RESEARCH

The Effect of Prerequisite Pharmacodynamics Course Timing on Student Performance in Pharmacotherapy Courses

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Objective. To evaluate the impact that decreasing the time from 12 to three months between prerequisite pharmacodynamics courses and their corresponding pharmacotherapy courses had on overall student performance in the pharmacotherapy courses measured by course examination scores.

Methods. Two cohorts of second-professional year (P2) and third professional year (P3) classes, respectively, following different curriculum plans, simultaneously took two pharmacotherapy courses (infectious disease and neoplastic disease). Admission data (age, gender, prior bachelor's degree status, grade point average (GPA), Pharmacy College Admission Test (PCAT) score, and interview score) were collected to establish baseline characteristics between the two cohorts. Examination scores in the corresponding prerequisite pharmacodynamics and pharmacotherapy courses were also collected. The variable was the difference in time each cohort experienced between the prerequisite pharmacodynamics courses and the subsequent pharmacotherapy courses.

Results. No difference was found in baseline admission characteristics between the two cohorts, except for increased average age, which favored the P2 cohort. In the infectious disease pharmacotherapy course, the P3 cohort performed better than the P2 cohort as measured by average examination scores. In the neoplastic disease pharmacotherapy course, the P3 cohort also achieved significant higher average examination scores than the P2 cohort. The P3 cohort achieved higher overall scores than the P2 cohort in both courses despite a longer interval between the applicable pharmacodynamic and pharmacotherapy courses (12 months vs 3 months, respectively).

Conclusion. Shortening the time interval from 12 months to three months between prerequisite and requisite courses did not result in improved, or even equivalent, academic performance relative to the P2 cohort that had only a 3-month interval between courses. Placing like content closer together, as the only intervention, is not enough to ensure improved student performance measured by examination scores in corresponding requisite courses.

Keywords: curriculum, course timing, curricular design

INTRODUCTION

Prior knowledge is considered an important factor that influences continued learning and student achievement. The Model of Prior Knowledge explains different types of knowledge and subsequent indicators necessary to validate the ability to understand and apply knowledge.¹ For example, declarative knowledge is expressed by recalling information and demonstrating the process of simply knowing a particular fact. Whereas, procedural knowledge is the ability to integrate facts and apply this ability to problem solving.² Prior knowledge that mainly

consists of declarative knowledge does not appear to contribute to lasting student achievement, whereas the opposite is true for procedural knowledge.^{1,2}

For students to effectively develop procedural knowledge, content should be delivered that provides a close temporal relationship between knowledge acquisition and opportunities for integration and application.³ Shortening the time between the acquisition of declarative knowledge and procedural knowledge facilitates, or increases the likelihood that, two critical facets of learning will take place. The first facet is reinforcement of existing declarative knowledge, which ensures the overlearning automaticity needed to embed that knowledge into long-term memory. The second is an immediate embedding of procedural knowledge based on that declarative knowledge. Students more effectively experience integration-based learning (or procedural knowledge) because they are more

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likely to grasp: (1) why the material they are learning is important (as the material isn't treated as a unique, stand-alone topic to be learned and subsequently forgotten); and (2) how the material is applied in pharmacist-provided patient care (and hence "matters" to the student). This logic of learning is also embedded and enforced in pharmacy accreditation standards. The 2016 Accreditation Council for Pharmacy Education (ACPE) specifies that the doctor of pharmacy (PharmD) curriculum must be organized to allow for the logical building of a sound scientific and clinical knowledge base that culminates in the demonstrated ability of learners to apply knowledge to practice.⁴ Further, the curriculum should be intentionally sequenced to promote integration and reinforcement of content. Standard 10 (Curriculum Design, Delivery, and Oversight) does not specifically prescribe how curriculum sequencing and integration should occur.⁴ Rather, it allows each school to determine the best method to fulfill this standard. Additionally in Standard 10, ACPE requires regular assessment and modification (if necessary) to ensure optimal achievement of educational outcomes. Specifically related to pharmacy education, examples of curricular assessment of PharmD programs exist in the literature, but there is a lack of research discussing how to best sequence courses to promote integration and reinforcement of content.

Prior to 2013, the PharmD curriculum structure at North Dakota State University (NDSU) followed a general theme of pharmaceuticals and pathophysiology in the first professional year (P1), pharmacodynamics (which includes pharmacology) in the second professional year (P2), and pharmacotherapy in the third professional year (P3). Based on revised educational outcomes at the overall program level, the curriculum underwent a major revision resulting in the addition of new courses (Public Health for Pharmacists, Pharmacotherapy Capstone, Interprofessional Health Care, and Pharmacy Practice Improvement and Project Management) in the PharmD curriculum and relocation of some prior P1 courses (Biochemistry, Pathogenic Microbiology, and Writing for Health Professions) into the prepharmacy curriculum. Additionally, while considering factors such as the Model

of Prior Knowledge, the PharmD curriculum committee and PharmD faculty members determined that it seemed logical to directly sequence a topic's pharmacodynamic and pharmacotherapy courses (ie, infectious disease pharmacodynamics given in the semester before the infectious disease pharmacotherapy course). This change in curricular structure shifted some pharmacodynamic courses (P2 to P1 year) and pharmacotherapy courses (P3 to P2 year) into earlier than usual parts of the curriculum. The shifts in curriculum placement were made possible, in part, by the addition of two of the new courses (Pharmacotherapy Capstone and Pharmacy Practice Improvement and Project Management) to the P3 year, which are ideally based on synthesis and procedural knowledge obtained from previously completed courses. The PharmD curriculum committee and PharmD faculty members concluded that these curricular changes might help promote higher-level synthesis and improve application of the scientific foundation earlier—and throughout—the curriculum.

Regarding assessment of this curricular redesign, the researchers took special interest in the Infectious Disease and Neoplastic Disease Pharmacotherapy courses because these were the first pharmacotherapy courses encountered by P2 students in the revised structure. Also, these two courses underwent the largest shift in timing (ie, the largest compression/shortening of time between the pharmacodynamics and pharmacotherapy content) for the P2 students. If there was a gain to be found, it would likely be found in these two courses.

During the transition to the revised curriculum, students in different years of the PharmD program were following a different course sequence as indicated in Figure 1. For example, the P2 cohort took the infectious disease and neoplastic disease pharmacodynamics courses during spring semester 2013, whereas the P3 cohort took these courses during fall semester 2012. Also during the transition, there were some course overlaps between cohorts in the old and new curricula. For example, during fall semester 2013, the P2 and P3 cohorts were scheduled to concurrently take the infectious disease and neoplastic disease pharmacotherapy courses. Course instructors

Figure 1. Cohort Timing for Neoplastic and Infectious Disease Pharmacodynamics and Pharmacotherapy Courses.

opted to offer the pharmacotherapy courses simultaneously to both cohorts in one classroom, rather than asynchronously in different classrooms. The combined cohorts provided a rare opportunity to compare outcomes between the previous and the new curriculum sequencing, albeit in only two topics. The investigators evaluated what impact shortening the time between prerequisite pharmacodynamics courses and their corresponding pharmacotherapy courses, from 12 months to three months, might have on overall student performance in the pharmacotherapy courses. Impact would be measured by course examination scores.

METHODS

In fall semester 2013, the infectious disease and neoplastic disease pharmacotherapy courses each contained 85 students in the P2 and P3 cohorts. Baseline admission data were collected comparing the two cohorts (Table 1). Admission data included qualitative variables, such as gender, average age, and prior bachelor's degree status, and quantitative variables, including average core grade point average (GPA), average Pharmacy College Admission Test (PCAT) composite, average PCAT essay, and average interview scores. Interview scores were tabulated based on performance in response to a standardized list of eight interview questions. This interview process was proven valid and reliable in a previous study.⁵ Examination scores from the infectious disease and neoplastic disease pharmacodynamics courses were also collected to further establish baseline characteristics of the cohorts (Table 2). Instruction in these two courses were primarily conducted via lecture; examinations were declarative knowledge-based and in multiple-choice format.

Table 1. Doctor of Pharmacy (PharmD) Program Admission Data

	P3 cohort (n=85)	P2 cohort (n=85)	p value
Average Age on Admission	21.4	22.6	0.04
Gender			
Female	56	44	
Male	29	41	0.06
Bachelor's Degree on Admission	10	18	0.10
Average Core GPA	3.7	3.7	0.44
Average PCAT Composite % (Max=99)	62.9%	65.0%	0.99
Average PCAT Essay (Max=20)	14.9	15.2	0.22
Average Interview (Max=50)	35.5	34.5	0.31

P3=third professional year; P2=second professional year; GPA=grade point average; PCAT=Pharmacy College Admission Test

In the infectious disease and neoplastic disease pharmacotherapy courses, instruction was a hybrid of lecture and case discussion. Throughout the semester, formative and summative assessments were given in the form of case study assignments, quizzes, and examinations. Examination questions throughout the course mainly consisted of procedural knowledge questions presented in multiple-choice and short-answer formats.

Statistical analysis with chi-square tests of homogeneity were used to compare differences between numbers of female and male students in each cohort. The remaining admission variables were evaluated with the *z* test for unmatched and large ($n>30$) samples and nonproportional data. Descriptive statistics were calculated from course examination results. The *z* test for unmatched samples was used to evaluate significance levels between examination performances by the two cohorts. The institutional review board (IRB) at NDSU designated exempt status for this study.

RESULTS

Table 1 contains the baseline admissions characteristics comparing the two cohorts. The average age of the P2 cohort was one year older than the P3 cohort (22.6 vs 21.4; $p=0.04$). There were no differences between the cohorts regarding gender, bachelor's degree status on admission, average core GPA, average PCAT composite, average PCAT essay, and average interview score.

Table 2 contains assessment data from the prerequisite pharmacodynamics courses and the subsequent pharmacotherapy courses. In the infectious disease pharmacodynamics course, average examination scores were not different for the cohorts. However, the P3 cohort achieved significantly better average examination scores than the P2 cohort in the neoplastic disease pharmacodynamics course. In the infectious disease pharmacotherapy course, the P3 cohort performed better than the P2 cohort in average examination scores (84.5% vs 80.3%, respectively; $p<0.001$). In the neoplastic disease pharmacotherapy course, the P3 cohort also achieved a significantly higher average examination score than the P2 cohort (82.5% vs 78.2%, respectively; $p<0.01$).

DISCUSSION

Based on admission data, there was no significant difference in baseline characteristics of the two cohorts entering the PharmD program, except for average older age on admission of the P2 cohort. Overall performance in the infectious disease pharmacodynamics course was not different for the cohorts; however, the P3 cohort performed better in average examination scores than the P2 cohort in the neoplastic disease pharmacodynamics

course. Even though a difference was noted in the neoplastic disease pharmacodynamics course, Hailikari showed that declarative knowledge (as taught and assessed in these courses) had a negligible effect on lasting student achievement.^{1,2} Additionally, any significant difference may have been mitigated by the fact that both cohorts achieved greater than a 90% average in that course.

During the infectious disease and neoplastic disease pharmacotherapy courses, which primarily assess procedural knowledge, the P3 cohort performed significantly better than the P2 cohort, according to examination scores. This overall difference in pharmacotherapy course performance may be based on increased program maturity of the P3 cohort, considering they would have spent an extra calendar year in program-specific didactic, laboratory, and experiential courses. An extra calendar year in the PharmD program may have increased the number of previous opportunities for the P3 cohort to be exposed to solving higher-order, procedural knowledge-based problems encountered in both pharmacotherapy courses. Additionally, if the time sequence was the only variable difference between cohorts, it is plausible that having less time between the two courses (as with the P2 cohort) would improve performance in the pharmacotherapy courses. In summary, placing like content closer together, as the only intervention, is not enough to ensure improved student performance on examinations in corresponding requisite courses. This is an important finding considering direct sequencing of like subject matter was a key component of curriculum restructuring at NDSU.

Another point of interest is whether student cohorts eventually converge back to the same point at the end of the program, regardless of how the curriculum is structured and sequenced. The NDSU PharmD program will be monitoring global indicators such as Pharmacy Curriculum Outcomes Assessment (PCOA) scores, North American Pharmacy Licensure Examination (NAPLEX) scores, and instructor and student feedback to compare trends since the curriculum revision. Prior knowledge examinations, or “progress” or “mile-marker examinations,” may be useful in screening for deficiencies at the

student, individual course, and overall curriculum levels.⁶ Lastly, how this change in curricular sequencing eventually translates to students developing higher-level synthesis and improved application earlier in the curriculum of the scientific foundation (procedural knowledge) is unknown at this time.

Study limitations include data being collected from only two cohorts in one PharmD program. If these particular cohorts differ from other years at NDSU, or if they are fundamentally different than other cohorts, or curricula at other schools of pharmacy, then our results may not be generalizable to those years of study or institutions. Secondly, the researchers compared a P3 cohort to a P2 cohort. Results may have been different if two P2 or P3 cohorts were compared with the same varying intervals of time between the pharmacodynamics and pharmacotherapy courses. Another limitation includes not taking into account the diversity of learning styles among students, and subsequently between the two cohorts. Additionally, it is unclear of the impact (regarding difficulty level and time consumption) that concurrent courses had on each cohort. Despite each cohort having seven courses in this particular semester, the P2 cohort had four more credits than the P3 cohort. Even though both cohorts had the same pharmacodynamics course taught by the same instructors, they were taken in different semesters, which could lead to unknown teaching and learning variability experienced in these courses. Lastly, this study may not have fully addressed whether course timing improved student performance beyond the two pharmacotherapy courses evaluated by the researchers. It remains to be determined whether the P2 cohort benefited in a way that was not measured directly in this study.

CONCLUSION

Decreasing the time interval from 12 months to three months between prerequisite and requisite courses did not result in improved, or even equivalent, academic performance relative to the P2 cohort that had only a 3-month interval between courses. Placing like content closer together, as the only intervention, is not enough to ensure improved student performance measured by examination scores in corresponding requisite courses.

Table 2. Total Course Average Examination Scores

Course	P3 Cohort (n=85) Mean% (SD)	P2 Cohort (n=85) Mean% (SD)	p value
Infectious Disease Pharmacodynamics	86.5 (8.5)	85.4 (8.7)	0.39
Neoplastic Disease Pharmacodynamics	95.6 (6.1)	93.3 (5.2)	< 0.01
Infectious Disease Pharmacotherapy	84.5 (7.3)	80.3 (8.9)	< 0.001
Neoplastic Disease Pharmacotherapy	82.5 (7.4)	78.2 (11.5)	< 0.01

P3=third professional year; P2=second professional year

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