INTRODUCTION
This article describes a new approach to the teaching of medicinal chemistry for pharmacy students and includes some examples used in the course. This innovative approach was developed by the medicinal chemistry faculty at the Chicago College of Pharmacy, a new pharmacy school, for the initial offering of the required medicinal chemistry sequence.

The Chicago College of Pharmacy was established in 1991 and admitted students into the first class of the BS in Pharmacy program in September of 1992. Medicinal chemistry was offered in the curriculum for the first time during the 1993-94 academic year for 92 students. The course is a 12 quarter hour sequence over three quarters during the second professional year of the program. Medicinal chemistry is taught in parallel with pharmacology, pharmacotherapeutics, and the applied pharmaceutical care laboratory.

The guiding principles used by the faculty in developing this course were: (i) medicinal chemistry should be taught so that it is relevant to the practice of pharmacy; (ii) that the relevance of medicinal chemistry to the practice of pharmacy should be readily apparent; and (iii) that problem solving and communication skills in pharmacy students need to be developed. In order to teach the medicinal chemistry course along the lines of these guiding principles, patient-related case studies were introduced into the course as a component of lecture, workshops, and examinations.

These patient-related cases pose realistic problems that pharmacists could encounter in practice and the approaches to solving the problems involve the application of medicinal chemistry principles. The use of patient-related case studies also led to interdisciplinary workshops with pharmaco-therapeutics faculty where cases were jointly developed and then jointly facilitated by faculty from both disciplines during the workshops. Workshops are two hour discussion periods where students work in small groups of 6 to 10 students and discuss problem solving exercises while the faculty facilitators float among the groups answering and asking questions to assist the students with their problem solving activities. There is usually a case summary by one or more of the faculty facilitators at the end of the period to make sure that everyone knows the right approach to the cases and the right answers. The small group discussions during workshops provide many opportunities for peer teaching throughout the year. At the College, small groups are formed at orientation before the first professional year and are used throughout the curriculum by several different courses from several departments for a variety of educational activities. The same group of students stays together throughout the professional program.

PATIENT-RELATED CASE STUDIES
A patient-related case study is a problem that is posed that involves a patient, some medical history, medication profile, and a problem or some discussion questions that are posed for the students to work on to attempt to solve or discuss. The patient is usually fictitious, but could also be taken from the professional literature. The case situation is chosen to illustrate the application of medicinal chemistry principles that have been developed in lecture. As the course progresses, the cases can get more complex, i.e., involving medicinal agents from earlier course topics. Every attempt is made to make the patient situations presented realistic, but the patient chart information is kept to a minimum. Social information is also included when it impacts on the case. Early in the course the cases focus on the ionic properties of drugs and their solubility and the effects of urinary pH on the rate of drug excretion. Relevant drug-drug interactions are illustrated for various drug classifications whenever possible. Toward the end of the course complex, multi-drug scenarios are presented and students are asked to prepare written group reports that are handed to the faculty one or more days after the workshop period for grading. A typical workshop exercise, however, is not graded. Instead, a quiz is given at the end of the workshop period that covers material from the workshop and also lecture. The quizzes are taken individually by the students. The most appropriate way to illustrate these patient-related cases is to give some examples:

SAMPLE CASES FROM LECTURES

Case #1
Mr. Zichowitz has been taking Motrin® (ibuprofen) for several years now to help relieve the pain and swelling associated with arthritis in his wrists and shoulders. He works as a construction carpenter. His physician recently prescribed a diuretic, acetazolamide, in an effort to control his hypertension. Now Mr. Zichowitz is complaining that his arthritis is bothering him more than usual even though he has been taking his Motrin regularly.

What advice would you have for Mr. Zichowitz’ physician?
1. The prescription for Motrin® should be replaced with a prescription for Clinoril® (sulindac).
2. The prescription for the diuretic should be changed to Lasix® (furosemide) and ask for him to call in a week to see if he is feeling better.
3. The doctor should suggest to Mr. Zichowitz that he take a medical leave from his job until he feels better.

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4. The dose of Motrin® should be doubled this week and then doubled again next week if there is no improvement with a caution to be aware of possible stomach irritation.

Case #2
You are a recently hired pharmacist at Southwestern DuPage Community Hospital. You have been assigned to work in the IV room. Everything was going fine until today when you started making up a solution of anticonvulsant drugs that had been requested for a pediatric patient that was having severe and frequent convulsions. The preparation called for making 1 liter of a solution containing 2 g of Dilantin sodium and 500 mg Depakene® in normal saline. You started by making a solution of Dilantin® sodium in saline, but when you added the Depakene® a voluminous precipitate formed.

What is the problem and what can you do about it?
1. Put the IV bag in the autoclave and heat it at 80° C for 1 hour to dissolve the precipitate.
2. Put the IV bag on a shaker and shake the mixture until the precipitate dissolves.
3. Increase the volume of normal saline to 2 liters to improve the solubility of the mixture.
4. Ask the physician to change one of the ingredients, and make a recommendation of Tegretol® (carbamazepine) in place of Dilantin® sodium.

SAMPLE CASES FROM EXAMS
Case #1
Mr. B.D. Taste approaches you at the prescription counter in ClinPharm Assoc. with a prescription for an ACE inhibitor, captopril (structure shown), written by Dr. Jones. In reviewing your patient profile records you find that Mr. B.T. was previously treated for hyperthyroidism two years ago by Dr. Zik using propylthiouracil (structure shown). At that time, B.T. complained of a bad taste in his mouth (like really bad burnt garlic) within two hours of taking his PTU and he also developed a severe rash on his forearms. His thyroid condition has since been corrected with surgery.

1. You have available in your pharmacy captopril, enalapril maleate, and lisinopril as ACE inhibitors. Should you call Dr. Jones or dispense as written? Discuss. If you decide to call Dr. Jones, what will be your recommendation?
2. Discuss briefly the role of an ACE inhibitor with regard to the renin-angiotensin system. In the structures of the three ACE inhibitors you have in stock, circle the functional group which is most critical for the action as an ACE inhibitor.

Case #2
Sally Doright is a 45 year old housewife who has decided to take some classes at a local junior college. She has been thinking that she might complete the requirements for pre-pharmacy so she can go to pharmacy school and become a pharmacist, now that her two children are grown and living on their own. She has chronic allergy problems and regularly takes chlorpheniramine (ChlorTrimeton®), especially in the autumn during ragweed and goldenrod season when she usually doubles her normal dose of two tablets per day. This past September she visited her regular physician for a checkup before school started. The physician discovered that Sally was suffering from mild hypertension and placed her on acetazolamide (Diamox®) to see if the hypertension could be managed readily. A follow up visit two weeks later indicated that the hypertension was now under control. However, Sally is routinely falling asleep during her morning classes at school, even in her favorite subject, Organic Chemistry. (Structures given for medications.)

Identify any problem situations regarding the medications that Sally is receiving. Develop a recommendation for the physician regarding appropriate drug therapy and briefly justify your recommendation.

GROUP CASE WORKSHOPS
Case #1
Mrs. X.Z. is a 68 y.o. female who has been seen in the hypertension clinic because of continuing problems controlling her blood pressure (currently her BP 150/100). You, as the pharmacist associated with the clinic, are called in to consult because of the large of number of prescription and OTC meds that the patient is taking as the result of seeing several physicians as well as self-medication. The patient's medication history reveals treatment for hypothyroidism (levothyroxine, 0.1 mg), diabetes (Humulin R, 10 units and Humulin N, 20 units 30-60 min. before breakfast and Humulin
R, 10 units 30-60 min. before dinner), cardiovascular disease (clofibrate, 500 mg qid; propranolol, 20 mg q8h; captopril, 12.5 mg q8h; aspirin, 325 mg qod; warfarin, 7.5 mg qd), and post-menopausal osteoporosis (DES, 0.25 rag qd x 21 then 7 days off, repeat). Mrs. Z. also keeps ibuprofen (2 x 200mg prn) on hand for frequent headaches.

Mrs. Z. recently retired from a full-time job as a production supervisor in a local manufacturing plant. As a result of her various ailments and “just being tired”, her husband is doing most of the housework and cooking all of the meals. She reports poor compliance with her physician’s recommended diet and exercise program.

1. Examine all of the medications that Mrs. Z. is taking. State briefly the mechanism of action for each and the appropriateness of the choice of therapy for the disease indication.

2. Identify any potential changes in drug therapy recommendations (from several physicians) based on evaluating all of the disease indications and the patient’s recent change of lifestyle.

3. Identify any real or potential adverse drug reactions based on the medication profile.

4. Make a new comprehensive drug therapy and patient education recommendation based on your assessment above. If there are areas where more information is needed or follow-up monitoring is warranted, then specify accordingly.

Case #2
P.Y. is a 57 y.o.w.f. with advanced epithelial ovarian cancer that is refractory to cisplatin (CBC, renal and hepatic function WNL). Following consult the patient was enlisted in the institutions taxol protocol.

Taxol (Paclitaxel®) is supplied to the institution as a concentrated sterile solution of 6 mg/mL in 5 mL ampules. The vehicle is 50 percent polyoxyethylated castor oil (Cremophore EL®) and 50 percent dehydrated alcohol, USP. One-third of the total taxol dose is prepared in each of three 1000 mL bottles of 5 percent Dextrose Injection, USP. Following pre-medication (see below), P.Y. was to receive her first dose of taxol. 135 mg/m² infused IV over 24 hours. P.Y. was also to receive recombinant granulocyte-colony-stimulating factor (G-CSF), 10 mg/kg/d from 24 hours after the taxol infusion was stopped until her total granulocyte count was > 1500/mL on two successive determinations(1).

Pre-medication regimen:
Dexamethasone, 20 mg IV 14 h and 7 h prior to taxol.
Diphenhydramine 50 mg IV 30 min. prior to taxol.
Famotidine 20 mg IV 30 min. prior to taxol.

1. What is the mechanism of action for each drug (taxol, dexamethasone, diphenhydramine and famotidine), and what is the rationale behind the pretreatment regimen?

2. Based on the inclusion of G-CSF in the protocol, what would you propose as a major side effect of taxol?

Within two minutes of beginning the taxol infusion, P.Y. developed bradycardia, severe chest pain, diaphoresis and respiratory distress. The taxol infusion was stopped and P.Y.'s condition returned to normal, except for the cancer being treated. Five hours later, P.Y. was given another 20 mg dose of IV dexamethasone, followed in 30 minutes by diphenhydramine 50 mg IV and famotidine 20 mg IV. The taxol infusion was begun again at a rate 10 percent that of the original rate for two hours, gradually increasing to the original infusion rate over the next three hours. After five additional taxol treatments repeated every 21 days without sequelae. P.Y. is in a state of remission.

3. What is (are) the major contributing factor(s) to the success of re-challenging the patient with this taxol protocol?

STUDENT FEEDBACK AND EVALUATION OUTCOMES
Feedback from students was invited in two basic ways. First a questionnaire was prepared that all students were asked to respond to anonymously and was constructed in a graded response format from 1 to 5. Summaries of some of the responses are discussed later in this paper. A second type of feedback was an invited essay by one representative from each of the eleven small student groups. These were each one to two pages in length. Space does not permit inclusion of all of these statements verbatim. However, one of the students (LS) prepared a composite of the cogent comments made by the various groups in their reflective statements. This composite is included below preceded by some quotes from individual essays.

Quotes
“Being able to work through these activities with a small group provides interaction and knowledge exchange that lecture cannot normally provide.”

“These chemistry workshops prepare us as pharmacists to face situations head on, and to rationally identify and solve them. This is an important part of our careers, and I personally feel better prepared to undertake these challenges.”

“These workshops, however, are not without some faults. The workshops depend on each individual group to be able to communicate effectively among themselves. If personalities clash, it could turn into a shouting match!”

“By allowing time for the group to discuss the cases before reviewing the answers, the group members are free to hypothesize and create solutions to the problems. Whether or not these answers are correct, there is one guarantee ... we will understand the chemistry behind the answers before we leave the workshop.”

“When working on a case, medicinal chemistry becomes connected to the other subjects pharmacy students are studying. Concepts already learned are reinforced from a new perspective and new concepts augment the learning in other courses.”

“I believe working as a group is challenging, as well as a great resource. Each individual has a strength that is unique and that trait is brought forth in workshops.”

“Instead of trying to remember interaction after interaction, I have been taught to critically evaluate each structure and determine not only how it will work, but also how it will interact with other molecules.”

“Applying what you have learned is the most important skill to have when leaving college. The cases in medicinal chemistry have taught me to apply chemistry knowledge to practical situations and hopefully will enable me to become a more effective pharmacist.”
Table I. Student opinions on workshops and cases in Medicinal Chemistry

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. The instructional approach and use of a combination of lectures and workshops is effective in helping me to learn the subject.</td>
<td>15</td>
<td>37</td>
<td>19</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5. The use of patient-related case studies in workshop is effective as a means to relate course subject matter to applications in the practice of pharmacy.</td>
<td>17</td>
<td>46</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>6. The patient-related cases that are a component of workshops in medicinal chemistry are appropriate problem-solving exercises.</td>
<td>16</td>
<td>44</td>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>7. The inclusion of patient-related cases on examinations was a good means of evaluation of my understanding of course material.</td>
<td>14</td>
<td>39</td>
<td>18</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>8. The use of small groups as the basis for the discussions in the workshop is useful for my learning of the subject material.</td>
<td>8</td>
<td>31</td>
<td>22</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>9. All of the members of my small group participated in discussions pertaining to the workshop tasks during the workshop period.</td>
<td>3</td>
<td>19</td>
<td>16</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>10. All of the members of my small group make important contributions to the outcomes of the learning experience during the workshop.</td>
<td>0</td>
<td>25</td>
<td>17</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>11. I understand medicinal chemistry better as a result of the workshop component of this course.</td>
<td>5</td>
<td>38</td>
<td>22</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>12. There should be more workshops during the medicinal chemistry sequence.</td>
<td>0</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>13. Overall, I think that workshops helped me to learn more effectively in medicinal chemistry.</td>
<td>12</td>
<td>36</td>
<td>19</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**COMPOSITE REFLECTIVE STATEMENT FROM A STUDENT'S PERSPECTIVE**

The prevailing attitude among students regarding the use of small groups throughout their coursework at CCP is generally positive. They have expressed that small group learning has been a means of fostering interpersonal communication, which can then be utilized in their future careers as health professionals. The process of expressing individual opinions and realizing that there is more than one way to solve a problem, are first steps to establish the open-mindedness needed for effective teamwork. This teamwork, as recognized by the students, is an important trait among health professionals. The utilization of dialogue is necessary to achieve the optimal patient outcomes. Thus, the utilization of small group discussions in various courses, including Medicinal Chemistry, serves to prepare CCP students for future interactions with fellow health professionals.

Through the use of Medicinal Chemistry workshops to augment weekly lectures, students have expressed that the class has been made “less intimidating.” In the workshop setting, the students welcome the opportunity to discuss the material learned with their peers on a simpler level. This setting facilitates “peer teaching” and also allows for more individualized contact with the professor, who is there to offer any assistance needed. The students feel that both of these aspects enhance the material learned in lecture. Too often students may have trouble understanding what is presented while they are not in the right environment to openly discuss it.

It is also recognized by the students that the workshop setting, where each group tackles a problem and attempts to solve it, will help prepare them to be more effective pharmacists, since it teaches them to rationally identify and solve complex problems. Like the use of patient-related cases, workshops help to initiate the critical thinking process, which is lost when rote memorization alone is emphasized. The students appreciate this attempt at forcing them to think critically and investigatively, for it will benefit them in the future in their practice setting.

The use of patient-related cases in Medicinal Chemistry lectures, workshops, and examinations has met with considerable approval from the students. One common opinion expressed involved the idea that Medicinal Chemistry was made more “relevant” to the overall pharmacy curriculum. Medicinal Chemistry, in the students’ perspective, can easily be thought of as an isolated part of pharmacy study which is irrelevant to common practice. Through the use of patient-related cases, the students have expressed that they now realize exactly how the application of Medicinal Chemistry is an integral part of the basic understanding of drug therapy. With having to evaluate a patient case and using
medicinal chemistry to solve the drug therapy problem presented, the students feel they are forced to critically evaluate the chemical structures and apply that knowledge to the solution. This process replaces the otherwise tedious task of memorizing structures and drug interactions, which does not facilitate true understanding of the chemical structure of the drugs they learn, rather than viewing them as an accessory to the lists of mechanisms and interactions they would otherwise memorize.

A survey of the PS-II Class was conducted in order to get focused feedback regarding the anonymous opinions of students concerning the use of patient-related cases in the medicinal chemistry course. Summaries of some of the data from this survey are found in Table I. A copy of the entire survey is included in the Appendix.

DISCUSSIONS
There are relatively few reports of the incorporation of patient-related case studies as problem-solving exercises in pharmaceutical science courses. Duncan-Hewitt(2) and Sims(3) have recently reported on the use of patient-related cases as an aid to teaching pharmacuetics. Sims(4) has also used them in teaching pharmacokinetics. Roche(5) is the only example of the use of patient-related cases as a component of teaching medicinal chemistry. Roche used them as application questions on examinations. This manuscript is the first to describe a broad application of case problem-solving throughout a required course in medicinal chemistry, e.g., lecture, workshop, quizzes, and examinations. Based on the positive responses from students, this approach to teaching medicinal chemistry has considerable potential. It has also provided a good avenue for collaboration with the pharmacotherapeutics faculty resulting in the joint development and facilitation of some cases in workshop.

CONCLUSIONS
1. Patient-related cases and workshops seem to be useful for teaching medicinal chemistry.
2. Feedback from students is generally quite favorable.
3. The approach taken will continue to be modified and expanded.
4. Developing patient-related cases has been challenging and fun for the faculty involved.
5. This approach to teaching medicinal chemistry promotes interdisciplinary cooperation, particularly with faculty in pharmacotherapeutics.

Am. J. Pharm. Educ., 58, 446-450(1994); received 9/30/94.

References
(3) Sims, P.J., “Utilizing the peer group method with case studies to teach pharmacuetics,” ibid., 58, 78-81(1994).
(4) Sims, P.J., “Utilizing the peer group method with case studies to teach pharmacokinetics,” ibid., 58, 73-77(1994).

APPENDIX

Questionnaire/Evaluation of Workshops and Case Studies as a Part of the Medicinal Chemistry Course Sequence

Instructions: This is an anonymous questionnaire. Please mark the scantron sheet only as Med Chem Workshop. Please respond to the following statements according to the scale: A = Strongly Agree; B = Agree; C = Neutral; D = Disagree; E = Strongly Disagree

1. Medicinal Chemistry is the one course in the PS-II curriculum that I found to be the easiest to understand.
2. Pre-pharmacy coursework prepared me effectively for the subject matter of the Medicinal Chemistry sequence.
3. The PS-I curriculum prepared me effectively to study and learn Medicinal Chemistry as a part of the pharmacy curriculum.
4. The instructional approach used in Medicinal Chemistry, use of a combination of lectures and workshops, is effective in helping me to learn the subject.
5. The use of patient-related case studies as a component of the workshop in Medicinal Chemistry is effective as a means to relate course subject matter to applications in the practice of pharmacy.
6. The patient-related cases that are a component of workshops in Medicinal Chemistry are appropriate problem-solving exercises.
7. The inclusion of patient-related cases on examinations was a good means of evaluation of my understanding of course material.
8. The use of small groups as the basis for the discussions in the workshop in Medicinal Chemistry is useful for my learning of the subject matter.
9. All of the members of my small group participate in discussions pertaining to the workshop tasks in Medicinal Chemistry during the workshop period.
10. All of the members of my small group make important contributions to the discussions and outcomes of the learning experiences during the workshop in Medicinal Chemistry.
11. I understand Medicinal Chemistry better as a result of the workshop component of the course.
12. There should be more workshops during the Medicinal Chemistry sequence.
13. Overall, I think that workshops helped me to learn more effectively in Medicinal Chemistry.

Note Different Response Scale
14. The grades that I received in Medicinal Chemistry are generally A = higher than; B = about the same as; C = usually lower than; grades that I received in other courses during the PS-II year of the curriculum.

Please use the space below for any additional comments that you wish to make regarding the use of patient-related cases for problem-solving exercises in Medicinal Chemistry and/or the use of workshops as a means of learning and applying Medicinal Chemistry.