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Research Note

Implementing a strategy for promoting long-term meaningful learning in a pharmacokinetics course

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ABSTRACT

Introduction: The purpose of this paper is to describe the evolution and effectiveness of instructional strategies that were implemented over a seven-year period to enhance the authenticity of instruction and assessment in a pharmacokinetics (PK) course.

Methods: Baseline data from 2011 and 2012 were analyzed to identify opportunities for improvement. In 2013 and 2014, lectures, PK workshops, and exam questions were modified to represent more authentic learning and assessment. Counter to expectations, 2013 and 2014 exam scores were significantly lower when compared to 2011 and 2012 scores. The course was modified further in 2015 to incorporate post-workshop quizzes that provided corrective feedback and required the use of retrieval as a learning strategy. Exam scores were compared across the three phases of course improvement (2011/2012 vs. 2013/2014 vs. 2015/2016/2017) using statistical analyses.

Results: The average final examination score in 2011-2012 was 84.6%. After increasing the number of authentic assessment exam items, the average on the final examination in 2013-2014 decreased to 80.3% ($p < 0.0001$). Following the implementation of the post-workshop quizzes, the average final examination scores increased from 2015-2017 to 85.9% ($p < 0.0001$, compared to 2013-2014; $p = 0.08$, compared to 2011-2012).

Discussion: Implementation of these evidence-based learning and instructional strategies (authentic learning, retrieval of new learning, and corrective feedback) was associated with higher student performance on the final examination over time.

Conclusion: These strategies may be valuable in improving student learning outcomes in other challenging professional program courses.

Introduction

Pharmacokinetics (PK) is traditionally a mathematically intensive course taught in the curriculum in schools of pharmacy. Mathematic-intensive courses are often challenging for students.[1] Abstract concepts of PK parameters, such as volume of distribution, half-life, and elimination rate constant are integrated and utilized in various complex formulas to calculate drug doses and concentrations. Further adding to the complexity of PK problems is the potential of an evolving patient case scenario in which disease-states and drug-drug interactions may affect PK calculations. Thus, having good command of the subject and obtaining the necessary

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Table 1
Descriptions and examples of activities and learning strategies.

Term	Description	Example of activity or strategy
Meaningful learning	A method of learning in which new knowledge to be learned is related to prior knowledge[28]	Students are required to understand and be able to utilize PK equations learned previously to calculate new items
Authentic learning	A method of learning in which concepts are taught, discussed, and explored in real-world context[29]	Patient case scenarios are designed to mimic the breadth and depth of a real-life patient medical record
Retrieval of new learning	The process in which learning and memory is reinforced by retrieving previously learned knowledge[30]	Students are assessed immediately after learning activity (post-workshop quizzes)
Constructed response	Assessment questions which require students to create a response rather than simply recognizing the correct response from provided option(s)[31]	Post-workshop quizzes require students to construct an answer (i.e. calculate drug dose or drug concentration)
Active learning	A learning process in which students engage with the material by working mentally with the new material or by participating in hands-on activities that promote learning of the new material[32]	The PK workshops are conducted with teams of 5-6 students working together to utilize concepts learned during lecture and applied to patient case scenarios to solve PK questions
Corrective feedback	A process in which students receive feedback on their performance with the opportunity to revise their work[33]	Students receive feedback on their post-workshop quizzes
Workshop	A group activity with collaborative application of the newly learned concepts to real life pharmacy problems and cases	There are ten 2-hour workshops in our college with approximately 1 workshop per week in the pharmacokinetics course

skills to perform PK calculations often requires practice of calculations and understanding the effects of an evolving patient case as it relates to the PK calculations.[2] Development of instructional strategies that promote meaningful learning (Table 1) that transfers to real-life settings can be challenging.

Effective instructional strategies, such as active learning (Table 1), play a substantial role in promoting learning through student engagement and reinforcement of challenging concepts presented in lectures.[3-5] Examples of active learning strategies in the literature include case-based learning, problem-based learning (PBL), team-based learning (TBL), audience-response (clickers), discussion-based learning, games, and patient simulations.[6-9] A meta-analysis found that implementation of active learning components into a course led to increased examination scores compared to courses where material was delivered via lecturing only.[10] The defining feature of active learning is effortful engagement with the material to be learned. Some active learning strategies can be completed in-class or independently by learners. For example, research indicates that retrieval of new learning (Table 1) and self-explanation is a particularly effective strategy that can be implemented within a classroom or independently outside of class.[11,12] Karpicke and Blunt[13] demonstrated that students who used retrieval when studying performed better on a final course assessment than students who used open-book studying only or open-book with concept mapping. Retrieval is a simple active-learning strategy that, when used appropriately, involves spaced practice over two or more intervals of time to bolster long-term learning. In another study, students benefited from explaining course content to themselves or others, demonstrating the effectiveness of explanation as a specific retrieval activity.[12] Explanation as a learning strategy can be readily incorporated into group work.

Another factor that impacts student learning outcomes is the authenticity of learning tasks and assessments. Authenticity connects student learning to real-world issues, problems, and applications.[14] For student pharmacists, authentic learning (Table 1) experiences should reflect the complexity and ambiguity of patient care and the pharmacy practice setting. Some of the characteristics of such problems include real life relevance, an ill-defined problem, multiple sources and perspectives, collaboration, reflection, and formative assessment. Providing in-class, yet authentic, PK problem in a small group format with the opportunity to retrieve and practice new learning could be a particularly effective active learning strategy for student pharmacists. In addition, enhancing the authenticity of examination items could also positively impact student learning outcomes. The purpose of this research is to describe the impact of these instructional strategies (authentic learning, retrieval of new learning with corrective feedback) over a seven-year period to enhance the authenticity of instruction and assessment.

Educational context

The PK course at Western University of Health Sciences College of Pharmacy in Pomona, CA includes 73 lecture hours over a nine-week period in the first-year (P1) spring semester. In addition, ten 2-hour workshops (Table 1) provide practice opportunity in small groups. Two instructors teach a class of approximately 120 students. The first instructor covers basic PK concepts such as absorption, distribution, metabolism, elimination, volume of distribution, half-life, elimination rate constant, and clearance over 34 lecture hours and five PK workshops. The second instructor covers how PK concepts and parameters are affected in disease-states and sub-populations, such as renal disease, cardiovascular disease, geriatrics, pediatrics, and obesity. The two instructors taught separately and covered the same topics for entirety of the study. Thirty-nine lecture hours and five PK workshops are devoted to clinical PK. There are two examinations and a final examination consisting of approximately two-thirds multiple choice and one-third constructed response format (Table 1). At the time of the PK course, first-year students are in the second (and final) semester of physiology, pathophysiology, and pharmacology and have not received therapeutics lectures.

The continuous quality improvement (CQI) process at Western University is applied to all courses in the didactic curriculum. Following the completion of a course, the instructor(s) meets with the assistant dean of curricular affairs to review and discuss course content, allocation and distribution of time for topics, student evaluations of the course, assessment scores, and possible changes for