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INSTRUCTIONAL DESIGN AND ASSESSMENT

Evaluation of an Instructional Model to Teach Clinically Relevant Medicinal Chemistry in a Campus and a Distance Pathway

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Objectives. To evaluate an instructional model for teaching clinically relevant medicinal chemistry.
Methods. An instructional model that uses Bloom's cognitive and Krathwohl's affective taxonomy, published and tested concepts in teaching medicinal chemistry, and active learning strategies, was introduced in the medicinal chemistry courses for second-professional year (P2) doctor of pharmacy (PharmD) students (campus and distance) in the 2005-2006 academic year. Student learning and the overall effectiveness of the instructional model were assessed. Student performance after introducing the instructional model was compared to that in prior years.
Results. Student performance on course examinations improved compared to previous years. Students expressed overall enthusiasm about the course and better understood the value of medicinal chemistry to clinical practice.
Conclusion. The explicit integration of the cognitive and affective learning objectives improved student performance, student ability to apply medicinal chemistry to clinical practice, and student attitude towards the discipline. Testing this instructional model provided validation to this theoretical framework. The model is effective for both our campus and distance-students. This instructional model may also have broad-based applications to other science courses.
Keywords: medicinal chemistry, distance education, instructional model

INTRODUCTION

It is an ongoing challenge for science faculty members, including medicinal chemists, to explicitly demonstrate the importance of their disciplines to pharmacy students. From previous experience, several factors are believed to impact student learning and overall attitude in our medicinal chemistry courses. These include general higher education issues, such as: (1) student having difficulty with integration of antecedent information in the curriculum, (2) increased difficulty with more advanced and complex learning, and (3) student resentment when they are asked to take more responsibility for their learning. Specific student concerns include: (1) lack of perceived value and importance of drug chemistry knowledge; (2) difficulty with deciphering clinically relevant structure activity relationships from major pharmacology/medicinal chemistry textbooks, (3) the perceived difficulty of the discipline, and (4) inability to find clinical relevance.

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In a previous article,[1] we described a sample lesson on the beta adrenergic antagonists that incorporated an instructional model to teach clinically relevant medicinal chemistry. This model follows a standardized approach. Each lesson plan has integrated clinical knowledge to meet specific ability based outcomes (ABO) and Accreditation Council for Pharmacy Education (ACPE) guidelines and standards, while retaining foundation knowledge. We incorporated Bloom's taxonomy of cognitive learning and Krathwohl's taxonomy of affective learning[1-2] (Table 1) in combination with our teaching strategies[3-5] to address the factors mentioned above. In this manuscript, a medicinal chemistry professor and a pharmacy practice professor with experience in classroom research and teaching methodology,[6-8] collaborate to describe the instructional model in more detail and how it can be implemented at other schools, and we assess the effectiveness of this instructional model in meeting course objectives and teaching clinically relevant medicinal chemistry.

DESIGN

At Creighton University, there are 2 program pathways available for a student to complete the doctor of

Table 1. Bloom's Taxonomy and Karthwohl's Taxonomy of Learning Within the Cognitive and Affective Domain As Mapped Against the Lesson handout Sections

Lesson Handout Section	Content and Bloom's Taxonomy Level[a]	Content and Krathwohl's Taxonomy Level[b]
Section I: Introduction	Recall of essential knowledge in chemistry, organic chemistry, anatomy, physiology and biochemistry; review of medicinal chemistry and pharmacology essential knowledge (I).	A brief but concise discussion of the continuum between medicinal chemistry, pharmacology and therapeutics (I). Introduce exercises that challenge the students to integrate prior and current knowledge (II).
Section II: Phamacophore	Identify the pharmacophore(s) of a drug class (I). Explain and apply basic nomenclature rule for identifying pharmacophores (II & III).	Discuss how identifying the pharmacophore is like knowing the names of the drug in pharmacology (III)
Section III: Structure Activity Relationship (SAR)	Summarize the SAR (II).	Emphasize that the knowledge of the SAR is the basis for making therapeutic decisions that are rational and patient specific (III and VI).
Section IV: Applying SAR	Predict activity of current and newly marketed- drugs based on the structure (III). Analyze drug structure to predict therapeutic activity (III & IV).	Incorporate exercises that emphasize how the structure explains pharmacological activity and common therapeutic decisions (III and IV).
Section V: Common Clinical Decisions	Summarize the common therapeutic decisions (II). Determine how specific functional features will impact therapeutic decision making (IV).	Explain how common clinical decisions are ascertained by the structure (IV).
Section VI: Predict Activity	Conduct an SBTE analysis of a patient case (IV). Analyze several structures to make therapeutic decisions based on SBTE case scenarios (IV).	Challenge students to apply the knowledge to new marketed compounds (IV). Challenge students to synthesize their own SBTE case scenarios (IV and V). Challenge students to apply knowledge in therapeutics and practice settings (V).

[a]Knowledge (I), Comprehension (II), Application (III), Analysis (IV), Synthesis (V), Evaluation (VI)
[b]Receiving (I), Responding (II), Valuing (III), Organization (IV), Characterization (V)

pharmacy degree. One pathway is taught on the traditional campus; the second pathway is completed predominantly through distance education.[9] Campus and distance-students are admitted to a 4-year doctor of pharmacy (PharmD) curriculum after completing a minimum of 2 years of prepharmacy studies. The instructional model described is used in the second-professional year curriculum of the required 2-semester course sequence *Chemical Basis of Drug Action I* (PHA 337) and *II* (PHA 447). PHA 337 is a 3-credit-hour course (meets for 50-minutes, 3 times a week) while PHA 447 is assigned 2 credit hours (meets for 1 hour, twice a week). This manuscript describes our evaluation of the effectiveness of the instructional model for both the campus (N = 106) and distance-pathway students (N = 60) after being introduced into the course in the 2005-2006 academic year. Data from prior academic years and from the 2006-2007 academic year (campus, N = 109; and distance, N = 50) are also included. All students who were enrolled in the course for 2 consecutive academic years were included.

Curricular Context and Learning Environment

Students come to the *Chemical Basis* courses having completed the first-professional year coursework in biochemistry, physiology, pathology, anatomy, pharmaceutics, and communication skills. Students enroll in the medicinal chemistry course sequence (fall and spring) in the second-professional year curriculum; concurrent

with a 10-credit-hour sequence in pharmacology (fall and spring) and a 4-hour course in microbiology (fall). The *Chemical Basis* courses require students to begin to apply professional clinical reasoning processes to patient-specific therapeutic problems, and help them realize how their unique knowledge of chemistry will assist them in being rational, scientific, and evidence-based practitioners.

The *Chemical Basis* courses meet in a classroom hardwired for laptop computers. Campus-based students bring their computers to class to take notes directly on electronically provided handouts and participate in interactive activities in class. Distance-students are scattered throughout the country. Campus- and distance-students follow the same outline, are required to meet the same learning objectives, and must complete the same evaluation strategies in the same timeframe. The students in both pathways use the same course web site which is authored in Microsoft FrontPage 2003. Each lesson is the same for both pathways and contains links to course objectives, lesson content, and learning activities. Readers are encouraged to view any of the lessons linked in the table of contents on the PHA 337 or 447 websites to see how course information is presented and communicated

(http://pharmacyonline.creighton.edu/pha337: **User Name** spahpweb2\guestpha337 **Password** 337Guest)

(http://pharmacyonline.creighton.edu/pha447: **User Name** spahpweb2\guestpha447 **Password** 447Guest)

Research Design

A quantitative-qualitative mixed methods study design was used to evaluate the effectiveness of the instructional model.[10-11] Data were collected in 2 phases. In the first phase, quantitative data about student performance were collected in the academic year preceding the introduction of the instructional model and then in the academic year that the model was introduced. These data were collected on both campus and distance pathway students enrolled in the class. Evidence of student performance included: student performance on pre-assessment quizzes (10% of course grade), examinations (90% of course grade), and the overall course grade (Table 2). In phase 2 of data collection, both quantitative and qualitative data on student performance and student perceptions about the course, the instructional materials, and the value of learning were collected after introduction of the instructional model during the second academic year of the course offering. This design brings together the strengths of both the quantitative and qualitative data using the qualitative data to validate the findings from the quantitative data. The addition of qualitative data improves our ability to interpret the quantitative findings in year 2, particularly because there is no concurrent control group of students with which to compare the quantitative findings within the first and second year. The design is considered triangulation because the qualitative and quantitative data were collected concurrently in the second phase of data collection and the qualitative data used in validation of the quantitative data. Figure 1 is a schema for the data collection and analysis design.

Analysis occurred in 2 phases. The campus pathway and distance pathway student performances were compared for differences during the same academic years and from one year to the next. The instructional model was introduced to the students in the second year. The quantitative approach was used to compare the student performance after introducing the instructional model to the student performance from the prior years (2001-2004) for both campus and distance pathways. Student perceptions of effectiveness post-intervention are also compared quantitatively. Students' perceptions of effectiveness were measured by a summative course evaluation (Table 3), and perceptions of course activities and attitudes toward medicinal chemistry learning (Table 4). Tables 3 and 4 are all from the academic year 2005-2006. The evaluative data were obtained from the schools standard department/school course (Table 3) and from an evaluation tool that we developed to address specific issues related to this manuscript (Table 3, lesson handout

Table 2. Measures of Change in Pharmacy Student Performance in a Medicinal Chemistry Course

	PHA337 (Fall 2004)		PHA337 (Fall 2005)		PHA447 (Spring 2005)		PHA447 (Spring 2006)	
Evaluation Technique[a]	**Campus (n = 110)**	**Distance (n = 59)**	**Campus (n = 106)**	**Distance (n = 60)**	**Campus (n = 110)**	**Distance (n = 59)**	**Campus (n = 106)**	**Distance (n = 60)**
Examination average, %	71.1	70.2	74.2[b]	73.6[c]	71.5	71.3	73.4[b]	72.8[c]
Pre-assessment quizzes, %	9.5	9.0	9.6	8.9	9.4	9.1	9.8[b]	9.5[c]
Course score, %	80.5	79.7	83.8[b]	82.5[c]	80.9	80.4	84.2[c]	82.3[c]

[c]Averages for examinations are out of 90%; pre-class assessment quizzes, 10%; and course score, 100%

[b]$p < 0.005$; comparison of pre-intervention group (fall 2004) with post-intervention group (fall 2005)

[c]$p < 0.005$; comparison of pre-intervention group (spring 2005) and post-intervention group (spring 2006)

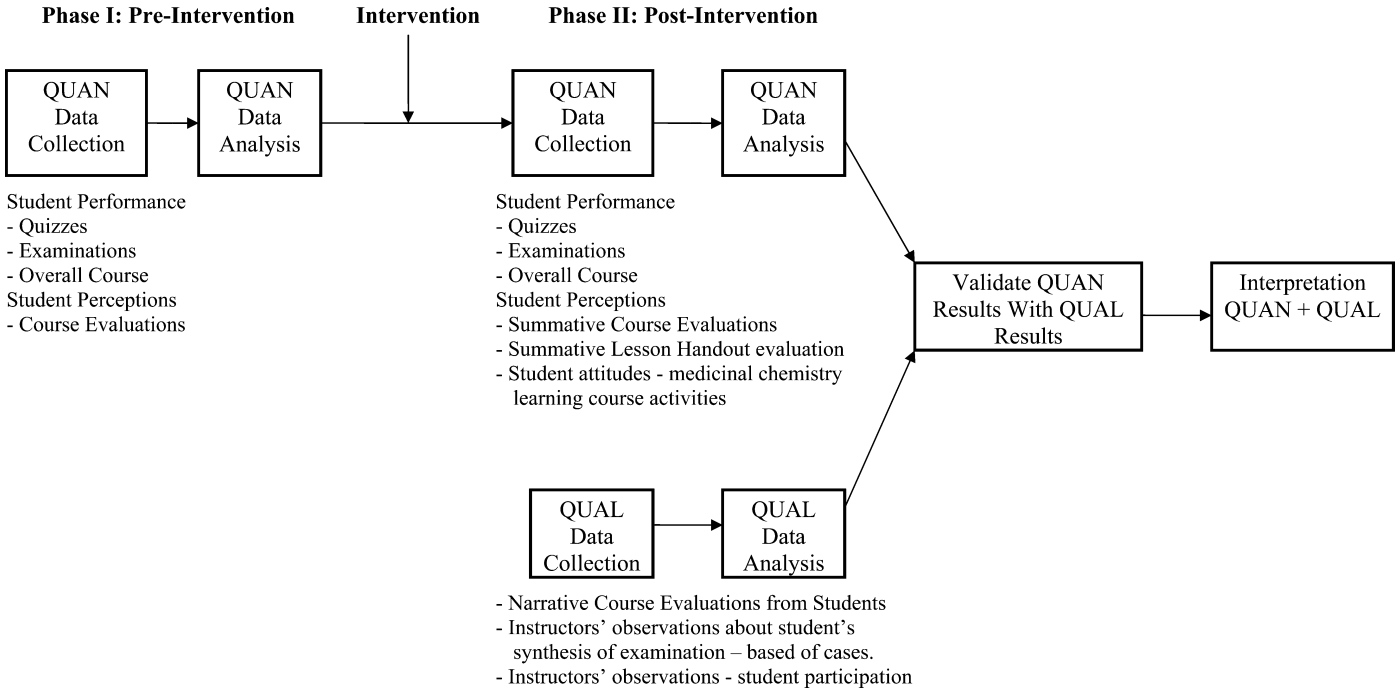

Figure 1. Research Data Collection and Analysis Design

questions, and Table 4). The former were required from all students while the latter was voluntary. The return on the latter was 82% (N = 87/104) and 87% (N = 52/60), for the campus- and distance-students, respectively. All evaluations were conducted electronically in QuestionMark and confidentiality was maintained.

Narrative course evaluations and instructor observations about student participation are analyzed separately and themes developed. These themes are compared to the quantitative findings to identify consistencies and inconsistencies between the quantitative and qualitative findings. The results are evaluated as a whole and interpreted. Table 5 illustrates the relationship of the types and forms of data collected that contribute to assessing the effectiveness of the instructional model.

Description of Study Intervention: Instructional Model

Prior instructional approaches in our course have emphasized cognitive learning objectives.[1,3-5,12-19] This instructional model explicitly integrates cognitive and affective learning objectives. Integration of these 2 learning objective domains was theoretically expected to result in students placing increased value on the use of medicinal chemistry in pharmacy practice and envisioning new ways in which to apply it.

The learning strategies in our course included the components of the Chemical Basis Lesson. Each Chemical Basis lesson consists of 6 discrete elements: (1) learning objectives; (2) the lesson handout; (3) a lesson summary of the most important "take home" messages; (4) a pre-class assessment quiz; (5) instructor-facilitated interactive in-class PowerPoint slide presentation and discussion; and (6) structurally based therapeutic evaluation (SBTE) cases.[3-5] The elements of each lesson transition the students' thinking through a constructive process that provides ample opportunities to recall and integrate previous knowledge, learn and apply new knowledge, establish a logical connection between the science and its clinical relevance, and finally to apply the knowledge to predict clinical activity and clinical outcomes. The design of the content presentation and course activities were mapped against Bloom's taxonomy of cognitive learning and Krathwohl's taxonomy of affective learning.[1-2] Bloom's taxonomy of cognitive learning contains 6 steps to help transition the students to the higher-level thinking required in our course: I. Knowledge; II. Comprehension; III. Application; IV. Analysis; V. Synthesis; and VI. Evaluation. Krathwohl's taxonomy of affective learning consists of 5 levels, ending with the highest level in which student incorporate the knowledge gained into their daily activities: I. Receiving; II. Responding; III. Valuing; IV. Organization; and V. Characterization. A detailed discussion of how our model and course activities help students meet both Bloom's and Krathwohl's learning goals is described in a number of previous manuscript[1,20-21] and table 1 is a summary of how this is accomplished with our lesson handout.

Table 3. Comparison of Summative Course Evaluations From Campus and Distance-Pathway Students in a Medicinal Chemistry Course for the Academic Year 2005-2006

	Percentage of Students Choosing Rating[a]									
	Campus (n = 106)					Distance (n = 60)				
Evaluation Item	**DA**	**SD**	**N**	**SA**	**A**	**DA**	**SD**	**N**	**SA**	**A**
The course content in chemical basis of drug action I is consistent with the syllabus.	0	3	1	35	61	0	0	0	47	53
The course assessments (examinations, quizzes, activities) are consistent with the syllabus.	0	2	2	43	53	0	1	1	40	58
The course prepared me to think like a health care professional.	1	5	9	41	45	0	0	10	41	49
The course included opportunities for me to actively participate in my learning.	1	2	8	46	43	0	2	10	36	52
Lesson handout aided learning	0	1	2	8	89	0	0	0	8	92
Lesson handout is organized	1	8	8	38	45	0	4	4	21	71
Lesson content helped in integrating previous information	0	1	5	31	63	0	2	4	19	75
The transition of content presentation in the handout encouraged critical thinking	0	3	9	24	64	0	0	1	10	89
Lesson content helped in appreciating the clinical relevance of the information	0	1	0	15	84	0	0	0	12	88
The lesson handout encouraged me to be more responsible for my learning	0	2	8	18	72	1	0	2	9	88

[a]Rating scale used: do not agree (DA) = 1; somewhat disagree (SD) = 2; neutral (N) = 3; somewhat agree (SA) = 4; agree (A) = 5

Quality Assurance and Improvement

Since our program has students in 2 pathways, ensuring learning parity for the 2 student cohorts is an explicit expectation in our courses. We have established a quality assurance and improvement process for all aspects of course delivery, lesson handout, learning strategy selection, and student performance to help achieve both learning and performance parity for both student cohorts.[9,19] The modifications needed to maximize performance and learning parity between campus- and distance-students are incorporated into the program and the course after evaluating formative and summative student course evaluations following each course offering. Lesson handouts and course activities are revised and updated each year in order to be current with contemporary literature. They are also revised according to students' comments and suggestions for improvement from previous and current course offerings.

ASSESSMENT

Student Performance Pre- and Postintervention for Campus and Distance Pathway

Table 2 shows that both campus- and distance-students performed better in the fall 2005 and spring of 2006 as compared to their respective cohorts' performance in fall 2004 and spring 2005, respectively ($p < 0.005$). This difference also holds true for student performance dating back to the academic year 2002-03 when the course was taught for the first time to both the campus students and the first distance-class. The class average for those years (fall 2002-spring 2005) was 77.6% and 78.2% for the campus and distance students, respectively. No significant difference is observed between campus and distance pathway student performance during the same semester class. Student performance in the PHA337 course in the fall of 2006 was 83.2% and 82.7% for campus and distance students, respectively. For the spring semester of 2007, the campus and distance students averaged 82.9% and 83.7%, respectively.

Student Perceptions of Effectiveness-Post Intervention

The summative course evaluations from both the campus- and distance-students for the academic year 2005-2006 (Table 3) were positive, with 96% or more of the students indicating that they somewhat agreed or agreed regarding the course content and assessments being consistent with the syllabus, that the course prepared them to think like a health care professional, and that the course provided opportunities to actively participate in their learning. Student perception from the fall of 2006 is highly consistent with the above perceptions from the

Table 4. Pharmacy Students' Perceptions of Course Activities and Attitudes Towards Medicinal Chemistry Course for Academic Year 2005-2006

	Percentage of Students Choosing Rating[a]									
	Campus (n = 106)					Distance (n = 60)				
Evaluation Item	**DA**	**SD**	**N**	**SA**	**A[a]**	**DA**	**SD**	**N**	**SA**	**A[a]**
Pre-assessment quiz:										
is a useful tool to become familiar with the lesson content.	0	4	0	6	90	2	4	5	12	77
made it easier to follow the interactive discussion session in class/on the web.	0	4	5	21	70	2	6	6	25	61
Instructor-Facilitated Interactive in class PowerPoint Presentation:										
was helpful to understand the content.	0	2	8	30	60	1	0	5	14	80
was helpful to transition me to think critically and perform at a higher level.	0	5	10	30	55	4	0	1	20	75
In-class clinical applications were helpful.	0	1	3	19	77	0	2	4	13	81
The SBTE concept:										
was helpful to relate to the content.	3	5	6	16	70	0	0	4	13	83
provided clinical relevance.	2	2	5	14	77	0	0	0	15	85
The active learning activities prepared me to apply the content knowledge to patient-centered therapeutic decision making.	0	1	5	32	62	0	0	4	27	69
The course helped improve clinical reasoning process.	0	0	1	24	75	0	0	0	11	89
Attitude towards Medicinal Chemistry:										
I had a negative attitude towards this course before taking it.	24	22	14	23	17	35	23	17	19	6
My attitude is more positive towards the course after taking it.	0	3	8	32	57	0	2	15	25	58
I attach more worth to medicinal chemistry knowledge after taking this course.	0	1	3	22	74	0	0	3	24	73
Med chem. knowledge can improve patient health and	0	0	3	13	84	0	0	2	13	85

[a]Rating scale used: do not agree (DA) = 1; somewhat disagree (SD) = 2; neutral (N) = 3; somewhat agree (SA) = 4; agree (A) = 5

academic year 2005-2006. In previous years (2002-2004), an average of only 75% of both student cohorts indicated that the course prepared them to think like a health care professional, with an average of 82% indicating that the course provided opportunities to actively participate in their learning.

Table 3 also contains a summary of the student perception of the lesson handout. This input was sought from the students at the end of academic year 2005-2006 when the new structure of the lesson handout was implemented. The majority of the students perceived the lesson handout as aiding student learning, integrating previous information, and transitioning them to think critically (Table 3). From Table 3, and to a larger extent from the narrative students' comments, campus students did not perceive the lesson handout as organized, encouraging critical thinking or encouraging them to be more responsible for their learning compared to the distance-students. A minimum of 83% of campus students responded "somewhat agree" to "agree" compared to 92% for the distance-students for the above evaluation criteria.

Table 4 is a summary of the student perceptions of the different course activities such as the pre-assessment quizzes, interactive in-class PowerPoint slide presentation and discussion session, and the SBTE concept. Based on student perceptions, the activities utilized in the course clearly support the goal of transitioning the students to find the clinical relevance in the information, think at a higher level, and meet specific ABO. Overall, all the students agreed that the course helped in promoting their clinical reasoning process (Bloom's Taxonomy IV: Analysis; Krathwohl's Taxonomy IV and V: Organization and Characterization).[1-2] Students' perceptions were also very positive in fall 2006, with more than 92% of students

Table 5. Types of Data Collected to Determine Effectiveness of Instructional Model for a Medicinal Chemistry Course

Research Phase	Quantitative Data	Qualitative Data Used for Validation
Phase I. Pre-Intervention	Student Performance - Quizzes (Table 2)	
	Student Performance - Examinations (Table 2)	
	Student Performance - Overall Course (Table 2)	
Phase II. Post-Intervention	Student Performance - Quizzes (Table 2)	
	Student Performance - Examinations (Table 2)	
	Student Performance - Overall Course (Table 2)	Instructors' Observations About Student's Synthesis of Examination – Based of cases.
	Summative Course Evaluation (Table 3)	Narrative Course Evaluation from students
	Summative Lesson Handout Evaluation (Table 3)	
	Student Perceptions - Course Activities (Table 4)	Qualitative Data about Students' Attitude Towards Medicinal Chemistry Learning
	Student Attitudes - Medicinal Chemistry Learning (Table 4)	Instructors' Observations - Student Participation

indicating they somewhat agreed or agreed on all questions criteria for course activities. This is in contradiction to the previous years (fall 2002-spring 2005) comments by a good percentage of the students (20%-30%) related to lack of the clinical relevance of the knowledge and that "we will never use this in practice."

Narrative student comments from 2002-2004 were indicative of a negative attitude towards the discipline, with several students' comments questioning the need for the discipline, as part of the curriculum. In 2005-2006, students' responses to the question about the value of the course were very positive. Students, in general, emphasized the clinical knowledge gained, integration of knowledge from previous courses, improved knowledge gained in pharmacology, and the importance of chemistry to drug decision making. This is also reflected in a positive change in attitude that students shared following the completion of the fall semester 2005 (Table 4) and that almost all the students responded that they attach more worth to the medicinal chemistry knowledge, that the knowledge can improve patient health and outcome, and that they will use this knowledge in therapeutics (Table 4).

There were 5 examinations in the academic year 2005-2006 over content that utilized the instructional model, with 4 examinations containing 35%-45% essay questions. The average performance for the 4 examinations with essay questions for campus- and distance-students was 81.6% and 80.4%, respectively. Examination questions were mainly application questions related to several patient scenarios. The essay questions are based on SBTE cases with a patient presenting with several complicating factors and the students were challenged to identify the best therapy for the patient based on the structure of the potential drug choices. The questions require the students to integrate information, make therapeutic decisions, identify potential drug-drug interactions and drug-food interactions, and counsel patients. Campus- and distance-students performed at the 85% and 83% level, respectively, on the essay part. In addition to the overall good performance on the examinations, several students provided what would be considered an answer key for some of the questions. Finally, one of the challenges given to students was to provide SBTE case scenarios that are educational and innovative. Several students submitted case scenarios and 4 were utilized on different examinations. Some aspects of questions submitted were also utilized on some multiple-answer and multiple-choice questions.

General themes were observed from the students' comments related to the course. These were consistent between campus and distance students for the academic year 2005-2006 and the fall of the academic year 2006-2007. The major themes identified from the students comments were: (1) organized, structured, and interactive, (2) integration of knowledge, (3) application of knowledge, and (4) relevance of the science to pharmacy practice. These general themes are consistent with the quantitative findings.

The current student course evaluations are the most positive since the course was taught in 1994 and they correspond well with the course goals set forth by using the instructional model. However, despite the consistency in the 2 student cohorts' perceptions of the course, campus students appeared to emphasize more the enthusiasm shown by the instructor in teaching the course and the active learning that made the course more clinically relevant. Distance-students were more impressed with the course organization, delivery, and the interactive nature of the course. As a distance student said about the lecture

audio: "I found myself yelling answers to the computer screen for the questions posed in class."

Other activities that were not addressed in the formal evaluation but addressed by student comments are the *Who Wants to be a Med. Chem. Millionaire*? (MCM) learning game[21] and the practice examinations. In general, students shared the importance of the MCM in helping them review for the examination and the practice examination for helping them with their readiness before the examination.

Students shared stories about how they were checking package inserts for structures at work to decipher clinical information and how they believed that the knowledge was important for patient safety (Bloom's Taxonomy VI: Evaluation; Krathwohl's Taxonomy IV and V: Organization and Characterization). This is expressed by the following 2 students' comments:

"When I received lower grades on certain exams, I was afraid that I missed something very valuable to my future practice" and "It gives me another angle at which pharmacist can look to make the most relevant clinical decision."

This perception is further emphasized by the students' responses to the question about the use of this knowledge. Many stated that they already used the knowledge as interns, to help friends and family with drug questions, and to understand pharmacology better, and that they would use the knowledge to help them in therapeutics (Krathwohl's Taxonomy IV and V: Organization and Characterization).[1-2] Again, this is in drastic contrast to previous attitudes shared by the students regarding the course lacking clinical relevance or any reference to utilizing the knowledge gained in therapeutics or in practice. Examples of some student responses from 2005 and 2006 are included below:

"Answer patient and physician questions about drug mechanisms, adverse effects, and interactions, based on the bottom line, the chemical structure. Also, I will have the tools to evaluate new drugs that hit the market down the road."

"More valuable than I could ever imagined. I feel like a real pharmacist now. I feel like I have a deeper understanding of what drugs actually do and why side effects occur."

"I was one of those who had the attitude 'why do we have to take this class and learn a whole bunch of structures?' However, I can now see the clinical importance of knowing the drugs from its very core, which is its structure."

"Even though I didn't get an 'A,' I believe I took a great deal from your material that I will be able to use in the future as a pharmacist."

"Medicinal Chemistry is a pharmacist trade."

After introduction of the instructional model, student willingness to participate was more evident and the quality of their questions and answers was striking. This was coupled with a very positive attitude towards the learning process and course activities with the students. Several students were willing to come in front of the class to answer questions and lead their classmates in discussions regarding course content and clinical applications. This was also extended to the voluntary recitation sessions with more student participation and active contribution to the interactive discussion. Distance-students also were highly motivated and were actively involved in the discussion folders, sending e-mails regarding the content, and participating in conferences with the instructor. Several distance-pathway students took the time to answer questions from their peers, from section VI in the lesson handout, and/or from the practice examinations. Many posted questions and answers in the discussion folders and via the class e-mail distribution list for discussion and validation of their knowledge. We attribute this engagement in part to the incorporation of the affective learning objectives into the instructional delivery model. This qualitative data is consistent with the student perceptions of course activities in Table 4.

DISCUSSION

The shift in paradigm in pharmacy practice and education to graduate pharmacists that are patient centered presents a variety of logistical and pedagogical challenges to all faculty members. This is certainly true for science faculty members including medicinal chemists. Some have embraced those challenges and have made it easier for others to follow and learn from their contributions. [12-18] Over the last 12 years, we have introduced the concept of SBTE to bring relevance to the teaching of medicinal chemistry, challenge students to integrate previous knowledge, meet ACPE guidelines and standards, and support ABO for graduates set forth by our school and accrediting body.[1,3-5] However, despite the extensive effort put forth to achieve the above mentioned goals over the last 12 years, they remained elusive to a certain extent. Part of the problem was related not only to the effort put forth but arose from many of the factors discussed in the introduction as affecting student learning in medicinal chemistry. Our instructional model attempted to address many of the above factors by providing a lesson handout package that was complete, challenging the students to recall and integrate previous knowledge with new knowledge in order to see the "big picture," instilling value and worth to the chemistry knowledge, showing how to apply the knowledge by utilizing different techniques, clearly

summarizing and explaining clinical decisions that can be explained by the structure, transitioning the students to develop clinical thinking skills, challenging students to think at a higher level, challenging students to be responsible for their learning, working closely with the students, acting as an advocate for student success, seeking mastery of course content, and making learning fun.

Our instructional model appears to have accomplished many of the above requirements. This is certainly an exhilarating feeling after all these years. What is also encouraging is the success of the instructional model for both campus- and distance-students based on the data for learning and the evaluative data. The model forced us to identify specific tools for achieving requirements for course goals. The tools we utilized, including the specific incorporation of cognitive and affective learning principles, were very helpful. More importantly, our tools can now be easily adjusted according to any change in the requirements based on course objectives and ABO, and the school's, the accrediting body's, and professional practice outcomes.

Although the evidence for student learning and the evaluative data are very positive, there are still issues and shortcomings that should be addressed:

Lesson Handout. Although the lesson handout appears to be effective, the clarity, flow, and overall organization for all the lessons are a must for our instructional model to be consistently effective. Therefore, we will consistently seek the help of other faculty members to review the lessons and suggest specific changes. Also, input from students who have taken the course on ways to enhance the clarity, flow, and organization of the lesson handout has been very valuable and will be sought for future course offerings. In fact, comments and suggestions from both campus and distance-pathway students were used to modify the handouts completed for the PHA447 spring 2006 course sequence and PHA337 for academic year 2006-2007. In addition, all the handouts were reviewed by 3 fourth-professional year APPE students and major modifications related to organizational flow, ease of readability suggestions, addition of relevant links to the course web site and incorporation of new clinical examples were made based on their input.

Pre-assessment Quizzes. In general, student performance on the pre-assessment quizzes has always been better (90% and above) than on the scheduled examinations (80%). Since the pre-assessment quizzes are done before the discussion in class, the level of the questions asked and clarity of the questions is very important. Therefore, care has to be taken in asking questions in Bloom's taxonomy level I. Also, although students are told that they can work in groups, stressing the pre-assessment quiz as a group effort may be helpful. In addition, although better clarity, flow, and organization of the notes will help the students when taking the quiz, care in the wording of the questions should be exercised and questions again can be reviewed by other faculty members or students who took the course. Further, based on some students' comments, we are considering adding 1 or 2 questions to the quizzes as the semester progresses to challenge the students at a higher level, similar to what they would expect on the scheduled examinations. Finally, distance students response to the impact of the pre-assessment quiz is lower (89% vs. 96% for campus). This may indicate that the distance-pathway students depend more on the practical and relevant activities to better relate, understand, and apply the content. It may also explain their lower average scores on the quiz over the past 5 years (Table 2) compared to the campus students. This despite efforts by the faculty members over the last 4 years to emphasize to all students the importance of taking the pre-assessment quiz activity more seriously.[19]

Instructor-Facilitated Interactive In-Class PowerPoint Slide Presentation. The PowerPoint slides contain many active-learning exercises. However, in the fall of 2005, the answers were not included and the students were challenged in the class for the answers. We have since included the answers to help them to transition better to a higher level of thinking by providing this feedback on the slides. In addition, more clinical exercises and SBTE case studies are included on the slides to encourage participation and to provide the students more opportunities to have a hands-on experience in tackling this hallmark activity for the course. A challenge that we always keep in mind is to what extent we include clinical application at the expense of depth of knowledge needed to understand the chemistry behind drug action. In fact, we still have comments from some students that we are diluting the chemistry knowledge, making us work harder to better balance the content.

On-campus class participation is one of the issues that we continue to struggle with. This is an important component for the overall success of our instructional model. In the fall of the academic year 2006-2007, our school invested in the Personal Response System (PRS) through which students can provide instant response to questions authored in PowerPoint. This is specific to campus students; however, distance students will also benefit since they may have similar content deficiencies that will be apparent from the campus student's responses to key concept questions. In effect, we are completing an extensive study for both campus and distance students to evaluate the impact of the PRS, as part of the in-class PowerPoint slide presentation, on student learning,

interactivity, performance and attentiveness for spring semester 2007.

It is interesting that the distance-students rated the impact of the interactive in-class PowerPoint presentation and the SBTE concept higher than the campus students. This may be related to the class meeting at 8:00 AM. Several campus students commented on how hard it is to become interactive at that time, while distance students listen to the in-class session according to their own schedule for that day. Currently, we are not considering shifting the course to later in the day.

Campus vs. distance-students. Although this is unique to our program, especially with the asynchronous nature of our distance pathway, modifications to the instructional methods used to enhance student learning and performance for both student cohorts is essential. Course activities to meet specific course objectives that may lend themselves to one pathway or another should always be pursued and evaluated. In addition, a quality improvement process has to be put in place to consistently evaluate the effectiveness of the instructional model for both student cohorts.

For the last 2 academic years and since the introduction of the instructional model (fall 2005), both campus and distance students have performed at a higher level compared to prior years (fall 2002-spring 2005). We did not control for student characteristics that may influence overall performances independent of this intervention. However, this may be minimized by our school admission criteria, which select for certain student characteristics. The absence/lack of differences in performance between campus and distance-pathway students also suggests there was no difference in the impact of the instructional model between pathways.

Instructor Evaluation. Instructor effectiveness and attitude in teaching a course is an essential component for the success of the students, but it is extremely critical in a science course that is part of a clinical degree such as the doctor of pharmacy. Over the years, we have struggled to find a balance between how far we challenge the students to meet course outcomes including critical thinking and how much we help them along the way to achieve these outcomes. To the extent that we were successful in the past, various levels of satisfaction or lack of satisfaction with the instructor and subsequently the course materialized. In the academic year 2005-2006, student perception of the instructor as measured by the department instructor evaluation form was the most positive since he started teaching the course in 1994, with ≥90% of both student cohorts positively rating the instructor on aspects related to effective teaching methods, promoting learning, promoting mutual respect, interest in student success, and demonstrating professionalism. The proportion of students responding positively is 20%-30% higher than previous semesters, which reflects the attempt by the instructor to utilize the instructional model to better transition the students to become more responsible for their learning rather than having high expectations from the students early on in the semester.

Study Design. As basic scientists, it is important to seek colleagues with expertise in instructional and educational research. Although we may be including certain aspects of the critical components of what we do as we structure our course, we may be losing on several other components. The introduction of Bloom's Cognitive Taxonomy of learning and Krathwohl's Affective Taxonomy of Learning[1-2] to the extent we did and evaluated for our course was very useful in developing course strategy, the lesson handout, and all the other components of the instructional model. This certainly helped us to meet the cognitive goals for the students and to transition them from their comfort zone of attempting to recall and define (Bloom's Taxonomy I: Knowledge) and to apply, analyze, and synthesize (Taxonomy III-V: Application, Analysis and Synthesis). To meet the affective goals, strategies were put in place to positively impact the 5 levels of the affective domain and in the process make the students more vested in the knowledge gained and its value for and impact on their career goal as future pharmacists.

Another limitation to this work is the recognition that perceptions about instructors can bias student responses to perceptions about a course. The influence of instructor performance was minimized by explicitly soliciting separate feedback about the instructor's performance and the course experiences from the students.

Finally, the input about students' attitude towards medicinal chemistry learning was sought for the first time in the academic year 2005-2006. In retrospect, it would have been helpful to gauge that for students in previous years. However, the use of narrative comments from previous years validated the finding that a positive student attitude was observed in 2005-2006 compared to prior years (2002-2004).

SUMMARY

The instructional model described above and utilized as a comprehensive strategy in our courses for the first time in the academic year 2005-2006 has provided the primary instructor and both campus and distance-pathway students with a rewarding interactive learning experience. Students' overall attitudes in class, outside class, and at a distance site have been more positive than in past years. It is also encouraging that students' performance

and attitudes were positive in the course sequence in the spring of 2006 and the fall of academic year 2006-07.

As programs shift to an outcome-based curriculum, affective and cognitive taxonomy strategies are being incorporated more as part of educating pharmacy students. A correlation between the course itself, the course activities and philosophy, and identified cognitive taxonomy for learning is helpful for both the faculty member and the students. In addition, the emphasis on bringing our students to a higher level of thinking is certainly served by a better understanding of Bloom's Taxonomy to prepare lesson plans that will transition the students to higher levels of thinking. Further, understanding student attitudes towards the course and developing strategies to improve and enhance the attitude of the students towards a specific course or the curriculum in general is a must to instill and promote the appropriate knowledge, skills, and attitudes in our future graduates.

REFERENCES

1. Alsharif NZ, Galt KA, Mehanna A, Chapman R, Ogunbandeniyi AM. Instructional Model to teach clinically relevant medicinal chemistry. *Am J Pharm Educ.* 2006;70(4), Article 91.
2. Krathwohl DR, Bloom BS, Masia BB. Taxonomy of Educational Objectives: book 2; affective domain. New York, Longman, 1964.
3. Alsharif NZ, Theesen KA, Roche VF. Structurally-based therapeutic evaluation: A therapeutic and practical approach to teaching medicinal chemistry. *Am J Pharm Educ.* 1997;61:55-60.
4. Alsharif NZ, Roche VF, Destache C. Teaching medicinal chemistry to meet outcome objectives for pharmacy graduates. *Am J Pharm Educ.* 1999;63:34-40.
5. Alsharif NZ, Shara M, Roche VF. Structurally-based therapeutic evaluation (SBTE): An opportunity for curriculum integration and interdisciplinary teaching. *Am J Pharm Educ.* 2001;65:314-23.
6. Galt KA, Barr CC, Young W, Royeen C. Are Doctor of Pharmacy students prepared for high technology learning? *Pharmacy Education – an international journal for pharmacy education* 2002;1:145-57.
7. Galt KA, Markert R. Description and assessment of an early curriculum to teach pharmacy students caring behaviors. *Pharmacy Education – an international journal for pharmacy education* 2002;2:31-5.
8. Galt KA. Developing Training Materials and Programs: Case-Based Teaching. Chapter 11, in Staff Development for Pharmacy Practice, American Society of Health System Pharmacists, Bethesda, MD, 20814, 2000. (5 Editorial Reviewers; pp. 8).
9. Malone PM, Glynn GF, Stohs SJ. The development and structure if a web-based entry level doctor of pharmacy pathway at Creighton University Medical Center. *Am J Pharm Educ.* 2004;68(2): Article 46.
10. Creswell JW. Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research (2nd ed). Columbus, Ohio: Pearson Merrill Prentice Hall.
11. Creswell JW, Plano-Clark VL. (2007) Designing and Conducting Mixed Methods Research. Thousand Oaks, California: Sage Publications; 2007.
12. Roche VF. Utilizing chemical knowledge in rational therapeutic decision-making. *Am J Pharm Educ.* 1985;49:154-7.
13. Roche VF, Zito SW. Computerized medicinal chemistry case studies. *Am J Pharm Educ.* 1997;61:447-52.
14. Harrold MW. Importance of functional group chemistry in the drug selection process: case study. *Am J Pharm Educ.* 1998;62:25-30.
15. Dimmock JR. Problem solving learning: applications in medicinal chemistry. *Am J Pharm Educ.* 2000;64:44-9.
16. Abate MA, Meyer-Stout PJ, Stamatakis MK, Gannett PM, Nardi AH. Development and evaluation of computerized problem-based learning cases emphasizing basic sciences concepts. *Am J Pharm Educ.* 2000;64:74-82.
17. Mehanna AS. NSAIDs: Chemistry and Pharmacological Actions. *Am J Pharm Educ.* 2003;67:1-7.
18. Webster AA, Riggs RM. A quantitative assessment of a medicinal chemistry problem-based learning sequence. *Am J Pharm Educ.* 2005;70(4), Article 89.
19. Alsharif NZ, Victoria RF, Ogunbadeniyi AM, Chapman R, Bramble JD. Evaluation of Performance and Learning Parity Between Campus-based and web-based Medicinal Chemistry Courses. *Am J Pharm Educ.* 2005;69(2), Article 33.
20. Roche VF, Alsharif NZ. Stayin' Alive: Advancing medicinal chemistry by enhancing student responsibility for learning. *Am J Pharm Educ.* 2002;66:319-28.
21. Roche VF, Alsharif NA, Ogunbadeniyi AM. Reinforcing the Relevance of Medicinal Chemistry to the Practice of Pharmacy through the *Who Wants to Be a Med. Chem. Millionaire* Learning Game. *Am J Pharm Educ.* 2004;68, Article 116.