Staying Alive. Advancing Medicinal Chemistry by Enhancing Student Responsibility for Learning[1]

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Our Innovations in Teaching portfolio describes the most recent of our strategies to increase student interest in medicinal chemistry and in taking responsibility for learning. Course content was updated, rewritten and packaged in conversational packets containing a detailed lesson handout, learning objectives, lesson summary, and case study problems. Students read the handout packet and complete a comprehensive quiz over the material no later than 24 hours prior to class. Quiz questions are provided in the lesson packet to guide learning and the final quiz average counts for ten percent of the final grade, serving as the reward for preparedness. Lecturing over handout materials has been abandoned in favor of interactive discussion on areas of difficulty, active learning exercises and group presentations designed to stimulate analytical thinking and sharpen clinical problem solving skills. Students have been much better prepared for class discussion than in previous years, and responded positively to the quizzes and the interactive classroom. Performance, as measured by exam and final grades, did not suffer. This approach shows that small changes in content delivery, and the offering of relatively small academic rewards, can stimulate students to preparedness and enliven the classroom by allowing time for activities which foster higher level thinking and reinforce clinical relevance. In addition, interest in the subject matter is increased when classroom activities are more meaningful to the learners. Finally, professionalism will be optimized when the entire academic culture fosters student responsibility for learning.

INTRODUCTION

With the continued expansion of the professional curriculum into the clinical arena, some faculty who instruct in medicinal chemistry have expressed concern that student interest and appreciation for the knowledge they have to impart will diminish accordingly. While totally convinced of the importance of their discipline to the practice of pharmacy, medicinal chemists around the country are taking steps to keep their discipline alive by participating in multidisciplinary integrated courses, bringing case studies and other active learning strategies into the classroom, and proactively offering to participate in the classes of faculty colleagues by participating in class discussions and other learning activities(1). This is all well and good, but some of these strategies are dependent upon the comprehensive curricular structure and/or the interest and willingness of colleagues to engage in collaborative teaching. Therefore, as important as they are, they must be coupled with interest-enhancing strategies that chemistry faculty can implement independently.

Demonstrating the professional relevance of chemistry to pharmacy students is now a major instructional objective of most medicinal chemistry faculty. Fortunately, this is not difficult to do if you can get students to take responsibility for truly learning this content, as we think the relevance is more than obvious. For, as we like to tell our students, if they believe that drugs are chemicals, and that pharmacists are drug experts, then simple logic says they must acknowledge that pharmacists are the chemical experts of the health care team.

In our courses, we have utilized a wide variety of active learning strategies to reinforce clinical relevance of our discipline. While these techniques certainly enhanced student interest in the chemical sciences, we continued to struggle with how to motivate students to take personal responsibility for their learning (and the learning of their classmates) and how to engage them in the course content independently, responsibly and actively. In this manuscript we describe our current approach to promoting student responsibility for class preparedness, which, in turn, advances our goal for an active interested and professionally engaged classroom where students truly learn.

BACKGROUND

Students come to the Chemical Basis of Drug Action courses (PHA 337 and PHA 447) having had formal coursework in biochemistry, physiology, pathology, anatomy, pharmaceutics and communication skills. Concurrent with the Chemical Basis courses, students enroll in a 10 credit hour sequence in Pharmacology (five credits in both fall and spring semesters) and a four hour course in microbiology (fall). While formal instruction in pharmacotherapeutics awaits them in their third professional year, Chemical Basis requires students to apply chemical thinking to patient-specific therapeutic problems, and helps them realize how their unique knowledge of chemistry will assist them in being rational, scientifically based practitioners.

Our classroom approach hybridizes techniques reported in

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[1]**Manuscript** based on the portfolio submitted to the 2002 Council of Faculties Innovations in Teaching Competition.

Am. J. Pharm, Educ, 66, 319-328(2002); received 7/1/02; accepted 7/17/02.

the literature that reward students for first exposure to content outside of the classroom. The Just-in-Time Teaching (JiTT) strategy was first described by Novak, *et al.(2),* and was expanded upon by Walvoord and colleagues at Notre Dame(3). The JiTT strategy meshes web-facilitated delivery of course content and communication with intimate, face-to-face interactions designed to respond to students' learning needs. Problem-solving skills, critical thinking skills, communication skills, motivation and confidence can all be enhanced through the use of this technique. According to Novak and colleagues, JiTT is suitable for all type of course work, but the most beneficial to courses perceived as of secondary importance to the learners. Walvoord advocates selecting teaching/learning strategies closely tied to major pedagogical goals, and employing technology thoughtfully to assist in the achievement of those goals.

Objectives. The strategies described by Novak and Walvoord were focused on the Chemical Basis course goals and objectives[2]. A major goal is to have our students come to class prepared for interactive discussion and active learning, and to lessen student dependence on lecture as a means to acquire knowledge. This course goal compliments our School's ability-based outcome that affirms our intent to graduate pharmacists who "embody the responsibilities of pharmaceutical care." A secondary goal is for students, having experienced the beauty, elegance and practical relevance of chemistry first hand through their own independent study, to take seriously their unique role as the chemists of the health care team. Course objectives in support of this goal that are specifically identified in the course syllabus include *(i)* "gain an appreciation of how knowledge of drug chemistry will allow the prediction of the pharmacological and therapeutic activities of new drugs encountered in future practice." and *(ii)* "grow professionally by gaining competence, as well as confidence in one's knowledge and abilities." We have previously described some of the techniques we use to enhance the practical relevance of medicinal chemistry (4-9) but now focus on how those techniques are made meaningful by stimulating and rewarding student responsibility for learning.

WEB-BASED MATERIALS

While our current courses are not web-based, they are web-facilitated, and we have found the technology extremely helpful in allowing us to expediently deliver content, share resources, solicit feedback, and communicate with students. The components of these web sites that are most pertinent to this manuscript are the entire "Professionalism" section (which includes a statement on The Importance of Professionalism, the Oath of a Pharmacist, and our School's Pledge of a Healthcare Professional, Honor Code and Plagiarism documents), the Lesson Handout, Lesson Objectives and Lesson Summary documents, and the Pre-Class Assessment Quizzes. Each is described in more detail below and available for full review on the course web sites[2].

Professionalism (Web Site Section II). We have a keen interest in promoting professionalism, and have made this topic a visible component of our course web sites. From day one, verbally, in writing and through our actions, we attempt to reinforce the message that responsibility is a necessary companion to competence in the provision of pharmaceutical care. As health professions students, their professional responsibility is to master the body of knowledge that is pharmacy to the best of their ability, and to take an active role in the learning process. We also include the Oath of a Pharmacist and our School's Pledge of a Health Care Professional on our web sites to put a real-life perspective on why taking responsibility for learning in the classroom is so critical. The remaining offerings in the Professionalism Section of the web sites support and expand upon the ideals articulated in these documents.

The Chemical Basis Lesson (Web Site Section VI). The heart of our innovation is the comprehensive "Chemical Basis Lesson," which is a self-contained packet of information and learning aids designed to thoroughly acquaint students with a class of therapeutic molecules. Students are held responsible for reading the entire lesson packet prior to the class period in which the content will be discussed and, because suitable rewards have been built into the class structure for compliance, they are actually doing it. We discuss the reward system under the section of this manuscript that describes the pre-class assessment quizzes. Readers are encouraged to click on any of the lessons linked on the PHA 337 and 447 web pages that interest them to see how course information is packaged and communicated.

While the two instructors use different vehicles to get the information across to students (Word documents and PowerPoint presentations), the elements of the lesson remain the same for each. Students have adjusted relatively easily to the different preferred forms of content communication (documented in the formative and summative evaluation statements), perhaps in part because of our commitment to active facilitation of learning in the construction of the lessons, our planned in-class activities which explain and reinforce lesson content, and our willingness to listen and respond to students' comments.

Each Chemical Basis lesson consists of five discrete elements that will be described separately. The lesson elements include: *(i)* learning objectives; *(ii)* the lesson handout; *(iii)* a lesson summary of the most important "take home" messages; (*iv*) a pre-class assessment quiz; and (*v*) one or two case study or SBTE problems.

Learning Objectives. The learning objectives provided for each lesson are concise, performance-based statements that are designed to focus students' study and help them understand the level of content mastery expected of them. Students are instructed to review the objectives prior to reading the lesson handout and the assigned pages in the text, and are encouraged to let them serve as their roadmap for comprehensive learning.

Lesson Handout. Each lesson handout is thoroughly revised and updated each year. We place a strong emphasis on providing accurate descriptions of the receptor target and mechanisms of ligand binding, and on identifying binding residues and their conformational characteristics where they are known. We also provide clinically relevant, literature-based information

[2]**Readers** are invited to visit our course web sites to review any and atl information of interest. The address for accessing both the PHA 337 (fall 2001) and PHA 447 (spring, 2002) courses is http://pharmacy.creighton.edu/innovations. Please enter the word innovations as both your username and your password when prompted through a dialog box. If you are provided with a three-line dialog box, type ad as the domain. If you arc provided with a two-line dialog box, modify your user name to add innovation. By clicking on the PHA 337 and PHA 447 links, you will be taken to a Table of Contents page that permits navigation throughout the entire site.

that can be directly linked back to drug structure. Significant effort has been expended to make the lesson handout descriptive, conversational and reinforcing, so that it is readily digested and enjoyable to read. Analogies which repeatedly have been found to enhance understanding of complex concepts (and which used to be communicated verbally in lecture) are now embedded in the handout, as are graphics, figures and diagrams. Color-enhanced structures, schemes and figures allow students to better follow metabolic and decomposition reaction mechanisms, and consolidate SAR *(e.g.,* Antiulcer Chemistry and Antidepressants lessons on the PHA 337 web site). Since the handouts are provided electronically, we are beginning to embed links to journal articles, web pages and/or published receptor binding diagrams in the lessons *(e.g.,* Antihyperlipidemics on the PHA 337 site, Penicillins on the PHA 447 site). Next year, we would like to add animation to help students visualize difficult concepts such as resonance, induction, metabolism and in vitro decomposition.

During the fall semester, when Chemical Basis is allotted three credit hours, each drug topic is divided into two segments covering the chemistry and important SAR, and the marketed therapeutic agents and clinical considerations. A separate lesson handout was most commonly developed for each segment. In the spring, when the course drops to two credit hours, drug topics are usually covered in one lesson handout *(e.g.,* NSAIDs, Opioid Agonists and Antagonists on the PHA 447 web site).

Lesson Summary. The summary statements, entitled "Med. Chem. To Go," are the major "take home" messages of the lesson handout. They compliment the learning objectives, but are more closely related to the specific information contained in the lesson handout. This component of the lesson package was initiated midway through the fall 2001 semester in response to a suggestion made in the PHA 337 formative course evaluation that followed the first examination, and it has been well-received.

Pre-Class Assessment Quiz. This component of the lesson package rewards students for preparedness. After reading the on-line handout and assigned pages from the textbook, students take a 15-20 question quiz that assesses how well they have mastered the learning objectives for that lesson. The pre-class assessment quiz is taken on-line, using the Blackboard™ course environment, and must be submitted electronically no later than 24 hours prior to the class period in which the lesson will be discussed. The due dates and times for each quiz are provided on the web site Table of Contents so students can easily keep track of when quizzes must be completed. Assessment quizzes are provided for all lessons.

The pre-class assessment quiz is designed to be a learning tool rather than purely an assessment instrument. Questions address key chemical concepts, knowledge of SAR and the application of that SAR to document an understanding of clinical relevance. A total of 16 quizzes were required of students in the fall 2001 semester. A copy of the quiz is provided to students along with the lesson handout, and they are encouraged to use it to guide their study of the lesson. The quiz is open book, and students may refer to the lesson handout and/or their text while they are taking the quiz. They are encouraged to initially work through the quiz in groups, so that potential answers to quiz questions can be discussed and debated, and learning can be reinforced. While group work is permitted in preparing for the on-line quiz, each student must complete and submit her/his own quiz electronically to receive credit toward the course grade. At the end of each semester, the two lowest quiz scores are dropped before the quiz average is calculated. The final quiz average counts for ten percent of each student's course grade. The aggregate performance of the class on each quiz is posted on the course web sites[2] as soon as the data are harvested so that all can see how the class, as a whole, performed.

The on-line pre-class assessment quizzes incorporate extensive feedback for both right and wrong answers. When students complete and submit their quizzes, they receive immediate question-by-question feedback on their performance, which they can print out or copy and save to their computer. One disadvantage of providing immediate and downloadable feedback is that students could conceivably take advantage of this learning opportunity and use the performance results of other students to submit their own "perfect" quiz. However, we currently believe that the learning advantages of this approach significantly outweigh the risk of undesirable behavior. Making appropriate choices about one's professional behavior is a hallmark of responsibility, and most students appear to be making wise choices when it comes to the pre-class assessment quizzes.

IN-CLASS ACTIVITIES

Since students are now coming to class having read the entire lesson handout and taken a quiz over the major learning issues, we no longer feel compelled to walk them, paragraph by paragraph, through the lesson. Rather, we use our class time to engage in activities that allow students to master application and integration skills.

Interactive Discussion. We begin each class by reviewing the aggregate performance on the lesson quiz that has been posted on the web site, discussing areas where performance was less than stellar and fielding questions from the class. There are often a few questions from students about why certain quiz answers that they selected were incorrect, and we allow classmates the chance to offer explanations to these questions before we summarize the main chemical issues. Approximately one quarter of our class time is devoted to this activity.

From almost 30 years of collective teaching experience, we know the major areas of difficulty and misunderstanding in our courses, and we come prepared with an in-class presentation that reinforces and addresses many of these learning issues. Depending on the complexity of the topic, approximately one-third to one-half of our class time is devoted to this activity. We use PowerPoint as the vehicle for communicating this component of the course content, and the slides used in each class are posted to the web site under the appropriate lesson[2].

Structure Challenge. As part of our active learning emphasis, we always include a structure challenge as part of our in-class activity. This is our main vehicle for helping students sharpen SAR application skills by predicting pharmacological actions and therapeutic utility of various drug structures, and is exemplified in Appendix A. The structure challenge gets students ready to do the critical thinking they need to do to solve the case study and SBTE problems that are a part of every lesson. To promote an interactive classroom, we employ the think-pairshare technique to get students discussing their answers to

the structure challenge with one another to build both competence and confidence. Some students speak up frequently but the class, as a whole, is not as vocal as we would like. None-the-less, the murmuring that we can distinguish when we ask for their responses to the structure challenge questions is almost always on target, and there will always be some brave soul who will clearly offer and justify his or her answers. On their more animated days, students have agreed to come to the front of the class to discuss the chemistry that is pertinent to the challenge, and/or draw key reactions or structures on the whiteboard. The structure challenge can be incorporated into the structured faculty-facilitated review of important concepts, or can be tackled by student groups working independently, as described below.

Active Learning Exercises. We regularly use class time to break students up into groups to work on application exercises similar to those that they will encounter on examinations, and/or which address learning difficulties made apparent by performance on the assessment quiz. While students are working, we walk around the class to "eavesdrop" on the discussions taking place, clarify the assignment expectations, answer questions and react to work completed. Unlike the pre-assigned student groups formed for presentations and group homework assignments, we have allowed these in-class groups to form spontaneously. However, we are currently considering requiring students to do their in-class work in their pre-assigned groups (see below), at least some of the time, to build team rapport and effectiveness.

The learning activities and exercises students do in class are not graded, but can be handed in for assessment and feedback. This gives students a chance to see if they are gaining understanding so as to be successful on examinations. It also gives faculty a chance to see where misconceptions and misunderstandings exist so that intervention (in the form of an email or mini-lecture during the next class period) can be accomplished in time for students to reap learning and performance rewards. Keys to the exercises are posted on the web page within a week after they are used in class. This time period is planned, as it gives students time to continue to work on the exercise outside of class before the "right answers" are known to all. On occasion, a group homework exercise is assigned and graded. We make greater use of this learning tool in the three credit hour fall semester course (PHA 337), and are finding that there are sufficient on-going learning opportunities in the two credit hour spring course (PHA 447) without adding the extra burden of graded homework.

Case Study and SBTE Presentations. The in-class presentation of a case study(4-6) or structurally-based therapeutic evaluation(7-9) problem by pre-assigned student groups is a required component of the Chemical Basis courses. Each group of four students is responsible for presenting one case study or SBTE problem to the class during the course of the academic year, but all students are asked to review the case prior to the formal in-class presentation. The case presentation serves as the capstone activity for each lesson, and requires a critical analysis of drug chemistry that is then explicitly related to a thoughtful evaluation of patient needs. Students must identify the major clinical issues and prioritize the patient specific factors in each case, and conduct a thorough and mechanistic SAR analysis of all therapeutic alternatives provided. Based on these evaluations, a therapeutic decision is made and justified, and their patient is counseled.

The case study and SBTE problems require students to apply chemical concepts and principles to real-world pharmacy practice, and demonstrate how chemical understanding can help them be more scientific practitioners. Case studies or SBTE sample problems are provided under many of the lessons on the course web sites[2]. Explicit criteria for performance evaluation have been developed and made available to students on the web sites, and student presentations are videotaped so that they can conduct peer-self evaluations. Students earn up to five course points for their in-class group presentation, and points are not awarded until the peer-self evaluations have been completed.

Student groups can elect to give a professional presentation, or add dramatic flare in a more artistically creative performance (for example, this year, we've been treated to a diuretics presentation entitled ***Win*** *Dr. Alsharif's Money* and an NSAIDs-related spoof of the Steve Irwin's *Crocodile Hunter).* Each presentation is approximately 20-25 minutes in length. The case and SBTE problems are also linked on the course web sites under the specific lessons[2]. While the case questions are focused and abbreviated, the students routinely do an excellent job of crafting informative, detailed and realistic therapeutic discussions in presenting their assigned case.

While the presenting groups must take responsibility for identifying the learning needs of their peers, reviewing and researching their assigned topic, organizing their time and planning their presentation, the instructors still take a very active role in guiding presenting groups toward a successful experience. Each presenting group is required to meet with the instructors to discuss their planned approach to their presentation, and to clarify key case issues and answer questions. Many groups will meet with faculty a second time to do a "dry run" of their presentation the day before it is to be given, so that the instructors can critique it and make suggestions for change. We also talk with each group before they watch their videotape to learn what they thought of the experience and to seek suggestions on how to make the assignment more productive and meaningful for students. Each of these meetings takes approximately 40-60 minutes. Each student then receives a descriptive written summative evaluation by the instructors that is organized around the specific evaluative criteria, their presentation score, and a summary of the peer ratings and evaluative comments. The student evaluates" identify is always protected. A sample faculty-generated evaluation document is provided as Appendix B.

ADDITIONAL LEARNING OPPORTUNITIES Practice Examinations. To give students an understanding of the types of questions they will experience on examinations, practice exams are made available on the web for students to download and work. The keys to these exams are deliberately not posted, since there is a huge difference between the level of understanding needed to recognize a right answer and that required to synthesize the right answer. We will review the performance of individual students on the practice exams at their request, and often use the practice exam as the basis for the voluntary review session that always precedes each current examination.

Group Homework. We have made use of group homework assignments to augment the pre-class assessment quizzes, and in-class learning activities and exercises. Students work

Table I. Chemical Basis I (PHA 337) examination and course performance

	Exam 1	Exam 2	Exam 3	Exam 4	Exam 5
Fall 2001	75.4%	75.2%	76.5%	70.8%	79.3%
Fall 2000	71.5%	74.8%	75.9%	NA	79.5%

together in their pre-assigned groups on these problems, and no more than four group homework assignments are assigned per semester. Of particular interest to in-depth learning is the Integration Exercise, which asks students to pull from previous courses and experiences to gain a comprehensive picture of drug action within a given class of molecules (refer to the Beta Adrenergic Antagonists lesson on the PHA 337 web site).

Recitation. We also offer a voluntary recitation period each week to go over difficult concepts and respond to student questions about the lesson handout and/or any of the in-class activities. Because it is voluntary, attendance at recitation is another indicator of student interest and responsibility, and our turnout for this session is generally between one-half and two thirds of the class. While we've experienced some difficulty in getting our students to be vocal participants in class, they seem to open up during the recitation period, and are much more willing to pose questions. The relatively smaller group size, and the more relaxed atmosphere of this voluntary session, might stimulate enhanced interactivity. Because we place such a high value on an interactive classroom, it is our goal to capture the essence of the dynamic recitation period and attempt to transplant it into the scheduled class periods. We are actively working on that challenge.

Extra Credit Options. With the conversion to a web-enabled course format, we are always on the lookout for links to web pages that will expand our students[1] understanding of the course topics and enrich their learning experience. Since many of our students are expert "web surfers," we thought it an attractive way to stimulate responsibility for furthering their own learning and that of Chemical Basis students to come. Therefore,' we offer an option for extra credit called *The Missing Link* where students can declare an area of interest and provide six high quality web sites that support and extend the information provided in a specific lesson. This option was offered in the fall 2001 semester, and eight students took advantage of it. Participating students write a one page summary report for each web site they selected which provides the following information: (*i*) a synopsis of the site contents, *(ii)* an explanation of why the site is viewed as high quality and *(iii)* an explanation of how the site will enrich the learning of fellow students (both current and future).

Students who have elected the extra credit option have expressed a keen interest in the topic they chose to investigate, and a desire to know more than what was covered in class. Because they must be analytical in evaluating the quality of the web sites they submit, they are taking professional responsibility not only for their own learning, but for those whom the links will serve in subsequent years. Many of the sites our students have found to compliment course content have been excellent ones, and advance learning in a wide variety of ways. We have linked the most outstanding sites to our own course web sites[2] and lesson handouts, so that future students may benefit from the independent work that current students have done.

EVIDENCE OF STUDENT LEARNING Performance on Application-Based Examination Questions. Evidence of student learning can be found by examining the quality of the responses to exam questions that assess critical thinking, application and problem-solving skills. We post exam keys on our web site as soon as we've completed the grading process, with the answers to essay or short answer examinations taken verbatim from the best student responses. Since there are generally many students with answers that could qualify as the keyed answer, an individual student's response is posted for only one question per exam. While student names are not provided on the key in order to protect students' right to privacy, most students who find that their answers have been chosen express pride in that honor.

Performance on Group Homework Assignments. The Chemical Basis group homework assignments are most commonly case-based, but one prompts students to apply information and integrate lessons learned from previous coursework into the current Chemical Basis topic. Several outstanding responses to this year's Integration Exercise homework assignment were submitted electronically, and one is linked to the Diuretics Lesson on the PHA 337 web site2.

Performance on *Missing Link* Extra Credit Option. Most of the students who elected to do the *Missing Link* extra credit assignment found web sites that were of high quality. Their summary reports were insightful, and accurately identified valuable learning issues addressed by their sites. Many related the content of their web sites to the lesson under study, indicating where it was complimentary and where it took learning to the "next tier." While students did well identifying useful sites on their own, we have recently added a link to a published table of critical questions students can ask themselves when evaluating web site quality(10).

Anecdotal Evidence. The first Chemical Basis exam of the fall 2001 semester was scheduled for September 13th, two days after the attacks on the World Trade Center and the Pentagon. After seriously contemplating the pros and cons of delaying the examination until a calmer time, and recognizing the disruptive effect that would have on already disrupted student schedules, it was decided to offer the exam on schedule, with the option of a "no-risk" re-take exam at the end of the semester for anyone interested. For those students who elected this option, the higher exam score was used to calculate their course average. For obvious reasons, no one was studying for the two nights preceding the September 13th exam, but the average performance was effectively no different from that of subsequent examinations. Performance was also consistent with the overall performance of the previous year's class (Table I). In our opinion, this is a strong piece of evidence that students were actually learning our content. The course average includes exam scores, homework scores, presentation scores (for half the class), extra credit scores (for students who elected the extra credit option) and pre-class assessment quiz scores (for fall 2001 students only).

Table II. Chemical Basis I (PHA 337) examination content

	Exam 1	Exam 2	Exam 3	Exam 4
Fall 2001	Acid-Base Chemistry, Acid-Base Strength and Acid-Base Functional Groups, Receptor Chemistry	Adrenergic Agonists, β-Antagonists, Diuretics, ACE Inhibitors, 15% review material	H_1 Antagonists Antiulcer Agents, Antihy perlipidemics, 20% review material	Anxiolytics, Antidepressants. 25% review material
Fall 2000	Adrenergic Agonists, β-Antagonists, H_1 Antagonists	Antiulcer Agents, Diuretics, ACE Inhibitors, NSAIDs, 15% review material	NSAIDs, Anxiolytics, Antidepressants, 20% review material	NA

Table III. Chemical Basis I (PHA 337) course performance

PHA 337 Grades	Number of students (percent) 1998 (n = 91)	1999 (n = 109)	2000 (n = 98)	2001 (n = 102)
A	12(13.2)	12(11.0)	19(19.4)	15(14.7)
B+	11(12.1)	17(15.6)	10(10.2)	14(13.7)
B	21(23.1)	25(22.9)	23(23.5)	20(19.6)
C+	23(25.3)	19(26.6)	14(14.3)	20(19.6)
C	16(17.5)	20(18.3)	23(23.5)	26(25.5)
D	8(8.8)	6(5.5)	7(7.1)	6(5.9)
F	0	0	2(2.0)	1(1.0)
Class average	79.1	79.9	80.3	77.5

Examination and Course Performance. Some additional commentary on Table I. is in order. Four examinations, rather than three, were offered in the fall 2001 version of PHA 337 because of the increased number of credit hours assigned to the course (3 vs. 2). In fall 2001, Examination 1 covered the traditionally difficult concepts of acid base chemistry, acid-base strength (including orbital hybridization, resonance and induction), functional group properties, alicyclic and heteroaromatic ring systems, and receptor chemistry. This was not covered in the fall 2000 PHA 337 course, as these students had completed another required course called Pharmaceutical Sciences Principles (PHA 317) where this content was addressed. The students who took Chemical Basis I in fall 2001 had not had PHA 317, and the additional credit hour was meant to cover this critical content. Students studying Chemical Basis I in fall 2000 had the topics of Adrenergic Agonists and β Adrenergic
Antagonists on their first exam.

The content of the examinations in both offerings of PHA 337 is provided in Table II. The last exam in each course is given during finals week. The content on Examination 3 in fall 2001 included both Antiulcer Agents and Antihyperlipidemics, the latter of which had never been covered in the Chemical Basis courses before. Students often rely on past examinations to prepare for their own examination, and they had no old exams to turn to. Even though they did well on the pre-class assessment quiz and had a structure challenge to assist them in preparation, many students expressed a lack of confidence in their ability to succeed on this exam. However, the average on Examination 3 was consistent with their past performance, indicating that learning had taken place.

Students' competence in the face of diminished confidence also speaks to the level of true learning that they are gaining in our restructured Chemical Basis course format. However, we did learn that, when introducing new topics into the course, it is wise to construct practice examinations in the style and format that students will see on their own examination, in order to build confidence and allay undue performance anxiety.

Table III documents that our experimentation with strategies to enhance student responsibility and interest did not compromise student performance as measured by final course grades. The percentage of students performing at the various grade levels in 2001 is comparable to those achieved in previous classes, as is the final course average.

We were not expecting that our students would do exceptionally better (grade-wise) with this approach when compared to our previous approach. In fact, we believe it is more difficult to master knowledge you are responsible for discovering (at least initially) on your own in the time students have to do it than it is to acquire what's needed to do well on an examination by taking copious notes from a professor's focused lecture. Faculty who lecture year after year on the same topic know what they're going to test on and, intentionally or unintentionally, may emphasize and reinforce concepts they know the students will see again on the exam. When formal in-class activities are guided predominantly by student questions, and exercises are geared to allow them to practice applications, their ability to discern what's actually going to be on the exam may be less, but they are just as capable of rising to the occasion and giving a quality performance. Additionally, because this quality performance had its beginnings in the students' independent investigation of the content, it is our premise that the knowledge gained will be more persistent. At the very least, the students will know where to return to reacquaint themselves with information they've forgotten, and will better comprehend what they read when they find it.

EVALUATIVE DATA

Student Perception of their Learning. While it's certainly true that you can't please all the students all the time, last year

Table IV. Formative assessment of PHA 337 (fall 2001)

Concern comment	Our response
Liked one quiz per week, rather than two	Initiated one quiz per week for some lessons
Thought quizzes were too long	Shortened quizzes to 10-15 questions, especially when two quizzes per week were required PowerPoint slides coior-enhanced and expanded to reinforce content and summarize main points.
PowerPoint presentations needed more explanation	Addressed issue in class
Somewhat intimidated by the consistent demand to answer questions in class. Requested toning down the intensity in class.	Structured in-class activities to do more faculty-driven explanations to problems encountered on quiz General questions were asked at the beginning of the interactive period to get students "warmed up" More application questions and exercises were implemented towards the end of the class period.
Felt the need for more in-class explanation of content	"Med. Chem. To Go" Summary documents were added to the lesson packet Prepared in-class exercises that summarized major concepts and learning objectives

we had the most enthusiastic response to our course in recent memory. The formative and summative evaluation documents, which include all responses obtained, are provided in the Course Evaluation portion (Section V) of the PHA 337 web site. "None" or "N/A" responses were omitted.

Formative Assessments. Two optional, but strongly encouraged, formative assessments were conducted immediately after the first two PHA 337 examinations and the majority of the class responded to our call for feedback. Table IV summarizes the main formative issues and our responses to them. The September 13th evaluation was very positive and supportive, but did point out some areas for improvement. These areas included shortened or less frequent quizzes, frustration with the amount of time spent on the course, and concern about the perceived lack of detail in the PowerPoint slides (a new lesson presentation format for them). Unfortunately, the data from the November 6th evaluation was lost before it could be posted but, in it, students expressed appreciation for the modifications made from the September 13th evaluation, particularly regarding quiz length and expanded and "colorized" PowerPoint slides. Additionally, students were concerned about the intensity with which the instructors approached the in-class active participation component of the course. We dealt with these issues in class, reinforcing our commitment to a learning partnership and reiterating our expectation that students come prepared to verbalize their thoughts, opinions and ideas. Having this open and honest discussions with the class about expectations served to help each party become more attuned to the issues of the other, enhancing mutual understanding and respect.

Summative Assessment - Department-Constructed Tool. In fall 2001 our School mandated the completion of department constructed summative course/professor evaluation documents in order for a grade to be issued. Therefore, all 101 enrolled students participated in the end-of-term course evaluation process. These data are provided on our course web sites under the individual instructors' names[2]. The major outcomes of the objective component of the assessment that relate to our stated goals follow:

- Over 80 percent of respondents felt that our course structure was organized and provided objectives to guide student learning that were clearly related to the lessons.
- Between 70-90 percent of respondents gave us high marks for activities, strategies and attitudes that promoted learning.
- Between 80-95 percent of respondents claimed the instructors demonstrated professionalism and prepared them to think as health care professionals.
- Between 70-95 percent of respondents recognized the instructors' commitment to role-model responsibility by responding rapidly to their requests for help.
- Approximately 85 percent of the respondents thought that the web-based content aided learning.

Narrative comments documented student interest in medicinal chemistry and their preparedness, not only for both the course but also for future practice.

Student Interest. Students recognized the instructor's encouragement of active student participation, felt that the course integrated information from previous courses, and that it would be helpful in preparing them for future courses. They also indicated that they were mastering practical applications of chemical knowledge to advance patient outcomes. As some students described it:

- "This is the meat of Pharmacy."
- "It is vital to know drug structures."
- "It (the course) opened my eyes to the chemistry part of the medications that are prescribed"
- "After just a few weeks, I was able to use things in this course at work when patients asked me questions about medications."

Student Preparedness. In general, students felt that the pre-assessment quizzes: *(i)* were a good way to test their understanding of the course content; *(ii)* ensured that they kept up with the material; *(iii)* helped make class time more productive; and (*iv*) prepared them well for examinations. They felt that the case studies and in-class presentations were helpful in preparing them for professional practice. Some indicated that they were actually using their chemistry at the workplace to help them explain anticipated drug action to patients. Some key quotes to underscore the sentiments expressed by students include:

- "The course helped expand my ways of thinking."
- " I learned so much from this class"
- (The course) "teaches the chemical basis of drug therapy. Helps one to make therapeutic decisions."

TRANSFERABILITY

Our methods to enhance student preparedness, responsibility and interest in medicinal chemistry are practical, workable and transferable to any institution. We utilize Blackboard™ for our pre-class assessment quizzes, in part because it is supported by our University. However, it is available to all schools willing to pay the registration fee. Technical support for Blackboard™ is also available on the web for a fee, but can be administered through the School's Office of Information Technology (or equivalent) or though the University's academic computing office. Other course environments (e.g., WebCT™) or examination software programs *(e.g.*, Question Mark™) would work just as well.

The emphasis on educational technology at Creighton University has made it easy for us to use the web for the delivery of content and assessment of student performance (quizzes) and evaluation. For those who prefer not to use a web-facilitated approach, hard copies of the lesson handouts can be delivered in the standard manner. Quizzes and course evaluations can be administered and readily scored using standard "scantron" sheets.

Many of our active learning techniques *(e.g.*, the Medicinal Chemistry case study and the SBTE concept) have already been shared with the academic pharmacy community through publication in the *Journal(4-9).* The remaining in-class exercise activities including the structure challenge, application problems and think-pair-share techniques, can easily be incorporated into standard "lecture-based" courses with a little advanced planning and preparation.

DISCUSSION

All schools and colleges of pharmacy are concerned about instilling responsibility and professionalism in students, and many faculty want to positively and proactively address these issues in their courses. We count ourselves among that group but, despite many successful and enjoyable years in the medicinal chemistry classroom, we have often been frustrated by the lack of preparation of our students for interactive classroom activities. Part of this frustration is our own fault. While we repeatedly voiced our clear expectation that students come to class having read the notes and the chapter, and have given the implication of the content some reflective thought, we provided neither an organized vehicle nor the academic rewards to make it work.

But the academic culture has a hand in it too. Most of us work in an environment that has tolerated, and in some cases rewarded, passive learning and teacher-centered classrooms. This practice flies in the face of ACPE standards and the ability-based outcomes that have been so carefully crafted and implemented by virtually all Schools and Colleges of Pharmacy, ours included. Many faculty members across the country have taken the ACPE standards to heart, and have incorporated active learning strategies into their syllabi, but have met with firm resistance when they attempted to implement these strategies in their classrooms. For any approach that seeks to enhance student responsibility for learning, preparedness and professionalism to work, the entire faculty must collectively buy into the philosophy and have the courage to stick it out when the going gets rough. Faculty who have not yet been through the promotion and tenure process feel particularly vulnerable standing up to negative student opinion, and need the vocal and visible support of senior colleagues and academic administrators to hold the quality line and keep learning at the heart of their teaching endeavors. We owe our junior colleagues, and our students, no less.

The change from the passive to active classroom is an evolutionary, rather than a revolutionary, one, and takes patience, persistence, flexibility and, in some cases, a thick skin. All human beings, our students included, want to be rewarded for their time, effort and success, particularly when so many academic and work and/or family-related pressures are competing for their attention. As alluded to previously, creative educators who would accomplish their goals for enhanced responsibility must build in appropriate positive reinforcements that are valued by their students.

Rewards can be explicit *(e.g.,* points on exams or assignments) or implicit. Our pre-class assessment quizzes provide the explicit reward for classroom preparedness, and in-class application exercises and other non-graded assignments provide insight into what examinations might be like. While most students are highly focused on these extrinsic rewards, the value of intangible rewards...hearing your ideas and opinions validated or praised by faculty, kudos from classmates on a good presentation performance, establishing a personal relationship with teachers as colleagues, having "flashes of insight" that come from self-directed learning and/or experiencing the joy of really understanding a difficult concept...becomes more apparent with time, when the pressure of immediate performance has abated. In the long run, they are the only rewards that last.

We decided to adapt the JiTT approach to the Chemical Basis courses when literature suggested that it had worked well in a "hard-science" course (physics) to accomplish the same goals for preparedness and responsibility that we had for our courses(2). Our School is well equipped to provide the technological support that this approach endorses. Our students, being technologically savvy thanks, in part, to a technology-emphasized curriculum and familiarity with the laptop computer they were assigned upon matriculation, have also welcomed our use of the web to deliver content, communicate "late breaking" information, and answer questions.

We recognize we may not be the first to employ JiTT in a required pharmacy class, but are unaware of any attempts to use this technique in a pharmaceutical science course. We believe our uniqueness involves not only the use of a pre-class assessment quiz to stimulate and reward preparedness, but also how we capitalize on that preparedness to creatively engage our class in active, analytical learning, and to foster a sense of professional responsibility for learning.

Our students' ready compliance with the weekly pre-class assessment quiz requirement, the summative course evaluation data, and the quality of student work all indicate that we have been moderately successful in accomplishing our goals for enhancing our students' sense of responsibility for learning, and their interest in our discipline. However, we do not yet believe that we have achieved pedagogical nirvana. In fact, there are several components of our courses where we remain less-than-optimally satisfied with our current level of outcome achievement. We have discussed ways to modify our approach to better achieve our goals, and are currently complementing the following revisions to our methods.

Improvement Goal #1: Make Better Use of the Pre-class Assessment Quiz to Enhance and Document Learning

Currently, as we are doing a major revision of our lesson handouts, we are writing the pre-class assessment quizzes only

shortly before they must be posted to give students sufficient time to study prior to the quiz submission deadline. Even though the quiz questions are made available to all through the lesson packet, we feel it is inappropriate to use the same quiz questions in consecutive years since students can print the correct answers to the quiz immediately after submitting their paper. Some students have said they would like the option of working ahead on future quizzes when their schedules permit advanced study, and we would like to ultimately develop a bank of quiz questions sufficiently large to allow us to publish a semester's worth of quizzes on our web page at the beginning of the course. Quiz questions not being used for graded assessment could be made available for students to use as a "practice challenge" before taking their graded quiz.

Another possible route to enhancing the utility of the assessment quiz is to offer no credit for the required pre-class quiz, but have the students take a second, graded quiz (preferably in class) when the day's active learning exercise was completed. The difference in each individual student's quiz scores (post-class minus pre-class) might indicate how effective the day's activities were in advancing learning. The advantage of completing the quiz in-class would be that the instructors could control how much group work to allow on the exercise. We currently encourage group work on quizzes, as we believe it advances learning if done properly, but we also realize the opportunity for "learning abuse" if one student martyr takes the quiz and prints out the correct quiz answers to distribute among his/her classmates.

Improvement Goal #2: Enhance Student Audience Responsibility for Familiarity with the Case Presentation Scenario or SBTE Problem.

Students who make an in-class presentation have been overwhelmingly positive about the impact of the experience on their learning. This is no surprise to us, as we both realize the value that teaching others has had on our own understanding of the chemistry of topics new to us. However, we know that opportunities for learning among the student audience are being wasted because a significant component of the class lacks faith in the ability of their peers to "teach them." Those who attend listen politely to the student presentations, but are silent and unresponsive during the post-presentation question/answer period, leaving it to the instructors to pose questions. Because we are the only ones asking questions, our exploration of interesting issues presented in the presentation has been perceived by some as "grilling."

Vesting the class in the presentation exercise requires that they anticipate gaining intellectually from actively listening to the presentation and participating in the discussion period. We currently post our performance expectations for each of the areas of presentation assessment on the web site (see Section IV: Group Activities and On-Line Discussion).[2] Next year, prior to the first student presentation, we plan to ask students to share their ideas on what they would value in a presentation. They will have the chance to provide advice to fellow students on engaging aspects of both presentation content and performance, and we will collect and post this "Student Guide to the Perfect Presentation" on the web site for all presentation groups to see.

In previous years we've required all student groups to solve the presentation case and turn in their written work as a homework assignment. The benefit of this approach is that everyone is familiar with the case scenario and has given thought to the application of SAR in the making of a wise therapeutic decision. The disadvantage is that, since everyone has worked the case to completion, they're bored with the presentation. We need to find the elusive "happy medium" and may experiment with requiring each student group to read the case prior to the presentation and submit their list of the most critical therapeutic issues of the case, and the patient-specific factors that must be taken into account when making a therapeutic decision. If adopted, points for this required activity would need to be identified and incorporated into the course grading scheme.

Another idea for enhancing student attention to the presentation is to ask the presenting group to submit 3-4 questions based on the key points made in their presentation to the instructors for possible inclusion on the next examination (this was a student's suggestion). If we opened this option up to any student in attendance at the presentation, it might generate a healthier interest in the session, as students would be listening for important ideas and summary messages, rather than attempting to discern what, from all they were hearing, might show up on the test. Also, since we're sure that the student-generated questions would not be kept secret for long, having a larger pool of potential questions to choose from would give the students more opportunity for thinking and discussion as they sought to answer the questions their peers were generating.

One area of presentation assessment, termed "Intellectual Curiosity," requires students to bring new information or insightful integration of previously learned information to the presentation. We are contemplating requiring two non-presenting student groups to research and submit an Intellectual Curiosity piece that supports the upcoming case presentation. Each student group would submit one pre-assigned Intellectual Curiosity piece each semester, and their work would be scored as a homework assignment. These Intellectual Curiosity documents would be linked to the course web site so that everyone could benefit from the higher level thinking done by the student groups.

Improvement Goal #3: Changing the Culture. Perhaps most importantly, we want to work to establish a culture within our School that not only appreciates, but also demands student responsibility for learning. Emphasizing responsibility in only a few courses in the curriculum sends an inconsistent message to students about professionalism, and does not shape behavior and attitudes to the extent we think they should be shaped for us to fulfill our own responsibility to our students and to society.

The two formal units in our School which are primarily responsible for curriculum assessment and quality assurance are the Pharmacy Curriculum Committee and Pharmacy Assessment Committee. We each play an active role on one of these two committees, and are committed to working with similarly motivated colleagues to establish an expectation for responsibility that permeates the entire curriculum. We have shared our teaching approach with our colleagues through formal faculty development program, and at informal gatherings of educators on our campus. We have listened with interest to the teaching approaches of others, both to gain insight from them as well to encourage them to keep examining and exploring ways to enhance student responsibility and interest in their own courses.

CONCLUSIONS

One sure thing you can say about educational research is that it never ends. Investigating one avenue of student learning will invariably lead you to several intersecting roads that cry out for further exploration. Our current focus on enhancing student responsibility for learning, and interest in medicinal chemistry will continue to evolve, and we expect it to take us in directions we haven't yet thought about. Therein lies the joy of teaching. One tenet to which we will always hold fast is the importance of engaging our students as collaborators in our pedagogical scholarship. We will continue to communicate our goals regularly, honestly and openly with our students, and talk with them about the reasons behind our choice of teaching method. We will continue to share the results of classroom assessment activities with them, and seek their input on how to better advance learning and establish the kind of learning community we're all striving for. In every way that we can, we will demonstrate our sincere interest in them as learners and professionals. In summary, we will strive to role model the type of responsible behavior that we are asking of our students, and make explicit our intent to establish an intellectual professional community collegially focused on chemistry and the practice of pharmacy.

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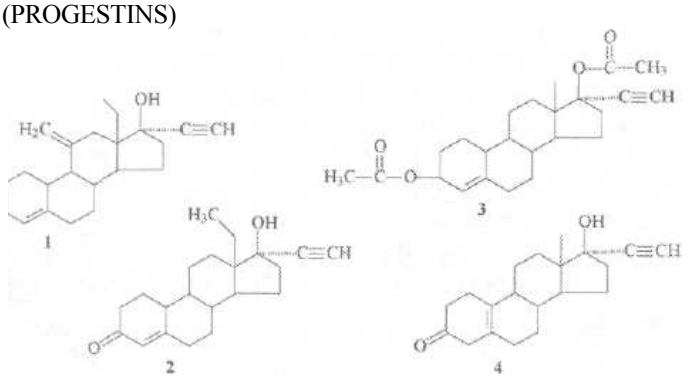
APPENDIX A. SAMPLE STRUCTURE CHALLENGE (PROGESTINS)



1. Which of the four progestin molecules would have the highest risk of androgenic side effects? What is the structural basis for your answer?
2. Which of the four progestins must be metabolized prior to interaction at progesterone receptors? What is the active form and why is it necessary?
3. What is the therapeutic purpose of the exocyclic methylene group of compound 1? What other substitution patterns provide similar activity?
4. Which progestin would have the lowest potency? What is the structural basis for your answer?

APPENDIX B. SAMPLE IN-CLASS PRESENTATION EVALUATION

Presentation Evaluation

GROUP: #17 CASE: Cardiovascular SBTE #1

Preparation for Discussion (0-3): 2.5

The slides were nicely done and the information you presented was accurate and complete. You met with Dr. Alsharif to discuss concept; and we could tell you did a lot of work for the presentation. However, the fact that you were totally tied to your notes (*i.e.,* read them verbatim with little eye contact with your audience) detracted from optimal effectiveness. Full preparation for the presentation must include sufficient familiarity with your content to allow for conversational delivery, connection with your audience and, when appropriate, spontaneity. This gets easier with every presentation you make and, in fact, you showed improvement during your second time at the mike.

Contribution to Discussion (0-2): 2

Your overview of hypertension and the therapies commonly employed for various populations added much to the discussion. Your discussion of the influence of body weight on cardiovascular health and the prognosis of hypertension was also very valuable, as was your discussion of hydrochlorothiazide SAR.

Appropriate Pace and Volume (0-2): 2

The use of the microphone guaranteed that most of the students in your group could be heard. Your pace was fine, and your vocal quality good.

Professional Demeanor (0-2): 2

You were professionally dressed which, when coupled with accuracy; always promotes credibility. You were conversational-and professional in your comments. While you were note-tied, you maintained an air of confidence when you spoke.

Intellectual Curiosity (0-2): 1.5

The overview of etiology/epidemiology of hypertension and the treatment options for various populations brought new information to the group.

Overall Group Effectiveness (0-3): 3

Very nice presentation, but it stopped very abruptly. Make sure you always bring closure to your presentation with some type of summary or final thoughts, rather than just stopping cold.

TOTAL SCORE 13 (5 course points)