American Journal of Pharmaceutical Education 2004; 68 (5) Article 114.

INSTRUCTIONAL DESIGN AND ASSESSMENT

A Learning-Centered Course in Pharmaceutical Analysis

Simon P. Albon, MSc,[a] and Harry Hubball, PhD[b]

[a]Faculty of Pharmaceutical Sciences, University of British Columbia, Vancouver
[b]Department of Curriculum Studies, University of British Columbia, Vancouver

Submitted March 31, 2004; accepted June 18, 2004; published November 18, 2004.

Objective. This article describes the development and impact of a learning-centered course in pharmaceutical analysis in the Baccalaureate of Science in Pharmacy program at the University of British Columbia.
Design. Using a flexible course design framework, principles and interactive strategies from learning-centered education were incorporated into a third-professional year pharmaceutical analysis course. Course impact was determined through 1- minute papers, student survey questionnaires, faculty interviews, and the instructor's reflective teaching journal. Action research methodology was employed to examine the impact of course redesign on student learning.
Assessment. Course redesign had a significant impact on the quality of teaching and learning in the course. Active-learning strategies positively impacted student learning and their views on the importance of pharmaceutical analysis. The instructor experienced significant professional growth as an educator.
Conclusion. A learning-centered approach to undergraduate-level course design in pharmaceutical analysis has the potential for enhancing teaching practice and student learning while balancing traditional pharmaceutical analysis content and skills with the need to demonstrate relevance across pharmacy settings. Course outcomes are transferable to other pharmacy courses.

Keywords: pharmaceutical analysis, course design, learning-centered, active learning

INTRODUCTION

Consistent with the development of educational outcomes-based pharmacy programs in Canadian universities,[1-3] there is an ongoing recognition of the importance for university faculty to reexamine and redesign the quality of undergraduate-level courses in order to meet the diverse needs and circumstances of the health care system, current and future health care professionals, and a changing society. As new outcomes-based programs take shape, increasing emphasis is being placed on clinical and pharmacy practice, often at the expense of basic sciences content and training in pharmacy programs.[4] The 4-year baccalaureate of science in pharmacy (BScPharm) program at the University of British Columbia (UBC) maintains a strong focus on the basic pharmaceutical sciences, including pharmaceutical analysis. One of the challenges in maintaining this subject area in pharmacy curricula is balancing traditional pharmaceutical analysis content and skills with the contemporary need to demonstrate relevance to clinical and pharmacy practice. While pharmaceutical education literature addressing this issue is limited[5-7] most Canadian schools of pharmacy continue to incorporate pharmaceutical analysis as a content area in their pharmacy programs. However, the integration of pharmaceutical analysis content and skills into undergraduate-level courses varies from incorporation into cases in problem-based learning curricula, to compressed lecture series, to full lecture/laboratory courses.[8]

This paper focuses on the development and impact of a learning-centered undergraduate course in pharmaceutical analysis within the BScPharm program at UBC.

Course Context/Background

During the fall term of the third year of the pharmacy program (September through December) students take the pharmaceutical analysis course, *Pharmacy* 325 (enrollment of approximately 140 students). The course includes 4 hours of lecture and a 3-hour laboratory period per week, respectively, over the academic term. The lecture component provides pharmaceutical analysis theory while the laboratory aspect of the course provides an opportunity for students to apply theoretical concepts in a "hands on" experimental context. Students entering the pharmaceutical analysis course have varying backgrounds and levels of confidence in the basic sciences, ranging from entry-level science courses (general and organic chemistry) to full degrees (usually in chemistry or biochemistry). The vast majority of these students has not been exposed to pharmaceutical analysis and has limited understanding of science and research.

Corresponding Author: Simon P. Albon, MSc. Address: University of British Columbia, Faculty of Pharmaceutical Sciences, 2146 East Mall, Vancouver, B.C. V6T 1Z3. Tel: 604-822-2497. Fax: 604-822-3035. E-mail: trout@unixg.ubc.ca.

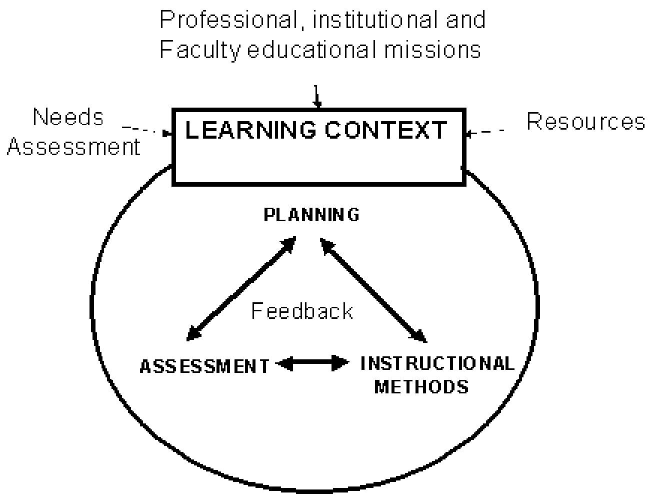

Figure 1. A learning-centered framework for course design.

Prior to the redesign of this course, which began in 1999, the pharmaceutical analysis course could be described as "teaching-centered."[9] Driven primarily by content, the teacher actively transmitted information by a singular delivery method (lecturing), while the learners were passive participants in the learning process. The course syllabus included a list of lecture topics and dates, and the lecture and laboratory components were viewed as discreet components of the overall course. The evaluation scheme tended to consist of a midterm and final examination (80%) supplemented by laboratory reports and technical skills evaluations (20%). Emphases placed on learning objectives, authentic methods of assessment, and links with other disciplines of pharmaceutical sciences and pharmacy practice were tenuous at best. In addition to a major curriculum review, these factors together with student and faculty dissatisfaction with the course were major triggers that prompted change and course redesign.

Transition to Learning-Centered Course Design

A learning-centered approach was employed to redesign the original pharmaceutical analysis course.[10] Learning-centered course design focuses on the learners' knowledge, skills, and values that are assessable, transferable, and relevant to their lives as workers and citizens in a diverse world.[11-13] In a learning-centered course, teachers assume a facilitation role and students are engaged in a carefully structured, responsive, and guided learning environment. Although not a new concept in higher education,[9,14] learning-centered approaches to course design are part of a larger process of educational change, shifting from knowledge transmission to an emphasis on facilitating active learning. Emphases are placed on developing classroom community, curriculum integration, and assessment and learning outcomes required by graduates in the 21st century. In the context of a course in pharmaceutical analysis, this entails designing learning experiences that bridge traditional pharmaceutical analysis content and skills with clinical and pharmacy practice to prepare pharmacy graduates for the realities and challenges of the pharmaceutical care practitioner in Canada.[1-3]

DESIGN

The process of redesigning the pharmaceutical analysis course began in 1999 through a collaboration with research expertise from the UBC Department of Curriculum Studies. Various course design frameworks and strategies have been proposed in the literature.[10,15,16] Figure 1 provides a heuristic and iterative model that integrates the learning context with planning, instructional, and assessment strategies for the systematic design of a learning-centered undergraduate-level course. This framework has been applied in various higher education settings[11-13] and provides: (1) a benchmark for analyzing existing course structure and design, and (2) guidance for the development and implementation of learning-centered courses.

Framework Application in Pharmaceutical Analysis

The learning context, which is shaped by many factors (ie, social, political, economic, organizational, professional, cultural, and individual), is an important part of the course design, influencing all key aspects of planning, assessment, and instructional methodologies. Learning context strategies for course design provide a means of (1) positively responding to influences from faculty, students, and institutional and professional educational missions when developing course learning outcomes and experiences; and (2) maximizing the use of available resources (physical learning spaces, learning resources, equipment, teaching assistant support, and course contact time) to help learners achieve the learning outcomes for the course.

Following a comprehensive needs assessment that included interviews and surveys with students and an interdisciplinary faculty group, key contextual factors influencing the design of the learning-centered pharmaceutical analysis course were identified. Of particular importance was (1) the changing focus on pharmacy education and practice in Canada[1-3]; (2) UBC's Trek 2000 visioning process and commitment to quality learning experiences[17]; and (3) the Faculty's extensive outcomes-based curriculum redesign and relevance to community, hospital, and indus-

Table 1. Global learning outcomes for the pharmaceutical analysis course.

On completion of this course pharmacy students will be able to:
(1) apply the theoretical principles of selected pharmaceutical analysis techniques involved in drug discovery and content uniformity and diagnostic testing in the industrial, hospital, and community settings.
(2) describe the fundamental aspects of and develop a general protocol for the scientific experiment.
(3) integrate and apply the theoretical principles to solve typical assay problems in the industrial, hospital, and community settings.
(4) complete selected laboratory exercises and critically analyze experimental findings to draw appropriate and defensible conclusions.
(5) plan, organize, and present an oral account of experimental findings.
(6) think critically about the extent and complexity of decision making inherent in the application of the scientific method.
(7) evaluate the importance of pharmaceutical analysis on drug research and development and on pharmacy practice.

trial pharmacy settings. In addition, addressing students' limited background in pharmaceutical analysis, heavy course loads, and part-time jobs required sensitivity and led to providing additional support mechanisms that enabled greater flexibility for students to study when and where they chose. A survey of local academic, private, and government research and testing laboratories identified a critical subset of analytical techniques that were key for the introductory pharmaceutical analysis course. This reduced the traditional scope of course content (7 analytical techniques) in favor of greater flexibility to explore theory and specific applications in greater depth. Finally, securing a team of 4 graduate teaching assistants and 8 student-peer teachers per 140 students was recognized as an essential requirement in supporting student learning in lecture and laboratory course components.

Planning strategies refer to the articulation of global (overall course goals) and specific (individual course sessions) course learning outcomes, which in part, drive the process of the lecture and laboratory learning experiences. The global and specific learning outcomes identify the knowledge, skills, and values important for the learner. For the redesigned course these included issues of self-directed learning, scientific inquiry, ethics, teamwork, and communication skills, all of which are considered critical attributes in the discipline of pharmaceutical analysis and to the pharmacy practitioner. Created with guidance from Bloom's taxonomy for higher-order learning,[18] Table 1 lists the global learning outcomes for the pharmaceutical analysis course. Clear expectations for course learning outcomes, learning experiences, and assessment methods for the pharmaceutical analysis course were communicated to students, initially via the course syllabus, then negotiated during the first lecture, and further refined and reiterated on a regular basis throughout the course. This approach to course design represented a significant shift from the previous traditional course offering in pharmaceutical analysis.

Instructional methods strategies refer to the range of teaching and learning methods employed to engage students in the development of knowledge, skills, and values for pharmaceutical analysis. Instructional methods can be considered on a continuum, from teacher-centered to learner-centered,[15] and are selected on the basis of diverse learning styles and specific course learning outcomes. A range of instructional methods provides balance and opportunities for individual work, partner work, small-group work, and large-class activities. The instructional methods used in the redesigned pharmaceutical analysis course are provided in Table 2 along with course content sequencing and applications.

For example, during lectures, questioning, think-pair-share, and one-minute paper activities required students to work individually or in pairs to analyze and respond to the instructor's questions on general principles of pharmaceutical analysis, spectrophotometry, chromatography, and mass spectrometry. Full-class discussions on topics such as the importance of experimental design and data analysis to experimental findings and the research process provided opportunities for students to integrate general principles into higher-order relationships. Periodic worksheets reinforced understanding of general concepts and structural analyses important for drug identity, separation of drug mixtures, and assay development, while laboratories provided students with opportunities to apply theoretical principles in "hands on" experiments relevant to the community, hospital, and industrial settings (eg, glucose monitoring and tolerance testing, drug screening, content uniformity testing, and screening and diagnostic testing for liver and kidney function). Case studies were of particular importance. In the "Case of the Missing Drugs," students were required to use general principles of chromatography and mass spectrometry to analyze and interpret qualitative and quantitative experimental data to determine which member of a 5-member neurosurgery team was responsible for the missing post-surgery pain medications. This case engaged students in fundamental aspects of experimental design, chromatographic separation, and mass spectral analysis, as well as established the mutual importance of pharmaceutical analysis and pharmacokinetics (a con-

Table 2. Content Sequencing, Applications and Instructional Methods Used in the Pharmaceutical Analysis Course

Week	Content Area(s)	Instructional Methods
1	**Course Introduction**	questioning, class discussion, lecture, one-minute paper
2	**Introduction to Pharmaceutical Analysis, Scientific Method** • general principles • applications important to academic, industrial, hospital and community settings (new drug development process, pharmacopeial monographs, content uniformity and diagnostic testing)	case studies, think-pair-share, group work, class discussion, questioning, lecture, peer teacher introductions
3-6	**Introduction to Spectrophotometric Analysis** • theoretical basis of absorption and emission processes, instrumentation, structural analysis, solution quantitation, sample preparation and data analysis • specific applications to industrial, hospital and community settings [e.g., content uniformity testing, glucose monitoring, drug photosensitivity, sunscreen technology, street drug analysis, clinical chemistry tests (glucose tolerance testing, creatintine clearance, bilirubin and protein analysis)]	case studies, think-pair-share, group work, class discussion, questioning, lecture, bulletin board discussions, quizzes, videos, demonstrations, worksheets, laboratory exercises, peer teacher and instuctor office hours, practice problem sets, previous exams and interactive modules available on course website and cd-rom, midterm preparation tutorial
7	**Oral Exam Preparation and Midterm Examination**	preparation session given by peer teachers, midterm exam, laboratory exercises, office hours, practice problem sets, previous exams and interactive modules available on course website and cd-rom
8-10	**Introduction to Chromatography, Oral Examination** • general principles of separation, chromatographic modes, optimizing separation in thin-layer, gas- and high performance liquid chromatography • applications to academic and hospital settings (e.g., drug screening, specific research projects, drug screening assays)	case studies, think-pair-share, group work, class discussion, questioning, lecture, demonstrations, one-minute paper, video analysis, in-class problems, oral exam, peer teacher and faculty office hours, practice problem sets, previous exams and interactive modules available on course website and cd-rom
11-12	**Introduction to Mass Spectrometry, Oral Exam, Course Review, and Final Examination Preparation** • general principles of mass spectrometry • applications to academic, industrial and hospital settings (e.g., drug screening, specific research projects, clinical trials, pharmacokinetic and bioavailability measurements)	case studies, think-pair-share, group work, class discussion, demonstrations, questioning, lecture, worksheets, laboratory exercises, peer teacher and instructor office hours, problem sets, previous exams and interactive modules available on course website and cd-rom, final exam preparation tutorial

current pharmacy course). Additional student-learning support strategies included student-peer teachers (fourth-year pharmacy students gaining academic credit as mentors), extended laboratory hours, weekly office hours for all teaching team members, and a course CD-ROM[19,20] and password protected Web site[21] (containing practice problem sets with answer keys, course notes, answer keys for in-class cases and problems, previous examinations, communication tools, and interactive computer modules and videos).

Assessment strategies and appropriate standards to judge student learning achievement are key components of learning-centered course design.[11,22] Emphasis is not placed on any one single method of assessment, rather, a range of methods (eg, peer/self assessment, student presentations, projects, examinations) are employed to gather data to make informed decisions about student learning.[22,23] Table 3 provides the evaluation profile for the pharmaceutical analysis course along with examples of the assessment strategies used. Both formative assessment methods (quizzes, in-class individual and collaborative work assignments, laboratory reports, laboratory group assessments and self-assessments, and oral examinations) and summative assessment methods (written and oral examinations) were incorporated into the course design. Important for students and the course instructor,

Table 3. Evaluation Profile for the Pharmaceutical Analysis Course

Assessment Strategy	Learning Objectives	Evaluation Weight (%)
Midterm written Examination	1-3, 7	20
December written Examination	1-3, 6, 7	25
Quizzes and in-class participation (collection of individual and collaborative work including problems, worksheets and case studies)	1-3, 6, 7	10
Laboratory reports including group and self-assessments	1-6	20
Laboratory oral examinations	1-7	25

formative methods provided ongoing feedback on student progress, whereas summative methods provided overall feedback on student learning achievement. The evaluation profile for the course addressed each learning objective, was weighted equally across lecture and laboratory learning experiences, and provided assessment methods that were interspersed throughout the course. Oral examinations, for example, addressed those course learning objectives that required students to think critically about theoretical concepts and practical applications, as well as apply criteria in order to make informed judgments about learning through self-assessment and peer assessments.

Investigating Course Impact

Action research (AR) methodology was employed to examine the impact of course redesign on student learning. AR enables instructors to reflect on and initiate positive changes to their practice.[24,25] Providing a range of evidence, including peer review, is an authentic validation strategy for AR since it provides a valuable critique of research methodology and interpretation of findings. For the purposes of this study, a variety of evidence was gathered to verify the impact of the course redesign on student learning. Qualitative and quantitative data were collected prior to, and during the 12-week course from the following sources: (1) a 1-minute paper completed on the first day of the course to gather initial student perceptions of the course and their perceptions of the importance of pharmaceutical analysis for pharmacy research and practice, (2) log entries from the instructor's reflective teaching journal, (3) interviews with faculty administrators and instructors in concurrent pharmacy courses, and (4) a 5-question survey instrument distributed at the end of the course (Table 4) to assess student perceptions of: (a) how the active-learning strategies impacted their learning, (b) how the active-learning strategies used in the course differed from those in other pharmacy courses, (c) to what extent their opinions had changed regarding the importance of pharmaceutical analysis on pharmacy research and practice, (d) their suggestions for course improvements, and (e) their perceptions of the laboratory learning experience. The latter question was included in response to previous challenges made concerning the relevance of the laboratory component of the course. Qualitative data were analyzed using the constant comparative method[26] for common experiences, themes, and data discrepancies. Quantitative data were analyzed using frequency and percentage counts. Student data from the 1-minute paper and the survey instrument were collected with the assurance that all responses would be kept anonymous and confidential.

RESULTS

Initial Student Perceptions of the Course

Analysis of the 1-minute papers submitted by 137 students (100% response rate) at the end of the first class, indicated that students expected to be challenged, and hoped the course would enhance their theoretical and practical knowledge of pharmaceutical analysis techniques and applications (through lectures, laboratories, and oral examinations) and help to strengthen the connection between pharmaceutical analysis and pharmacy practice. The following excerpt from one student's paper expresses these expectations:

"I expect this course to be very challenging and difficult. Hopefully the "hands-on" work in the lab and the oral exams will make the material easier to understand. I hope to learn different analytical techniques and see how they can apply to pharmacy practice."

Furthermore, the vast majority of students (98.5%) recognized the importance of pharmaceutical analysis to drug research and development. Typically, these students commented that pharmaceutical analysis was important for drug discovery, purification, effective dosing, identifying drug toxicities, and ensuring patient safety. Fewer students commented on the importance of pharmaceutical analysis on pharmacy practice (48/137; response rate 35%). As expressed in the following excerpts, these students commented that learning about pharmaceutical analysis would help their competence and confidence as a pharmacist and practitioner:

"Pharmaceutical analysis (PA) is very important for drug research. It's important that the drug/compound is

Table 4. Postcourse Survey Results, N = 117*

	Percent of Students Choosing Each Response				
Questions†	**Not at all 1**	**Somewhat Significantly 2**	**Significantly 3**	**Very Significantly 4**	**Entirely 5**
1. As a student enrolled in Pharmacy 325 you have participated in many "active learning" strategies such as 1-minute papers, videos, demonstrations, working with the cases and problems, questioning, discussions, quizzes and laboratory activities. How have these activities helped your learning? Please comment.	7.6	28.8	33.3	25.8	4.5
2. How do the active learning strategies in this course differ from other pharmacy courses you are currently taking (or have taken)? Please comment.	4.5	30.3	34.8	22.7	7.7
3. As a student enrolled in Pharmacy 325 you have completed four of eight laboratories and two oral exams. To what extent have these laboratory activities helped your learning in this course? Please comment.	4.4	29.0	13.7	42.7	10.2
4. On the first day of this course you were asked in a 1-minute paper to give "your opinion on the importance of pharmaceutical analysis on drug research and development and on pharmacy practice". How has your opinion changed since the beginning of the course? Please comment.	16.7	53.8	18.9	7.6	3.0

*Response rate: 85% (117/137 students).

†A fifth question, "What suggestions could you make to improve this course?" was also asked. Students' responses to the question are discussed in the Results section of the paper, under the subheading, "Postcourse Survey (Question 5): Students' suggestions for course improvements."

sufficiently analyzed to help determine its purity, functional components, toxicities etc., in order to determine the compound's actions. As well, these techniques are crucial for the development of new drugs and compound…PA gives numbers, concrete information for pharmacists to rely on, so that pharmacists can be confident in their advice to their patients!…All I know as of present is that any type of analysis is vital in developing a safe and effective drug therapy"

Alternatively, 21% of students questioned the importance of pharmaceutical analysis on pharmacy practice and believed it to have limited relevance to, or opportunities for application in, the practice setting. Some students felt they did not have enough background to judge the importance of pharmaceutical analysis on practice.

Postcourse Survey (Question 1): Impact of Active-Learning Strategies

As shown by the responses to survey question 1 (Table 4), more than 92% of the students felt that the active-learning strategies used in the course helped their learning, with approximately 64% of students rating the active-learning strategies from "significantly" to "entirely" helpful to their learning. Active-learning strategies identified most often by students as helpful included case studies, in-class problems, quizzes, laboratories, and oral examinations. Clearly, students' learning habits adapted to those that were important to achieving success in the course. Typically, students commented that active-learning activities engaged their thinking, provided feedback on their understanding, helped their motivation, and helped them integrate theory with practice in the lecture and laboratory environments.

"The case studies helped us think through a problem ourselves, not just absorb what we are told. I think this way of learning helps us remember the material better. Also, it is more interactive. We can feel that we're participating in the lecture itself…The quizzes helped me realize what I thought I understood but really didn't and helped me keep up on the work…I felt the labs definitely helped clarify important points and showed the application of the theory learned in class…I found the oral exams immensely helpful. The process of preparing for the exam made me learn the material in great detail. Participating helped me put things all together."

In contrast, approximately 7% of students found the activities "not at all" helpful or were uncomfortable with the active-learning strategies, preferring more traditional approaches to learning via lectures or laboratory demonstrations. This sentiment was typically expressed in the following ways by students:

"I learn better when the Prof. lectures, rather than the in-class activities… I find direct instruction much more helpful than active learning…The labs are too tedious and time-consuming. The lab should be 3 hours and the marks should be based on lab reports only, drop the oral exams."

While the use of active-learning strategies was an important aspect for the redesigned pharmaceutical analysis course, significant barriers to learning still existed within the laboratory setting due to the lack of adequate scientific equipment and resources required for 140 students. Accommodating students (course enrolment: 137) required the use of a laboratory rotation scheme that was, at times, out of sequence with the lecture component of the course for approximately 25% of students.

Postcourse Survey (Question 2): Comparison to Other Pharmacy Courses

Student responses to question 2 (Table 4) indicated that the active-learning strategies used in this course did differ from the instructional methods used in other pharmacy courses they were taking or had taken. Over 95% of students indicated that this course was different from other pharmacy courses, with 65% indicating the difference was "significant." Most students commented that this course was more interactive than other pharmacy courses. While students did participate in active-learning activities in other pharmacy courses (eg, cases, discussions, and laboratories) the use of active-learning strategies in this particular course was perceived to be more extensive and a central feature of the course. In particular, students commented that they had not previously experienced activities such as 1-minute papers, video analysis, student demonstrations, regular quizzes, collection and grading of in-class work, and oral examinations.

"This class is very different from other pharmacy courses in that it is much more interactive. The discussions, problems and other activities made this class more interesting…This class is more interactive; there were more opportunities for discussions, working on problems/cases and demonstrations. There were also quizzes held almost every week, which helped reinforce the learning process, rather than just midterms and finals… We do labs in other courses (pharmacy practice) but these labs are different. We needed a lot of preparation and teamwork to get the work done. This is the only course that has oral exams."

While the majority of students adapted well to the active-learning strategies used in this course, approximately 4% of students did not.

"Other courses spend time on teaching the students concepts relative to what's being tested on. This course didn't do that. The material is complicated enough without the extra confusion that results from the active-learning strategies."

Postcourse Survey (Question 3): Impact of Laboratory Activities

Analysis of student responses to survey question 3 (Table 4) indicated that over 95% of students felt that the laboratory activities (laboratories and oral exams) did help their learning in this course, with 66% of students rating the active-learning strategies as "significantly" to "entirely" helpful to their learning. In addition to helping them integrate lecture and laboratory learning experiences (as identified from student responses to survey question 1), students commented that the laboratory activities provided "hands-on" experience, helped them visualize course concepts; improved their data analysis, teamwork, presentation, and problem-solving skills; and helped them make the connection to "real-life." Importantly, many students commented that the laboratories and oral examinations promoted deeper thinking.

"It is always easier to understand materials learned in class if you actually get to do the experiment. It ties theory and reality together and it is a chance for us to demonstrate good teamwork and problem solving…The labs and oral exams kinda pushed us to think deeper as to what is actually happening in this course and you can never see this from a textbook or in class…At first the oral exams didn't seem helpful, only intimidating. However, after completing them I have a greater understanding of what this course is about. I appreciate their value much more!

Issues identified as barriers to learning included the laboratory rotation scheme, which was out of sequence with the lecture for some students, the limited equipment available for the laboratories, and the excessive time required for some students to complete the laboratories and prepare for oral examinations. The spectrophotometry, chromatography, and clinical chemistry laboratories were generally well received, whereas students saw less relevance for the content uniformity (titrimetry) testing experiments.

Postcourse Survey (Question 4): Course Impact on Student Perceptions

Interestingly, approximately 80% of students indicated that their opinions had changed at least "somewhat" since the beginning of the course. While most of these students commented that they had always thought pharmaceutical analysis was important, taking the course served to reinforce their opinions. Of the approximately 30% of students reporting that their opinions had changed "significantly" to "entirely," most commented that, prior to taking the course, they had limited background in pharmaceutical analysis, but after taking this course, felt they knew what it was and its importance to both research and development and pharmacy practice. Typically, students indicated that the course helped them build more competence and understanding, and a knowledge base in pharmaceutical analysis (theory and practical applications); exposed them to a range of pharmaceutical analysis techniques used in the hospital, community, and industrial settings; and helped them appreciate the complexity and rigor of the drug development process, and content uniformity and diagnostic testing. In contrast, approximately 20% of students reported no change in their postcourse opinions, and commented that while they felt pharmaceutical analysis was important, the course did not focus enough on the community setting.

Postcourse Survey (Question 5): Students' suggestions for course improvements

Data from students provided many constructive suggestions to further improve the course design. These suggestions focused primarily on context building, as well as the extent to which active-learning strategies were employed. In particular, students felt it would be beneficial to provide greater emphasis and clarity at the onset of the course to explain how students are expected to learn. Specifically, students suggested a formal presentation by the instructor to explain the role, function, and benefits of active-learning strategies, and how students would be evaluated, would further help them to adapt their approach to learning in this course. Students also commented that the active-learning strategies in the course could be enhanced by providing more opportunities to work on cases and problems during class time, reducing the open-ended nature of some of the activities (eg, the use of open-ended questions and cases to promote critical engagement with the course material), and enhancing the application focus in the pharmacy practice context (eg, using a disease-state approach to course design or increasing the focus on screening and diagnostic tests sold and/or performed in pharmacies, such as pregnancy and bone-density measurement testing systems, as well as interpreting laboratory values in the hospital setting).

Postcourse Reflection: Instructor's suggestions for course improvements

The instructor's reflective teaching journal provided critical insights regarding the impact of the learning-centered course design on teaching practice and the quality of student performance. Although a substantial task, the redesign process was invigorated by the collegial nature of the collaboration with colleagues in the UBC Faculty of Education and the learning experienced by the students and the course instructor.

The instructor experienced significant professional growth as an educator and critical improvements were made to the overall quality of the course, including establishing a greater sense of learning community within the classroom.

Reduction of content in favor of increased flexibility to involve and connect with students on a more frequent basis, along with the use of a variety of instructional methods to "break-up the pace," stimulate discussion, and engage students during instructional sessions, helped energize the teaching and learning process. Observing students engaging in critical discussions of course materials during the practice and final oral examinations was particularly satisfying.

Compared with the traditional course design, observations of student performances in the re-designed course revealed a much higher quality of student work. For example, the quality and frequency of questions posed by students, as well as the high level of interaction, participation, and discussion generated regarding course material (during lecture, laboratory, and office hours) provided evidence of improved understanding of and engagement with key course concepts. Students' written work (eg, written responses to 1-minute papers, in-class problem sets and cases, examination questions, and laboratory reports) showed a marked improvement in their depth of understanding of course content along with its application and integration across pharmacy settings. This was evident through their abilities to problem-solve in lecture and laboratory activities, draw conclusions and disseminate experimental findings, and identify the clinical significance and impact of pharmaceutical analysis on pharmacy research and practice, along with their communication and teamwork skills. In general, students took greater ownership in their work.

In addition to students' suggestions, further strategies to improve the quality of this learning-centered course would be to: (1) incorporate performance criteria for learning assignments (eg, A, B, C grade criteria), combined with more opportunities for self-evaluation and peer-evaluations throughout the course, (2) develop a greater congruence between the lecture and laboratory course sequence (this could be achieved by reducing the number of laboratory exercises offered, spreading laboratory completion time over additional laboratory periods, and maximizing the efficiency of available scientific equipment through the use of innovative learning technologies),[27] and (3) further reduce the theoretical focus of the course in favor of a greater focus on relevant pharmaceutical analysis applications in community and hospital pharmacy.

Transferability of Learning Outcomes

Anecdotal evidence from Faculty administrators, along with instructors who teach the same cohort of students in concurrent pharmacy courses (eg, pharmacology and therapeutics, pharmacokinetics and pharmacy practice) suggest that the students were able to transfer various skills and knowledge to other elective and required courses. In particular, administrator and instructor interviews revealed that these students: (1) were more confident communicators, particularly regarding formulating and responding to questions, defending decisions, and delivering presentations; (2) demonstrated enhanced abilities to evaluate and think critically about cases regarding therapeutic choices, identify drug-related problems, and develop appropriate patient care plans; and (3) showed improved teamwork skills. Knowledge transfer was most noticeable in the concurrent pharmacokinetics course, the instructor for which stated that students were more aware of the importance and impact of pharmaceutical analysis on pharmacokinetics. Overall these students were judged to show greater maturity, leadership, and confidence. Administrators also recognized the impact of this course on the design of other pharmacy courses, specifically regarding the adoption of password-protected Web sites and the use of student-peer teachers.

Data from this study support other studies that have been conducted in various higher education settings regarding the impact of a learning-centered framework for curricula and course design.[11-13] Further research is required to investigate the impact of learning-centered course design on teaching practice and students' retention of knowledge in the pharmacy curriculum.

CONCLUSIONS

Significant pedagogical change is taking place in pharmacy education in Canada, requiring greater attention to undergraduate-level course design. Emerging educational outcomes-based programs not only underscore the need for learning-centered approaches to pharmacy education, but are intensifying the debate on the relevancy and importance of basic sciences content and training in the education of today's practicing pharmacist.

This paper describes a learning-centered course design in pharmaceutical analysis. A learning-centered course design framework provided guidance for analyzing the traditional pharmaceutical analysis course, as well as for the systematic development and implementation of the learning-centered course. This framework was the focal point of the redesign process and reinforced the importance of the integrated relationship between learning context, planning, instructional methods, and authentic assessment strategies to enhance student learning. In particular, responding to students' backgrounds, needs, and motivations, and the educational missions of the Faculty and University, as well as to the demands of a changing profession, were key contextual factors influencing course redesign. The learning-centered course positively impacted student learning as demonstrated by student engagement in the learning process, the quality of student performance, the transfer of knowledge and skills to other pharmacy courses, and increased recognition of the importance of pharmaceutical analysis in their development as practitioners. In addition, the course instructor's teaching practice was enhanced and significant professional growth occurred.

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