INSTRUCTIONAL DESIGN AND ASSESSMENT

Prospective Measurement of a Problem-Based Learning Course Sequence

Christian R. Dolder, PharmD, Jacqueline L. Olin, MS, PharmD, and Gregory L. Alston, PharmD

Wingate University School of Pharmacy, Wingate, NC

Submitted May 3, 2012; accepted June 14, 2012; published November 12, 2012.

Objective. To measure the effect, over time, of a 2-year problem-based learning (PBL) sequence on the skills, knowledge, and abilities it was designed to develop and enhance.

Design. At the start of each PBL semester, students were provided a “work sample” case with a main medical issue not previously covered in the curriculum. A standardized form containing 6 sections (hypotheses, learning issues to investigate, how hypotheses ruled in/out, primary-problem identification, plan, and goals of plan) was completed for each case. To rate student performance, investigators used a standardized form with 5-point Likert scale.

Assessment. Sixty-seven students who completed 4 assessments were included in data analyses. Scores significantly improved for each semester compared with baseline. Minimal significant differences were observed among semesters 2, 3, and 4.

Conclusion. The 2-year PBL sequence improved students’ performance compared with baseline, but the performance ceiling observed in our study requires further investigation.

Keywords: Problem-based learning, pharmacy students, case studies, assessment, self-directed learning

INTRODUCTION

An essential component of pharmacy education involves the development and maturation of skills to integrate knowledge. However, few situations in pharmacy practice present themselves with all the information needed for problem resolution.¹ Whether pharmacists are providing clinical medication management or advising patients on health self-monitoring, they use a process of reflecting on the situation, accumulating further information, and solving the problem. The set of skills needed for deliberating, creating hypotheses, gathering new information, and developing a solution have been referred to as metacognition.¹ The problem-based learning (PBL) model may aid students in applying knowledge acquired in the classroom and developing metacognitive skills.

The Accreditation Council on Pharmaceutical Education standards and guidelines emphasize the need for educators to foster the development and maturation of critical thinking and problem-solving skills, which will help provide a framework for students to become active, self-directed, lifelong learners.² The primary educational objective in the Center for the Advancement of Pharmaceutical Education Educational Outcomes 2004 describes the pharmacist as a member of an interprofessional

healthcare team providing patient-centered care. Practitioners are expected to retrieve, analyze, and interpret literature to design, implement, monitor, evaluate, and adjust pharmaceutical care plans.³ A review of research in pharmacy education described incorporation of PBL activities into the curriculum either as restructuring of traditional classroom courses or as a part of clerkship modules. In some instances, when compared with traditional lectures, PBL led to significantly improved examination scores, clerkship grades, and self-confidence ratings on scales assessing critical-thinking skills.⁴ Seventy-one percent of pharmacy faculty survey respondents use PBL as an active-learning strategy, including case-based learning.⁵ Long-term assessments of the effectiveness of PBL in pharmacy education are lacking because of the inherent difficulties in proving causal relationships between PBL and educational outcomes. Several reports have described challenges of implementation and various hurdles before and after implementation of PBL in a course or curriculum.⁶⁻¹⁰

Romero and colleagues described the application of PBL in a pharmaceuticals course over a period of 10 years.⁶ They observed a relationship between student grades on group case-study reports and average examination scores. A 25% difference in case-study report grade translated into approximately a letter-grade difference. The authors described their PBL model as different from “true PBL” in that it contained a classroom-learning component. Additionally, examinations were used as a form of assessment.

Corresponding Author: Jacqueline L. Olin, MS, PharmD, Wingate University School of Pharmacy, P.O. Box 159, 515 N Main Street, Wingate, NC 28174-0159. Tel: 704-233-8340. Fax: 704-233-8332. E-mail: jolin@wingate.edu

Among students who had PBL-style learning in the first semester, midterm examination scores improved but final examination scores were not significant between groups. PBL had a short-term effect with respect to material retention over weeks and potentially months.⁷ Student examination scores were compared between traditional lecturing and a self-study PBL model (n=373).⁸ Two topics within a therapeutics course (hyperlipidemia and thromboembolic diseases) were presented in a PBL-style format; students were provided patient cases and suggested reading materials as a self study. Hyperlipidemia examination scores improved with the traditional lecture format, and thromboembolic disease examination scores improved with the PBL format. The authors acknowledged that the results may have been impacted by faculty members having gained more experience in PBL or by the nature of the topics in question.

Faculty members at the University of Mississippi revised their entire third-year curriculum to a PBL-based model and described their 10-year experience.⁹ The mode of delivery was “progressive disclosure cases” provided over 8-week blocks, with grades based on facilitator, peer, and self-evaluation, along with examinations based on content and problem-solving. While the authors did not provide specifics of longitudinal assessment, student performance has been consistent on internal examinations and on the North American Pharmacist Licensure Examination.⁹

Lecture-based sessions were compared with PBL in the delivery of 2 modules of an MSc clinical pharmacy program.¹¹ Students (n=17) were randomized to a PBL group (5 to 6 students) or a tutorial group using traditional approaches (15 to 20 students). After the first module, students were crossed over to the other learning format. No differences were found between learning-format groups with respect to the scores or assessments.¹⁰

Many colleges and schools of pharmacy have incorporated PBL experiences into their programs. When PBL is compared with traditional formats, assessment of examination scores has varied; however, studies have been limited based on small numbers of participants or adjustment changes to new teaching and learning styles. Similar difficulties have been encountered in determining PBL’s impact on knowledge and skills in medical education.¹¹ An inherent challenge in measuring PBL effectiveness is the difficulty of identifying and measuring the appropriate student outcome. The overall principles of PBL are for students to learn and apply the skills of critical thinking, problem identification, and care-plan development. A single multiple-choice examination is not an ideal instrument for assessing metacognitive abilities.

Wingate University School of Pharmacy created a PBL Case Studies sequence when it opened in 2003.

The purpose of the PBL Case Studies sequence is to provide students with the opportunity to gather, analyze, and synthesize medical information in order to formulate pharmacotherapeutic treatment plans designed to improve patient outcomes. This process should enhance students’ ability to be independent and active learners, foster individual and group problem-solving abilities, promote critical examination of medical problems, and develop clinical skills and reasoning; all of which are tied to the School of Pharmacy’s terminal ability-based outcome statements.

We have previously surveyed students about their perceptions and opinions of the 4-semester PBL Case Studies sequence.¹² The positive response obtained from this qualitative assessment prompted a quantitative assessment of the PBL course sequence. The goal of the present study was to measure the long-term effect of a 2-year PBL course sequence on the skills, knowledge, and abilities that it was designed to develop and enhance.

DESIGN

All students in the class of 2013 who were enrolled in PBL Case Studies courses were eligible for study inclusion and were assessed throughout their 4-semester PBL sequence. The investigation itself prospectively measured student performance related to the following 8 course objectives: (1) identify, examine, and critically reexamine hypotheses regarding medical problems; (2) identify and answer learning issues from a case and then apply the knowledge gained to current and future medical problems; (3) apply aspects of biochemistry, human anatomy, human physiology and pathophysiology to diagnose, treat, and monitor the medical problem(s) of case patients; (4) apply laboratory and patient assessment data to diagnose, treat, and monitor case patients; (5) create and apply a patient database for the purpose of diagnosing, treating, and monitoring case patients; (6) develop a patient-specific care plan; (7) identify patient-specific therapeutic goals, endpoints, outcomes and monitoring parameters for case patients; and (8) select appropriate drug therapy (eg, drug, dose, duration) for case patients applying the principles of pharmacokinetics and pharmacodynamics.

The PBL course sequence consisted of 4 courses, 1 semester credit hour each, taken in each semester of the students’ second and third years. Case design and course delivery were created to adhere closely to the tenets of PBL, as described by Southern Illinois University.^{1,13} The School of Pharmacy facility was deliberately designed with rooms to facilitate PBL courses. Faculty members were trained in the techniques of PBL and then served as tutors for 6 to 7 student groups that were randomly assigned to them each semester.

Groups worked through 4 PBL cases each semester. The objective of each case was to diagnose new medical problems, assess existing medical problems, and develop new and optimize existing medication regimens. The tutors were not experts in each case and, as part of their PBL tutor training, were instructed not to study upcoming topics in preparation for cases. The primary problem of each case was aligned with topics covered in pharmacotherapy modules from the same semester. In that respect, the PBL Case Studies sequence served as a laboratory for the pharmacotherapy modules. At the end of each case, student groups turned in a SOAP (subjective, objective, assessment, plan) note, individual students submitted assessment summaries, facilitators completed evaluations of each student in each of their groups, and students provided verbal and written feedback to their peers.

After each semester, group assignments and tutor assignments were randomly reassigned. Each semester, the course coordinator compared grades by group to ensure that there were no significant differences in grades based on tutor assignment.

For the purposes of this study, a PBL work-sample assessment was conducted at 4 points during the PBL course sequence, each during the first week of the semester: baseline (PBL semester 1); follow-up 1 (PBL semester 2); follow-up 2 (PBL semester 3); and follow-up 3 (PBL semester 4). For each assessment, each student was provided a brief (ie, no more than 1 page) patient case with an embedded medical issue that needed to be identified and addressed. The medical issue had not been a major pharmacotherapy course topic on or before the time of assessment. The difficulty of each case, taking into account its place in the curriculum, was rated on a scale of 1 to 10 by 2 faculty members not involved in the study in an effort to create cases of similar difficulty at each assessment time point.

Students were asked to reach a solution for the case (using available electronic resources) within a 50-minute class period (Appendix 1). Students documented their answers using a standardized answer sheet comprised of 6 short-answer sections (hypotheses; key things looked up; method used to rule in/out the hypotheses; primary problem; method of addressing the primary problem; and goal of the plan). The answer sheet for each assessment had a space for students to "opt in" and "opt out" of the study itself. Participation was voluntary and had no effect on course grades. The investigation was approved by the University's Research Review Board.

EVALUATION AND ASSESSMENT

A standardized grading sheet that consisted of 9 assessment items overlying each of the 6 sections of the

student answer sheet was used. Student performance on each assessment item was rated on a 5-point Likert scale (grading sheet available from corresponding author upon request).

For each assessment period's work sample, students received a total score and 3 predetermined sub-item scores (ie, bioinformatics, knowledge and reasoning, and application). Two of the investigators assessed approximately half of the students' work samples at each study time point. Inter-rater reliability was assessed by randomly selecting 10% of work samples from each time period, having both investigators blindly grade the 10% sample, and calculating Cronbach's alpha.

Primary analyses consisted of comparing total and sub-item scores from the PBL assessment at baseline to the follow-up periods using repeated measures analysis of variance. For total and sub-item scores in which overall significance was found, mean-difference student's *t* tests were used with Bonferroni adjustments for multiple comparisons. Secondary analyses used Pearson's correlation to examine total scores on the PBL study assessments with overall pharmacy GPA (after first year) and total pharmacy annual assessment scores (taken at the end of the first year). All tests were 2-tailed with alpha set at < 0.05 . Students were included if they completed PBL assessments at baseline and at a minimum of 2 follow-up points.

Seventy-three students were eligible for study inclusion. Of these, 70 consented and 67 (92%) met predetermined completion criteria and were included in data analyses. Inter-rater reliability was excellent for the work sample (Cronbach's alpha = 0.89)¹⁴, and difficulty of the clinical problem to be addressed in each case was similar at all 4 time points (ie, rated as a 7 out of 10 for each assessment). In an examination of the correlation between total scores on the PBL study assessments and first-year pharmacy student cumulative GPA, no significance was found (*r* range, 0.021-0.13, *p* range, 0.29-0.87). Similarly, no significant differences were found between PBL study assessment total scores and total scores on the first-year pharmacy student annual assessment examination (*r* range, 0.018-0.18; *p* range, 0.14-0.89).

Total scores on the PBL study assessment increased significantly at each time point (semesters 2, 3, and 4) when compared with baseline (semester 1) (Table 1). Although total PBL assessment scores improved numerically at each time point after baseline, no significant differences were found among semesters 2, 3, and 4. Significant improvements from baseline were also seen in the bioinformatics, knowledge and reasoning, and application subsets. A similar trend of nonsignificance among semesters 2, 3, and 4 was seen when examining sub-item scores for the PBL study assessment (Tables 2 and 3). The

exception to this finding was the bioinformatics subset in which scores continued to increase significantly at time points other than baseline. No significant interactions between variables were found using ANOVA.

DISCUSSION

Student performance in a 4-semester PBL case studies sequence was examined over time. Based on a standardized assessment of student work samples, student performance significantly improved compared with baseline. This improvement was noted in the overall score and in all subscales of the assessment. The improvement seen in all 3 measured areas of performance is consistent with PBL's ability to affect a variety of academic achievement areas.⁴ However, with the exception of the bioinformatics subscale, significant increases in student performance did not occur after the second semester of the PBL sequence. These results demonstrate the merit of the PBL sequence's longitudinal design but also prompt a number of questions.¹⁵

One area of concern is whether students in the PBL case studies sequence reach a performance ceiling after just 2 semesters. If such a ceiling actually exists, could the content and expectations in the third and fourth semesters of the PBL sequence be modified to promote continued improvements in performance? Formative assessment itself could be changed to address the possibility of a performance ceiling during the course sequence.¹⁶ Cases in the latter half of the PBL sequence are designed to contain more complex primary problems and a variety of secondary issues to reflect the differences in knowledge accrued between second- and third-year students. Interestingly, gains in bioinformatics improved more consistently throughout the 4-semester sequence, leading to the question of whether other specific components of the PBL sequence (eg, pharmacology, patient assessment, care planning) could be emphasized or modified to produce significant longitudinal gains along with improvements in the bioinformatics subset. At a minimum, the course sequence's outcomes should be examined to determine if the outcomes are

Table 1. Mean Problem-Based Learning Assessment Total Scores Over Time

Semester	Total Scores, ^a Mean (SD)
1	27.4 (5.3) ^b
2	31.8 (6.4)
3	32.7 (5.0)
4	33.0 (5.3)

^a Range = 9-45.

^b Differences in significant mean determined by *t* tests. Semester 1 vs 2: $p < 0.001$, 95% CI (1.80 to 6.97); Semester 1 vs 3: $p < 0.001$, 95% CI (3.41 to 7.22); Semester 1 vs 4: $p < 0.001$, 95% CI (2.82 to 8.49).

Table 2. Mean Problem-Based Learning Assessment Subscores Over Time

Semester	Bioinformatics, Range (SD) ^a	Knowledge and Reasoning, Range (SD) ^b	Application, Range (SD) ^c
1 ^d	9.1 (2.4)	12.4 (2.4)	5.8 (1.7)
2 ^d	10.5 (2.0)	14.5 (3.3)	6.7 (2.2)
3 ^d	10.2 (1.7)	14.9 (3.4)	7.6 (1.3)
4 ^d	11.4 (1.9)	14.7 (3.4)	7.0 (2.2)

^a Range 3-15

^b Range 4-20

^c Range 2-10

^d Within-subscore difference, $p < 0.001$.

appropriate and if the course needs to be modified to better achieve desired outcomes.¹⁷

The lack of significant gains in performance after the second semester of the PBL sequence could also be partially explained by the study's limitations. Although there was a high rate of study participation and the group was followed over a 2-year period, only 1 class of students was examined (ie, class of 2013). Another limitation is that the work sample and its subsequent rating using Likert scales may not have allowed for a comprehensive analysis or for sensitive measurements of some outcomes. For instance, we used a written work sample that did not allow for the assessment of communication skills, a component of the PBL sequence. Our study also did not assess other important factors, such as motivation or additional baseline academic characteristics. On the other hand, any other single method used to measure the effects of PBL likely would not have captured the additive or synergistic gains produced by PBL.¹⁸ Our decision to allow students to use electronic resources when working on the sample case, which we believed would more closely mirror real-world practice settings, also may have impacted performance over time. Another limitation is that this study did not include qualitative assessments of the PBL sequence.⁴ Our positive qualitative results in the past¹² drove the

Table 3. Significant Mean Difference *t* Tests Within Subscores

Semester	Bio-informatics	Knowledge and Reasoning	Application
1 vs 2	0.001	< 0.001	NS
1 vs 3	0.007	< 0.001	< 0.001
1 vs 4	< 0.001	< 0.001	0.005
2 vs 3	NS	NS	NS
2 vs 4	0.04	NS	NS
3 vs 4	0.001	NS	NS

Bonferroni correction applied for multiple comparisons; semester 1 = baseline; semesters 2-4 = subsequent semesters.

current study aim of quantitatively assessing student performance over time. Important additional information could be acquired by a future analysis focusing on the relationship between performance in the pharmacotherapy sequence and the PBL sequence to gauge how performance in pharmacotherapy modules affects performance in PBL case studies (and vice versa). Continued assessment of multiple classes of pharmacy students at our school of pharmacy for periods of time longer than 2 years also will provide valuable information regarding the consistency of the current findings and allow for more in-depth analyses of outcomes (eg, factors that affect PBL performance).¹⁹

SUMMARY

The PBL Case Studies sequence, assessed by following a class of pharmacy students over a 2-year period, was associated with significant improvement in areas of knowledge, skill, and ability. The design and efficacy of the PBL sequence are supported by the improvement in student performance seen over time and the design of the sequence to complement other coursework in the curriculum. However, the improvement ceiling noted after the second semester of the PBL sequence warrants further investigation to identify how the course or methods could be modified to result in improved student performance.

ACKNOWLEDGEMENTS

Initial data were presented at the AACP Annual Meeting in San Antonio, July 9-13, 2011.²⁰

REFERENCES

1. Barrows HS. *The Tutor Functions at the Metacognitive Level*. In: Barrows HS. *The tutorial process*. Springfield, IL: Southern Illinois University School of Medicine; 1988: 1-6.
2. Accreditation Standards and Guidelines for the Professional Program in Pharmacy Leading to the Doctor of Pharmacy Degree. Accreditation Council for Pharmacy Education. Adopted January 23, 2011. <https://www.acpe-accredit.org/pdf/FinalS2007Guidelines2.0.pdf>. Accessed October 16, 2012.
3. Educational Outcomes 2004. American Association of Colleges of Pharmacy Center for the Advancement of Pharmaceutical Education. <http://www.aacp.org/resources/education/Documents/CAPE2004.pdf>. Accessed October 16, 2012.
4. Cisneros RM, et al. Status of problem-based learning research in pharmacy education. *Am J Pharm Educ*. 2002;66(1):19-26.
5. Stewart DW, Brown SD, Clavier CW, Wyatt J. Active-learning processes used in US pharmacy education. *Am J Pharm Educ*. 2011;75(4):Article 68.
6. Romero RM, Eriksen SP, Haworth IS. A decade of teaching pharmaceuticals using case studies and problem-based learning. *Am J Pharm Educ*. 2004;68(2):Article 31.
7. Romero RM, Eriksen SP, Haworth IS. Quantitative assessment of assisted problem-based learning in a pharmaceuticals course. *Am J Pharm Educ*. 2010;74(4):Article 66.
8. Cheng JWM, Alafiris A, Kirschbaum HL, Kalis MM, Brown ME. Problem-based learning versus traditional learning in pharmacy students' short-term examination performance. *Pharm Educ*. 2003; 3(2):117-125.
9. Ross LA, Crabtree BL, Theilman GD, Ross BS, Cleary JD, Byrd HJ. Implementation and refinement of a problem-based learning model: a ten-year experience. *Am J Pharm Educ*. 2007;71(1): Article 17.
10. Shaw S, Gerrett D, Warner B. A preliminary study to evaluate the impact of problem-based learning (PBL) to a postgraduate clinical pharmacy programme in the UK. *Pharm Educ*. 2006;6(1):33-39.
11. Albanese M. Problem-based learning: why curricula are likely to show little effect on knowledge and skills. *Med Educ*. 2000;34(9): 729-738.
12. Dolder CR, Jolly J, Nuzum D, Veverka A. Development and implementation of a novel problem-based learning case studies course. [Abstract] 106th Annual Meeting, Cincinnati, Ohio, July 9-13. *Am J Pharm Educ*. 2005;69(3):Article 60.
13. Barrows HS. *The Authentic Problem-Based Learning Process*. In: Barrows HS. *Problem-based learning applied to medical education*. Springfield, IL: Southern Illinois University School of Medicine; 1994: 48-66.
14. Cronbach, LJ. Coefficient alpha and the internal structure of tests. *Psychometrika*. 1951;16(3):297-334.
15. Hammer DP, Paulsen SM. Strategies and processes to design an integrated, longitudinal professional skills development course sequence. *Am J Pharm Educ*. 2001;65(1):77-85.
16. Sadler DR. Formative assessment and the design of instructional systems. *Instructional Sci*. 1989;18(2):119-144.
17. Daugherty KK. Backward course design: making the end the beginning. *Am J Pharm Educ*. 2006;70(6):Article 135.
18. Norman GR, Schmidt HG. Effectiveness of problem-based learning curricula: theory, practice and paper darts. *Med Educ*. 2000;34(9):721-728.
19. Haworth IS, Eriksen SP, Chmait SH, et al. A problem based learning case study approach to pharmaceuticals: faculty and student perspectives. *Am J Pharm Educ*. 1998;62(4):398-405.
20. Olin JL, Dolder CR, Alston G. Prospective measurement of a problem-based learning course sequence for pharmacy students [abstract]. 112th Annual Meeting. *Am J Pharm Educ*. 2011; 75(5):105.

Appendix 1. Sample Work Product

CC “What is going on with me!?”

HPI

PB, a 58 yo Caucasian male, presents to clinic complaining of increasing dyspnea, fatigue, and sputum production over the last few weeks. Patient has had a “cough for months” that has worsened recently. Current symptoms do not worsen at night or when lying down. Denies N/V, headaches, nasal congestion, or sore throat. No blood in stool, urine, or sputum. Denies fever or night sweats. Denies recent travel except to South Carolina. Patient also reports of occasional “chest tightness” over the past week. Only other complaint is that his sexual dysfunction has not improved since last clinic visit 6 months ago. Patient is bothered by increased coughing, dyspnea, and fatigue and is requesting your medical care.

PMH

Hypertension, dyslipidemia, hypothyroidism, erectile dysfunction

SH

Married with 4 grown children. Works as manager at automobile parts store. Smokes 1 ppd X 30+ years; occasional EtOH, denies illicit substances

Medications

Levothyroxine 75 mcg po daily, atorvastatin 10 mg po QHS, amlodipine 10 mg po daily, albuterol/ipratropium 1 puff inh Q6h prn, multivitamin po daily, aspirin 162 mg po daily

Allergies

NKDA

Physical Exam

HEENT = unremarkable; Neck = supple, no JVD or other abnormalities noted; Lungs = clear to auscultation except for occasional expiratory wheezing. Pursed lips noted during expiration. Barrel chest appearance; Cardiovascular = regular rate and rhythm; Abdomen = soft, nontender/nondistended and normal bowel sounds; Genitourinary = deferred; Skin/Extremities = good skin integrity, no edema noted, cigarette stains noted on R hand; Neuro = A & O X 3.

Laboratories and Procedures

VS = BP 138/79, P 84, RR 26, T 98.8F, Ht 70, Wt 88kg; Pain 0/10

Na 140, K 4.2, Cl 101, CO2 32, BUN 18, SCr 0.9, Glu 84; CBC = pending; Liver panel = pending. TSH = 1.4; Lipid panel = TC 207, LDL 109, HDL 38, TG 233

EKG = within normal limits; chest x-ray = hyperinflation of lungs present, no cardiomegaly, no infiltrates; CT of nasal sinuses ordered; spirometry = FEV₁ 65% of predicted value, FEV₁:FVC ratio 60%