Integration of Medicinal Chemistry and Pharmacotherapeutics Courses: A Case-Based, Learner-Centered Approach

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This report describes the development, implementation, and evaluation of a student-centered, case-based, integrated sequence of core courses in medicinal chemistry and pharmacotherapy at the University of North Carolina School of Pharmacy. Goals for the courses include: (*i*) minimization of redundant or conflicting content; (*ii*) enhancement of student ability to integrate and apply basic science and pharmaceutical care principles; and (*iii*) facilitation of student development of effective problem-solving, critical thinking, communication, and self-directed learning skills. Following interdisciplinary faculty team development of specific course content and adoption of a mixed didactic, case-based, and problem-based structure, these courses were implemented, with subsequent student evaluation. Student surveys indicate that integration of content simplifies and improves understanding and application of concepts. Case-based learning increased the amount of time spent in class preparation/self-directed learning and improved student's ability to grasp and apply concepts. Student criticisms included discomfort with case or problem-based techniques, inconsistencies in teaching and assessment techniques between learning modules, and time-related stresses.

INTRODUCTION

As the curriculum for pharmaceutical education evolves with the introduction of the entry-level Doctor of Pharmacy degree, pharmacy educators must reconsider teaching process as well as curricular content. Background Paper II elucidates a variety of the competencies and teaching innovations appropriate to contemporary pharmaceutical education(1). In preparation for the transition to an entry-level Doctor of Pharmacy program, the School of Pharmacy at the University of North Carolina at Chapel Hill has implemented a variety of curricular and pedagogical changes aimed at achieving learning outcomes consistent with those outlined in Background Paper II. One such effort is the development and implementation of an integrated pharmacotherapy and medicinal chemistry course sequence. This three-semester sequence, offered in the second and third years of the professional curriculum, integrates concepts, skills, and knowledge addressed previously in separate lecture-based courses in the Divisions of Medicinal Chemistry and Pharmacy Practice. Faculty from both disciplines participate in a combined didactic and case-based instructional format. Concepts covered by the Medicinal Chemistry faculty include design, mechanism of action, essential chemical features relating to biological activities, and metabolic pathways leading to activation/deactivation of the parent drug. Methods for assessing the patient, identifying patient-specific problems, formulating solutions/treatment plans, monitoring pharmacotherapy, and communicating with patients and health care practitioners are stressed by Pharmacy Practice faculty.

BACKGROUND

Variations of problem-based and case-based learning have been described as mechanisms for enhancing active student learning(2-4). The two approaches share the common attributes that: (*i*) teaching and learning center around the use of cases or scenarios in which one or more problems can be identified, analyzed, and solved, and (*ii*) evaluation of students is centered around student's ability to approach and solve novel problems. Generally speaking, traditional objective testing methods (*e.g.*, multiple choice, true/false, or short answer examinations) are insufficient to evaluate the learner's ability to respond to a novel situation (*i.e.*, case). More subjective and open-ended methods, either written or oral examinations, are required.

Case-based instruction generally refers to the use of cases as a focal point around which instruction is conducted. Faculty exert significantly more control in defining content in case-based instruction than in problem-based instruction, using cases in class to illustrate and exemplify concepts and/or to increase student participation in an active learning process through large or small group discussion of the cases. Cases typically focus on one or two main concepts, but may be constructed such that multiple issues or concepts are considered within the context of a single case.

Problem-based learning (PBL) generally describes a system in which students "discovery learn" the content of all or part of a curriculum through the independent research, analysis, and solution of a series of case scenarios. Several variations of problem-based learning in medical education(5-8), ranging from fully problem-based curricula to programs in which PBL experiences are woven into a traditional curriculum, either as a stream of experiences throughout the curriculum, or as a capstone experience near the end of the curriculum. Individually and collectively, the problem(s) drive the students into the sub

stance of the curriculum.

The central feature of PBL is a set of problems which prompt learners, working in groups, to search for, analyze, integrate, and apply information to the identification and resolution of ill-structured problems that present much as they would in everyday life — without previous study of the topic or other preparation. Students must define learning tasks, locate appropriate resources, identify and record pertinent information, and to test the viability of potential solutions. The focus of student evaluation is upon his/her ability to organize a problem-solving approach and to access and apply specific basic science content knowledge to effectively resolve each clinical problem(8).

Faculty generally exert less control of content covered in a PBL system than in a traditional setting, but students tend learn the information more completely and recall it more reliably because they must actively discover and apply the information. PBL research indicates that students do not focus exclusively on the clinical dimensions of a case, but attempt to master and apply the basic and social science concepts within a clinical subject area and to develop a reasoned approach to outlining and comprehending the learning issues in all areas of the cases. Finally, PBL enables students gain skill and confidence in approaching and solving collaboratively or independently, thus satisfy the goals of developing the clinical reasoning and problem-solving skills and acquiring specific content knowledge necessary to become independent learners and skilled clinicians(12).

COURSE DEVELOPMENT AND IMPLEMENTATION

Planning for Change

In 1991, the faculty of the UNC-CH School of Pharmacy began planning an entry-level Doctor of Pharmacy curriculum by reviewing curricula and teaching innovations at UNC-CH and other schools of pharmacy and by soliciting and reviewing the opinions of faculty, preceptors, students, and employers. This process resulted in the articulation of a mission statement which says that the primary mission of the professional curriculum at the UNC School of Pharmacy is "to educate and prepare graduates to provide pharmaceutical care." From this perspective, the faculty developed a number of specific curricular goals and associated competencies aimed at providing graduates with the necessary knowledge, skills, and attitudes to begin a pharmaceutical care practice. In addition to goals addressing specific content knowledge and practice skills, several more general and global goals emerged. These included the student's development of: (*i*) critical analysis, problem solving, and decision making capabilities; (*ii*) counseling and communication skills; (*iii*) ability and motivation to be active learners and to develop a personal commitment to life-long learning; (*iv*) professional pride and self-esteem; (*v*) sense of professional and personal responsibility; and (*vi*) commitment to participate in professional organizations and to enhance their profession.

Several aspects of this developmental process lead to the development of the integrated course sequence. First, throughout the process, faculty repeatedly expressed concerns regarding the ability of a six-year program to maintain the quality previously seen with the postbaccalaureate Doctor of Pharmacy program. Secondly, surveys of clinical faculty, particularly those involved in clerkship training, suggested that students often had difficulty identifying patient-specific drug-related problems, responding appropriately to variations in patient presentations, developing complete and rational treatment plans, and/or communicating effectively with patients or clinicians. Student surveys and focus group discussions indicated that content in the separate pharmacotherapy and medicinal chemistry courses was often redundant and sometimes conflicting, and that marginal effort was made to coordinate topics between courses or to link basic science principles to clinical application. Students complained that the large lecture format discouraged class preparation and participation and that heavy reliance on multiple-choice testing denied them an opportunity to fully demonstrate their knowledge and skills, and reinforced their tendency to memorize information for tests rather than learning to apply their knowledge to patient care. All of these factors lead faculty in Medicinal Chemistry and Pharmacy Practice to develop a series of integrated (*i.e.*, multidisciplinary) courses emphasizing active learning and multifaceted student assessment strategies that would: (*i*) minimize redundant or conflicting content; (*ii*) enhance student development and application of pharmaceutical care principles; and (*iii*) enhance students' active and self-directed learning skills. It was expected that this pedagogical shift would also help learners integrate the various elements of the core curriculum into a functional knowledge and skill base, improve their communication and problem-solving skills, and acquire skills and strategies to facilitate life-long learning and career developmental(11-13).

Table I. Sequence of organ system-based modules in the second professional year

Fall semester 9 credit hours	Spring semester 7 credit hours
Dermatology	Pulmonology
Infectious Diseases	Gastroenterology
Hematology	Cardiology
Oncology	Nephrology
Rheumatology	Neurology
Endocrinology	Psychiatry
Autonomic Nervous System	

Course Structure and Sequencing

Faculty from Medicinal Chemistry and Pharmacy Practice met over a period of several months to determine specific learning outcomes, *e.g.*, appropriate course content, structure, and sequence, and faculty roles in developing, teaching, and administering the integrated course sequence. A decision was made to follow an organ system-based format that would allow faculty from each discipline to participate in the teaching/learning process for each system. Multi-system modules in infectious diseases and hematology/oncology were also described. Table I outlines the original structure and sequence of the modular courses offered at UNC in the second professional year of the baccalaureate curriculum between Spring Semester 1994 and Spring 1998.

Additional courses in pharmacology, pharmacokinetics, and social/administrative sciences continue to be

Table II. General outline for integrated modules

I. Overview of disease(s) for the organ system (definitions, terminology, epidemiology, patient and societal costs)
II. Pathophysiology and pathology
III. Pharmacology (focusing on "key" drugs)
- Basic (MOA, A-D-M-E, ADEs, SARs)
- Toxicology
- Biopharmaceutics (dosage forms, bioavailability)

IV. Therapeutics
- Rational drug selection
- Clinical pharmacokinetics

V. Pharmaceutical Care Functions
- Establish therapeutic objectives
- Recommend dose and dosage schedule
- Select dosage form, formulation, administration, delivery system
- Select drug source
- Ensure proper preparation of medication for patient use
- Counsel
- Monitor drug therapy outcomes
- Perform appropriate physical assessment techniques to monitor for achievement of therapeutic outcomes or adverse drug events
- Anticipate, prevent, and correct drug interactions or adverse drug events
- Perform drug use evaluation
- Educate other health care professionals

taught concurrently. Pharmacology instruction, provided by the School of Medicine, is sequenced to parallel topics in the integrated sequence and content in the pharmacology course is considered when developing the syllabus for these courses. Additional integration and application of content from concurrent courses occur through simulated patient care activities in the Pharmaceutical Care Laboratory (PCL) courses. PCL faculty coordinate activities with faculty in each of the concurrent courses, including the integrated modules, to develop simulated patient encounters that illustrate and help students apply concepts learned in those courses.

For purposes of course registration and grade assignment, the integrated course sequence is divided into two and three credit-hour courses, each composed of two organ-based modules. Modules are taught in a sequential manner, *i.e*., students complete one disease-state module at a time. Students meet six to ten hours each week, depending on the length and number of credits assigned to the module. Students spend one to two hours in weekly or biweekly problem-based, small group sessions (recitations) with eight to ten students and one faculty facilitator. The remainder of the time is spent in the large classroom (100 students) in a combination of traditional didactic lecture and case-based instruction.

The instructional goals of each module are to encourage student discussion of all topics. This is done by: (*i*) progressing to case-based discussions as quickly as possible; (*ii*) giving students frequent problem-based assignments to complete both in and out of the classroom; and (*iii*) encouraging students to take cases in directions that they feel are interesting and relevant to their professional development. Before starting each module, students are provided an instructional outline, handouts and readings for the medicinal chemistry component, a list of assigned *readings in Applied Therapeutics*(14) and/or *Pharmacotherapy*(*15*), and collection of cases for classroom and recitation discussion. A general outline for the integrated modules is shown in Table II.

A typical class begins with a brief didactic presentation of key instructional concepts, then proceeds to case presentations and discussion facilitated by a faculty member. Medicinal chemistry faculty focus on the chemistry, pharmacology, and pharmacokinetics of relevant compounds, while pharmacy practice faculty focus primarily upon epidemiology, pathophysiology, pathology, pharmacotherapeutics, and socioeconomic considerations. Class activities are structured around active and collaborative learning principles to the extent possible in a large classroom. Discussion cases are distributed to students in advance of the class meeting and students are expected to review the assigned related readings and complete a written work-up of the case prior to class. Instructors use a Socratic method in the large classroom setting to engage students in a discussion of the various elements of the cases. On occasion, faculty may assign a student or group of students to facilitate one or more case discussions. Students are given some freedom to determine the direction of the case discussion but are challenged to support their opinions or recommendations with evidence from the literature.

Case-Based Instruction and Problem-Based Learning Applications

Each module is conducted primarily through discussions of cases designed to illustrate key concepts and help students develop the following strategies for: (*i*) identifying, resolving, and preventing drug-related problems; (*ii*) developing patient-specific therapeutic plans; (*iii*) communicating effectively with patients and other clinicians; and (*iv*) documenting the pharmacist's intervention. Cases are discussed both in the large classroom and in weekly recitation sessions (8-10 students). Students are instructed to review each case prior to its classroom discussion, to prepare a pharmacist's pharmacotherapeutic work-up(16) for each patient, and to come to class prepared to give their assessment of the case. In most cases, students are allowed to collaborate with classmates to prepare the work-up, but are expected to write their own case notes and to be able to defend their responses if called upon in class. Some faculty require each student to hand in a written work-up or consultation note prior to discussing the case in class, while others simply require students to be prepared to discuss the case when randomly called upon in class. Written notes are generally organized into a standardized "S-O-A-P" or "F-A-R-M" format(16-17). This standardized process can be easily transferred to various educational (*e.g*., classroom, recitation groups, evaluation sessions, clerkship rotations, etc.) and practice settings (*e.g*., community practice, managed care, chain store pharmacy, long-term care, and institutional-based pharmacy)(18-20).

Case discussions in the large classroom typically center on relatively simple, single-issue cases that exemplify major concepts and model an approach to identifying and resolving drug related problems. Because many students are hesitant to speak out in the large classroom, the level of active learning in which students engage in this setting is moderate and variable and more closely adheres to a model of case-based instruction than problem-based

learning. While students participate in the discussion when compelled to do so, they do not typically lead the direction of discussion. Faculty generally guide the direction of discussion to ensure that key concepts are addressed.

Weekly or bi-weekly recitation sessions provide students with more active, problem-based learning opportunities. Small group size and flexible time requirements enable students to explore and propose their own solutions to more complex or multi-issue cases in a less threatening environment. Recitation cases are unique and novel problems that require students to explore beyond the limits of the cases discussed in the large classroom setting. Recitation cases are introduced during the large class meeting, prior to the recitation date, and clarified if needed. Students then work independently and with their teams to work-up the case prior to the recitation meeting. It is their responsibility to: (*i*) identify pharmaceutical care problems in the case; (*ii*) locate critical information to clarify and solve the problem; (*iii*) articulate reasonable therapeutic goals; (*iv*) identify and select from among therapeutic alternatives; (*v*) develop a monitoring plan; and (*vi*) develop a plan for consulting with and educating the patients and clinicians involved. During the scheduled recitation time, students present their proposed solutions for review and discussion with a faculty facilitator.

The role of faculty is critical in establishing case-based or problem-based learning as a viable part of the curriculum. While faculty members in both the clinical and basic sciences have served as facilitators, a weakness of the UNC program is the nearly exclusive reliance on clinical faculty, residents, and fellows to serve as recitation facilitators. Students have the opportunity to meet with medicinal chemistry faculty before recitation sessions to ask questions, clarify concepts, etc. Further, medicinal chemistry faculty can move from room to room during recitation sessions to monitor the progress of each group, and to answer questions that arise.

Prior to and during recitation sessions, facilitators help to guide case discussions, direct students to appropriate resources when needed, and provide feedback about the process. Case authors prepare a standardized answer key for each case, and facilitators meet with the case author prior to the recitation to discuss the issues that are likely to be discussed and general strategies for developing alternative therapeutic approaches. A concerted effort is made to focus on the students' problem-solving strategies and ability to justify their treatment approaches rather than looking for "one right answer."

Evaluation of Students

A variety of objective and subjective techniques for evaluating students are used in the integrated courses, both summative for the determination of grades and formative for the purpose of providing corrective feedback(21). For evaluation of the knowledge acquired and utilized, multiple formats such as the case work-up, brief essay, or multiple choice questions are used. While one of the initial objectives of this project was to move away from reliance on multiple choice and short answer testing, this objective has not been fully accomplished. Some of the modules continue to rely exclusively on the objective test format in which students are assessed with questions for which there is only one correct answer. Although not optimal for assessing students' ability to formulate solutions and deal with variability, this approach does allow for more rapid turn around of test scores and a perception of greater equity and consistency in grading. In other modules, students are evaluated on their work-up of one or two cases, emphasizing the student's ability to articulate a sound rationale for his/her solution rather than a "one right answer." While this approach provides more information about the student's ability to apply fundamental concepts to patient care, it often results in a prolonged turn around time for providing feedback to students and to a perception that examinations are not graded in a consistent manner for all students.

An intermediate approach that has been experimented with is the use of examinations that present case scenarios followed by a series of both objective and subjective questions related to the case. Students may be asked to list therapeutic alternatives, select from a list of therapeutic alternatives and explain the rationale for their choice, identify relevant scientific concepts, and/or explain how these concepts relate to the patient care situation. Because this testing format provides a relatively high level of structure, it may allow for more rapid and consistent grading and thus provide more useful feedback to students. On the occasions that is has been used, this testing approach has been well received by both faculty and students.

In addition to examinations, faculty evaluate student abilities and provide feedback during recitation and/or through review of written case notes. In some cases these assessments contribute to the student's grades, but in most cases they simply provide formative feedback to students. Self-assessment tools have also been developed and used in at least one module.

COURSE EVALUATIONS

General Observations

While both students and faculty report a perception that the new format covers less content, students generally report that they feel more confident of their knowledge when learned in a patient care context. Via survey, clinical clerkship preceptors indicate overall improvements in students' abilities to solve problems and to interact with patients and other providers in the health care setting since implementation of these courses. Additionally, overall performance, as measured by course examinations, has produced grade distributions over the last four years as follows: A = 20.3 percent, B = 53.6 percent, C = 25.6 percent, and D = 0.5 percent. As no baseline data was collected from prior segregated courses, no direct comparison of achievement of specific learning objectives or retention of learning has been possible.

Student Course Evaluations and Exit Interviews

After the first four years of implementation, written student exit surveys indicate a generally positive response to the integrated, case-based instruction (Table III). Students reported that integration of instruction made learning easier and facilitated understanding and application of concepts. Students were somewhat less positive regarding the case-based instructional format in the large classroom. Some students find the approach difficult and

Table III. Student evaluation of Medicinal Chemistry/Pharmacotherapy modules (N = 152)

Question	Mean (SD)[a]	Percent agree or strongly agree
Integrated instruction made learning easier	5.23 (0.69)	80
Integrated instruction helped me to understand fundamental concepts	5.25 (0.61)	83
Integrated instruction helped me to apply content/concepts on rotation	5.46 (0.55)	92
Case-based instruction made learning easier	4.55 (1.02)	50
Case-based instruction helped me to understand fundamental concepts	4.70 (0.95)	53
Case-based instruction helped me to apply content/concepts on rotation	4.91 (1.01)	53
The pace of instruction provided adequate time to master fundamental concepts	2.68 (1.00)	16
Case-based instruction requires that you come prepared for each class	4.96 (0.83)	76
Case-based instruction requires that you learn on your own	5.15 (0.82)	72
Case-based instruction requires that you spend more time (than in other pharmacy courses) actively learning	5.02 (0.74)	69
Case-based discussions encourage students to participate	4.91 (0.78)	69
Case-based are dominated by just a few students	4.87 (1.24)	62
Case-based allow ample opportunity for everyone to participate	3.86 (1.11)	24
Case-based allow students to "hide" in the classroom	4.05 (1.27)	36
Recitation discussions helped me to learn	5.23 (0.66)	82
Recitation discussions helped me to understand fundamental concepts	5.17 (0.79)	78
Examinations should be entirely multiple-choice format	3.00 (1.28)	10
Examinations allow students to adequately demonstrate knowledge	2.69 (1.49)	18

[a]Response scale: 1 = Strongly disagree; 2 = Disagree; 3 = Disagree slightly; 4 = Agree Slightly; 5 = Agree 6 = Strongly Agree.

Table IV. Revised sequence of organ system-based modules

Second professional year		Third professional year
Fall semester, 6 credit hours	**Spring semester, 6 credit hours**	**Fall semester, 8 credit hours**
Rheumatology	Cardiology	Dermatology
Endocrinology	Nephrology	Infectious Diseases
Autonomic Nervous System	Neurology	Hematology
Pulmonology	Psychiatry	Oncology
Gastroenterology		Immunology

uncomfortable, initially, but ultimately prefer the format to traditional didactic methods and consider the process applicable to future learning and practice. They also prefer taking modules sequentially, rather than taking multiple modules concurrently, although this sometimes means covering a module in a very short time period. Students also generally agree that the case-based instruction and problem-based recitations encouraged them to come to class prepared, spend more time learning on their own, and participate in class discussions, although some students expressed the opinion that large numbers of students could still "hide out" in class and not participate . Finally, students noted that the small group sessions helped them to learn relevant information and increased their confidence in solving patient care problems. The problem-based format and the opportunity to interact with faculty in small group recitation sessions were identified as highlights of the courses, both in end of course and end of curriculum reviews.

Student criticisms primarily focused on differences in teaching styles between instructors; inconsistencies of module organization, testing and grading; the compressed time frame of the modules (generally three to four weeks); and intense competition between students for grades. As earlier mentioned, some students expressed the opinion that case-based discussion in the large classroom allowed a few students to dominate the discussion while the rest did not participate. Lack of consistency of expectations between modules was a recurring criticism, and many students admitted that they neither completed the assigned reading nor prepared their case work-ups prior to class unless they were required to hand in a case note. Students also complained that the courses were inconsistent in format and poorly integrated with other concurrent courses; they suggested that more core courses be integrated into the modular sequence. Finally, students objected in some cases to the sequencing of the courses, noting that some of the earlier modules dealt with complex, multi-system issues before they had completed their study of single organ-system topics.. Based upon feedback from students regarding the compressed nature and sub-optimal sequencing of the modules, the integrated courses have been resequenced and extended over three semesters with the implementation of the six-year Doctor of Pharmacy curriculum (Table IV).

CONCLUSION

While potentially covering fewer content topics, case-based and problem-based learning opportunities allow students to become more active participants in the learning and evaluation process, potentially enabling them to better grasp and retain key concepts and to apply them to patient care situations. Reduction of redundant content achieved by integrating instruction across two or more disciplines may minimize the loss of content coverage while reducing student boredom and frustration with the curriculum.

Although conversion of traditional, independent courses to more an integrated and active-learning approach has been challenging, faculty generally view the process as positive and rewarding in terms of improving student participation and performance, and enhancing faculty collegiality. Students generally respond positively to the more active learning methods, indicating a preference for additional courses taught by a similar process and expressing the belief that they are better prepared for future learning and practice. Commitment of faculty to focus on the learning process and to hold students accountable for their learning outcomes is critical to implementing successful case- or problem-based courses. Continued efforts are needed to determine the effectiveness of this approach in improving student learning and retention, and motivating students to become more self-directed learners.

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