

INSTRUCTIONAL DESIGN AND ASSESSMENT

Modification of a Pharmacokinetics Course Design to Improve Student Performance

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Objective. To determine if the addition of weekly quizzes or reducing the number of faculty members teaching improved third-year (P3) pharmacy students' final grades in a clinical pharmacokinetics course.

Design. Four sections of a pharmacokinetics and pharmacodynamics course were divided according to the number of faculty members teaching the course and the administration of weekly quizzes. Two sections were taught by 6 faculty members and 2 were taught by 3 faculty members. Also, 1 section in each group received weekly quizzes, creating a 2-by-2 design.

Assessment. The performance of the 201 P3 students enrolled in the course was assessed by comparing the average of 3 examination grades while excluding quiz grades. The mean final grade of classes in which quizzes were not administered was lower than that for classes in which quizzes were administered ($p=0.019$). The mean final grade in classes taught by 3 faculty members vs 6 faculty members was higher, but not significantly. A positive significant correlation existed between performance in a prerequisite biopharmaceutics class and this advanced class.

Conclusion. Making minor modifications to the delivery of a course, such as number of quizzes administered and number of faculty members teaching the course, had a positive impact on student performance. Grades in a prerequisite course may enable earlier identification of students at risk of poor performance in advanced courses.

Keywords: assessment, pedagogy, pharmacokinetics

INTRODUCTION

The Accreditation Council for Pharmacy Education has identified pharmacokinetics/clinical pharmacokinetics as an area in the doctor of pharmacy (PharmD) curriculum that is critical to the foundation and delivery of effective patient care.¹ Accordingly, Clinical Applications of Pharmacokinetics and Pharmacodynamics has been a required 3-credit course in the PharmD curriculum for third-year pharmacy students at St. John's University College of Pharmacy and Health Sciences. It is divided into 4 sections and taught entirely by members of the clinical pharmacy practice department. Biopharmaceutics and Basic Pharmacokinetics, a prerequisite course taught by the pharmaceutical sciences department in the prior semester, introduces basic pharmacokinetic principles. The Clinical Applications of Pharmacokinetics and Pharmacodynamics

course builds upon these principles and incorporates drug-specific clinical application of these principles using simulated patient cases. It has traditionally been taught by a team of 6 to 7 different faculty members in the department of clinical pharmacy practice. The same syllabus is followed regardless of which faculty member teaches each section.

The course is considered challenging by the students and routinely results in about 20 failures and/or withdrawals each semester. All graduating pharmacy students from our institution participate in mandatory exit interviews where they are given an opportunity to comment on the curriculum, including laboratories, classroom-based courses, and practice experiences. Students have commented that the difficulty of the Clinical Applications of Pharmacokinetics and Pharmacodynamics course is partly because of the math-intensive nature of the material, the burden of the concurrent therapeutics courses, lack of sufficient examinations, and the number of different instructors. Student suggestions have included the addition of

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quizzes to better prepare them for examinations, which has also been considered in higher education literature.^{2,3} They have further stated that it was difficult to adjust to the teaching and examination styles of multiple faculty members teaching a single course.

We hypothesized that the addition of regularly scheduled quizzes would serve several potentially beneficial functions in the Clinical Applications of Pharmacokinetics and Pharmacodynamics course. Administering quizzes might improve P3 students' grades by employing a variety of assessments that contribute to grades vs examinations only. Also, because attendance was not mandatory, weekly quizzes would give students the opportunity to self-assess their learning and identify areas of weakness throughout the semester that could otherwise go unnoticed until performance on one of the higher-stake examinations. Regular quizzes could assist students in pacing their study of the material and increase time-on-task throughout the semester. In addition, quizzes might give students insight into how questions would be structured on their higher-valued examinations.

Team-taught models are characteristic of most clinical pharmacy practice classes at our university and are used in many colleges and schools of pharmacy nationally. This learning model enables faculty members to teach pharmacokinetics in their particular area of expertise using actual patient cases and allows a reduction in classroom time commitment to help maintain presence at the clinical site. An English-language search was performed in PubMed, Google Scholar, and Google for pharmacy and medical education articles evaluating the effect of the number of faculty members teaching a course on student performance. The search revealed no articles that directly addressed this question. We did not consider studies outside of these fields because of their limited external validity in the specific design of health science education.

The primary objective of our research was to assess the effects of 2 independent variables on students' final grades in the team-taught Clinical Applications of Pharmacokinetics and Pharmacodynamics course: the addition of regularly scheduled quizzes and altering the number of faculty instructors. Though P3 students cited numerous reasons for the difficulty of the course, changing the number of faculty members and adding quizzes were minor variations that could be studied and replicated with ease if found to be beneficial. Other difficulties such as concurrent classes, course content, and math-intensive nature of the course could not be easily modified.

Because many concepts in the course are first introduced in Biopharmaceutics and Basic Pharmacokinetics, faculty members also considered whether students' performance in the prerequisite course could predict future

performance in the Clinical Applications of Pharmacokinetics and Pharmacodynamics. Potential early identification of students who are likely to struggle in the advanced course might enable faculty members to advise these students to seek extra tutoring or other help to achieve a satisfactory grade. A secondary objective was, therefore, to determine if an association existed between performance in the prerequisite course and the subsequent advanced course. The number of failures among sections was also examined.

DESIGN

During fall semester 2011, four sections of the CAPP course ran concurrently, with 2 offered in the morning and 2 in the afternoon. The 2 experimental variables were implemented in alternating sections, creating a unique experience in each course section. Two of the 4 sections were taught by 6 faculty members each, while the other 2 sections were taught by only the 3 faculty members with the most experience in teaching the course. The other variable, weekly quizzes, was added to one 3-faculty section and one 6-faculty section, creating a 2-by-2 design. This design enabled us to designate 1 section as our control group (6 faculty members and no quizzes), which conformed to the typical teaching design of the course in previous years.

The format and structure of the course was identical for all 4 sections in terms of units of instruction, number of examinations, review days, textbook, learning objectives, and examination format. In the 2 sections not administered quizzes, the final student grade was an average of 3 equally weighted multiple-choice examinations. In the 2 sections administered weekly quizzes, mean quiz grades comprised 10% of the total grade, while 90% was the mean of 3 equally weighted multiple-choice examinations. This 10% provided an incentive for students to keep up-to-date with the material in addition to regularly attending class throughout the semester. For the purpose of performing statistical analyses in our study, quiz grades were not included in the calculation of the final grade (all final grades hereafter are an average of the 3 examination scores in all sections, except where specifically stated). Our goal was to measure the effect of student quizzes, if any, on examination grades, and including quiz scores into the final grade analysis would have altered the results. All students were given homework practice problems for each topic regardless of section. Enrollment into 1 of 4 sections was determined by a random lottery process. Students were not aware of differences in sections prior to enrollment regarding time of day, specific faculty members, location of lecture, or any of the study variables, and were mandated to attend their registered section. Students

were not permitted to switch upon learning the study arm of their section.

In the sections receiving quizzes, items were multiple choice and written at the Bloom's Taxonomy cognitive level of analyze, evaluate, or create. Items written for quizzes were similar to those written for the examinations in cognitive level and format. All quizzes had 5 questions each and questions were not identical between sections to avoid collusion among students. Examinations in all sections included the same number of items but were not identical in order to prevent collusion by students in different sections.

EVALUATION AND ASSESSMENT

Two-way analysis of variance (ANOVA) was used to determine significance of final course grades between groups. To test for an association between the prerequisite course and the subsequent advanced course, we compared final grades using the Spearman rank correlation coefficient. Baseline characteristic homogeneity of P3 students in the Clinical Applications of Pharmacokinetics and Pharmacodynamics course sections was determined through ANOVA of the Biopharmaceutics and Basic Pharmacokinetics grades. Grade point averages were not available and we felt the Biopharmaceutics and Basic Pharmacokinetics course grades were sufficient to determine internal validity between group baseline abilities. Free-text comments from the university's semester-end course evaluations were reviewed for individual student feedback. This study was deemed exempt status by the university's institutional review board.

The results from all 201 students enrolled in the course were analyzed by the 2 independent variables. The mean final grade of classes not administered student quizzes (n=109) vs those administered quizzes (n=92) was 80.4 ± 7.9 and 83.1 ± 8.6 , respectively ($p=0.019$). The mean final grade of classes taught by 6 (n=100) vs 3 faculty members (n=101) was 80.7 ± 7.7 and 82.5 ± 8.8 , respectively ($p=0.13$) (Table 1). The Biopharmaceutics and Basic Pharmacokinetics course grades from 2010 were compared to the student-matched 2010 Clinical

Applications of Pharmacokinetics and Pharmacodynamics grades to determine if there was a positive correlation in a prior nonstudy year. These grades were compared again in the 2011 study group. The 2010 and 2011 student-matched grades for the 2 courses showed a positive correlation, $R^2=38\%$ and 61% , respectively ($p<0.001$ for both). Among the 4 course sections in the study year, there was an even distribution of course performance in the Biopharmaceutics and Basic Pharmacokinetics course ($p=0.67$), indicating comparable baseline abilities.

By calculating the final grades in the quiz sections in 2 ways, both including and excluding quizzes, we were able to see whether the quizzes brought the final grades up or down for these students. We found that final grades were actually improved when based solely on the average of the 3 examination scores. While students may have performed poorly on the quizzes, they achieved better examination scores (82.4 with quizzes included in the analysis vs 83.1 with quizzes excluded from analysis, $p<0.001$). The university end-of-semester surveys were completed by less than 10% of students in the course. A brief discussion of the free-text responses is found in the discussion below.

DISCUSSION

The primary outcome of our study was to determine if frequent quizzes would ultimately affect students' performance on examinations. The administration of frequent quizzes is a practice that is generally viewed positively by students and has been associated with improved class participation and preparation.^{2,3} Our study found that frequent quizzes did lead to improved student performance on examinations (83.1 ± 8.6 vs 80.4 ± 7.9 , $p=0.019$), when the grades for the quizzes themselves were excluded. Our results differed from a study conducted by Freilich that sought to determine if frequent quizzing would translate to better learning for students and overall improvement in students' performance in a general chemistry course with 421 students enrolled.⁴ The course's grading scheme included 4 major quizzes (20 to 25 minutes each), 3 lecture

Table 1. Pharmacy Students' Final Grades by Section in Clinical Applications of Pharmacokinetics and Pharmacodynamics Course

| Instructors, No. | No Quizzes | | Quizzes ^a | | Total | |
|------------------|-------------------------|-----|-------------------------|-----|-------------------------|-----|
| | Mean (SD) | No. | Mean (SD) | No. | Mean (SD) | No. |
| Three | 81.1 (8.7) | 60 | 84.6 (8.6) | 41 | 82.5 (7.7) ^b | 101 |
| Six | 79.5 (6.8) | 49 | 81.9 (8.4) | 51 | 80.7 (8.8) ^b | 100 |
| Combined | 80.4 (7.9) ^c | 109 | 83.1 (8.6) ^c | 92 | | |

^a Final grades in quiz-containing sections do not include quizzes as part of the final assessment, though they did in the actual class.

^b Comparison of the totals $82.5 (7.7)$ and $80.7 (8.8)$, $p=0.13$.

^c Comparison of the combined totals $80.4 (7.9)$ and $83.1 (8.6)$, $p=0.019$.

examinations, and a final examination. Of those students enrolled in the general chemistry course, a third received additional weekly quizzes for credit, a third received additional weekly quizzes for no credit, and a third received no additional weekly quizzes. Freilich's study revealed that the increased frequency in quizzes did not impact students' final grades as originally hypothesized. However, the students felt that weekly quizzes would provide them with more guided studying opportunities and a higher likelihood of better performance on their final examinations. Unlike our study, Freilich already had built 8 assessment opportunities into his "no quiz" group, which may partially explain why there was no difference in final examination grades between study groups.⁴

Co-teaching or collaborative team teaching is an instructional design that has been used in various areas and levels of education.⁵⁻⁷ Co-teaching is defined as "...a restructuring of teaching procedures in which two or more educators possessing distinct sets of skills work in a co-active and coordinated fashion to jointly teach academically and behaviorally heterogeneous groups of students in educationally integrated settings, that is, in general classrooms."⁵ This method is used in many schools with professional tracks whose faculty members often have to split their teaching time between classroom and experiential teaching.⁸⁻¹¹ At our university, many of the pharmacy practice courses, including the Clinical Applications of Pharmacokinetics and Pharmacodynamics course, are taught using co-teaching methods to provide students the opportunity to be taught by faculty members who have expertise in certain areas/topics and to allow faculty members the time to maintain their clinical services at their experiential sites. In-class student evaluations revealed that students found it difficult to adjust their learning preferences and study habits to the varying teaching styles among faculty members within a given course. With this in mind, we sought to determine if addressing these issues would impact students' performance. There was a slight difference in mean final grade between classes taught by 6 vs 3 faculty members; however, this did not reach statistical significance. Although students may have subjectively felt that they were not performing well because of the needed adjustments in their learning preferences, it ultimately did not affect the grades students achieved in the Clinical Applications of Pharmacokinetics and Pharmacodynamics course. Garton and colleagues demonstrated this same principle in their study in which instructors co-teaching an animal science course found that diversity of learning or teaching styles had no influence on student achievement or their perception of faculty members' teaching performance.¹² In our study, although the number of faculty instructors was reduced in certain sections, students in both

groups were still subjected to co-teaching practices. We may have found a greater difference if we compared the impact on students' performance of multiple faculty members co-teaching a course vs a single faculty member teaching a course. Upon completion of the course, student feedback was sought via anonymous online evaluation forms. Completion of evaluations was not required and only a few students provided free-text feedback regarding the class. Several students commented that they preferred being assigned to the 3-faculty section because of less variation in style of individual faculty member questions on the multiple-choice examination. Regarding quizzes, most of the free-text feedback held the quizzes in a positive light in that the quizzes required the students to keep up with their studies in a timely manner. Several students felt that by having an incentive to learn the material from week to week, they only needed to refresh their memory with practice problems before the examination. One student commented that she would remember the material from this course better than that from any other course because of the week-to-week accountability. The response number to this anonymous survey was also hidden from faculty members.

Students who excelled in the prerequisite course also excelled in Clinical Applications of Pharmacokinetics and Pharmacodynamics (positive correlation of 38% and 61% in 2010 and 2011, respectively, $p < 0.001$). Therefore, a reasonable conclusion is that high-performing students will continue to perform well in subsequent courses despite the challenges posed by variations in teaching and learning preferences. It may be useful to identify at-risk students early to provide them with early interventions, like frequent quizzes or tutoring, to ensure their success.

While our study revealed useful interventions to improve Clinical Applications of Pharmacokinetics and Pharmacodynamics course grades, there were some limitations. An assessment of students' perceptions was not conducted. It would be interesting to determine if students' perceptions of performance did correlate with their actual overall performance in the course. Research on students' performance and study habits has revealed varying effect sizes for different study methods.¹³ The final analysis of our study was not adjusted for confounders, including student factors (ie, learning preference of student), faculty factors (ie, teaching experience, variability in student assessment questions), and environmental/logistical factors (ie, time of day in the course, proximity to faculty member in class), which have been known to affect students' performance. One notable improvement from previous years was that only 2 students received a failing final grade during this study (1 in the 6-faculty-member section that was administered quizzes and 1 in the 3-faculty-member

Table 2. Pharmacy Students' Final Grades Distribution by Section in Clinical Applications of Pharmacokinetics and Pharmacodynamics

| | A | A- | B+ | B | B- | C+ | C | C- | D+ | D | D- | F | n |
|---|----|----|----|----|----|----|----|----|----|---|----|---|-----|
| 2011 CAPP Class | | | | | | | | | | | | | |
| 3 faculty members, no quiz | 11 | 7 | 12 | 3 | 6 | 12 | 1 | 4 | 3 | 0 | 0 | 1 | 60 |
| 3 faculty members, quiz | 12 | 4 | 9 | 1 | 4 | 8 | 0 | 3 | 0 | 0 | 0 | 0 | 41 |
| 6 faculty members, no quiz | 3 | 2 | 8 | 14 | 5 | 9 | 2 | 5 | 1 | 0 | 0 | 0 | 49 |
| 6 faculty members, quiz | 9 | 3 | 11 | 9 | 6 | 3 | 5 | 2 | 2 | 0 | 0 | 1 | 51 |
| Total | 35 | 16 | 40 | 27 | 21 | 32 | 8 | 14 | 6 | | | 2 | 201 |
| 2010 CAPP course Class | | | | | | | | | | | | | |
| 6 faculty members, no quiz (all sections) | 1 | 3 | 12 | 9 | 8 | 8 | 4 | 5 | 7 | 0 | 0 | 2 | 59 |
| | 6 | 3 | 4 | 7 | 8 | 7 | 2 | 3 | 1 | 0 | 1 | 3 | 45 |
| | 3 | 0 | 10 | 6 | 7 | 7 | 4 | 4 | 5 | 0 | 0 | 2 | 48 |
| | 4 | 7 | 8 | 5 | 8 | 10 | 9 | 3 | 2 | 0 | 0 | 0 | 56 |
| Total | 14 | 13 | 34 | 27 | 31 | 32 | 19 | 15 | 15 | 0 | 1 | 7 | 208 |

Abbreviations: CAPP=Clinical Applications of Pharmacokinetics and Pharmacodynamics.

section that received no quizzes)(Table 2). Typically, there have been up to 20 failures and/or withdrawals from the course, which necessitated offering it during the summer session. Perhaps the idea that performance was being studied by professors was its own type of incentive for students, resulting in an improvement in grades overall. We also used final grades as a proxy for learning and these 2 factors may not necessarily be equivalent.

SUMMARY

Clinical Applications of Pharmacokinetics and Pharmacodynamics has long been a difficult course in the PharmD degree curriculum. Two interventions were conducted in an attempt to improve P3 students' final grades in this course. The addition of quizzes had a modest but significant effect on students' performance while altering the number of instructors through the semester had less of an impact. These simple and easily implementable modifications might be useful in other courses.

Past performance in the prerequisite course was found to be a predictor of students' final grades in Clinical Applications of Pharmacokinetics and Pharmacodynamics. Identifying students who are likely to struggle in the course may also enable faculty members to provide them with additional resources and guidance.

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