in general. The comments reveal that subject material students previously perceived as very intimidating now seems useful and non-threatening to them. Some consider this course among the best they have ever taken. We have also learned that students consistently do not feel that in-class group learning exercises are productive. After initially resisting their assessments, we have finally concluded that exercises involving calculations are cumbersome when undertaken in a group setting. Much time is spent performing the calculations and, since students work at different speeds, continuity of effort deteriorates. We will continue to use the collaborative group approach for problem identification and strategy planning, but not for dose or parameter calculations.

While student opinions cannot be regarded as unbiased measures of learning, they are reliable indicators of interest and motivation. Of note, when students’ performance on similar in-class examinations is compared between the present and prior to 1994 when we initiated comprehensive changes in the course, no outstanding differences are noted. This can be interpreted in various ways, but indicates to us that most classroom-based examinations offer so many contextual limitations and cues that they do not measure students’ ability to manipulate and apply information. Thus, measuring actual changes in learning which can be attributed to our teaching methods and course revisions continues to be problematic.

Since we have not established a systematic instrument which measures our students’ or graduate pharmacists’ command of pharmacokinetics, a true, long-term indicator of our success in the classroom is not available. We have given less than 10 grades below B- over the past five years without lowering our standards (as indicated by the performance in classroom exams which have been similar over many years). Also, solicited and unsolicited reports from graduates and observations of faculty and preceptors may offer some insight. During the first quarter of our two-year post-BS PharmD program, students take a very rigorous pharmacokinetics course. The professor has noted that students who have taken Pharmacy 712 seem to struggle less than students from our own or other institutions who have not taken it. Some graduates of our undergraduate program have commented to us and others that the course has made a difference in the way they practice and that they do incorporate principles of pharmacokinetics into their day-to-day care of patients. In at least one institution, entry-level pharmacists who have taken Pharmacy 712 are noted by the administration to integrate much more readily into the responsibilities of the pharmacokinetic dosing service than pharmacists who have not taken the course. Similarly, preceptors who incorporate pharmacokinetic principles and dosing into their practices have clearly stated that there is no comparison between the abilities of pharmacy externs who have taken Pharmacy 712 and those who have not. The preceptors note that students who have taken our course are more comfortable with terminology and concepts, can identify altered physiology and its likely effect on drug disposition, perform basic calculations, and are less intimidated by drug dosing in general than students who have not taken it. How much of this difference is purely the result of an extra quarter’s exposure to pharmacokinetics irrespective of teaching methods is impossible to discriminate. However, prior to changing the course in 1994 this type of feedback did not occur. The methods we use are still evolving, but are consistent with current research in active learning and teaching contextual transfer. Evidence obtained from students, their experiential preceptors, and employers suggests that the teaching/learning strategy enhances application of pharmacokinetics in the practice environment.


References