Computerized problem-based learning (PBL) cases were developed that replicate the critical thinking process undertaken by students during traditional facilitator-led PBL sessions. Eight computerized PBL cases emphasizing medicinal chemistry and pharmaceutics concepts were developed initially from among those used previously during facilitator-led sessions. Two case versions were developed: one incorporating concept maps emphasizing key ideas and another lacking the maps. Quiz scores and attitudes were measured and compared among students using the computerized PBL cases (with and without maps) and the previous year’s class who attended only facilitator-led sessions. Scores on the 12 quizzes administered did not differ significantly among the different student groups. Students consistently felt that the PBL sessions improved their problem-solving skills, use of information resources, and communication/interaction skills. Computerized PBL cases can be a useful alternative to facilitator-led sessions to reduce faculty time demands in this process while retaining the benefits.

INTRODUCTION
Pharmacy students, as well as students in the other health sciences disciplines, need to be taught how to solve problems effectively(1,2). Several competencies identified for future health care practitioners include the ability to provide appropriate and cost-effective patient care, to manage a continually increasing volume of available information, and to continue to learn(3). An American Association of Colleges of Pharmacy (AACP) commission has stated that “because pharmacy practice is primarily a process of solving problems on behalf of patients, the education of entry-level practitioners must ensure that they are adept at problem solving.”(4)

The transmission model of teaching, in which students as passive learners simply “absorb” facts and knowledge transmitted during lectures and readings(5), has been used extensively by pharmacy and other health sciences schools(6). In addition to producing dependent learners through teacher-centered instruction, many pharmacy schools have employed a method of discipline-based teaching in which knowledge is gained in fragments rather than through integration across disciplines(7). During faculty discussions at our school, it became apparent that students were compartmentalizing the knowledge gained in different courses. Students were often unable to recall or apply the information taught in one course to another, a concern particularly evident when students were asked to apply basic science principles to problems in the clinical environment.

Changes in the traditional methods of instruction will be required to educate future doctoral level pharmacists who can provide comprehensive patient care. Teaching methods that promote critical thinking and “meaningful learning,” defined as the ability to relate new knowledge to the existing concepts and facts that a student possesses(8), should be striven for. Two instructional techniques that have been used to promote meaningful learning and problem-solving skills in higher education include concept mapping (i.e., the preparation and use of concept maps or trees) and problem-based learning (PBL).

Several terms (e.g., knowledge mapping, cognitive mapping, semantic networking) have been employed for the type of meta-cognitive learning strategy represented by concept mapping. Concept maps are schematic drawings in which individual concepts are connected by linking phrases and labelled to represent the relationships among them (9,10). A number of advantages involving the areas of teaching, learning, curriculum development, and assessment have been reported with the use of concept mapping. Concept map research has shown the maps to promote active, meaningful student learning and enhance motivation. Concept maps, when provided to students to demonstrate key concepts, have also been shown to improve test scores and student satisfaction with learning(8). Further, the use of concept maps could enhance student note taking and their ability to extract and organize the information gained from assignments and readings(11).

Concept maps have been used by several disciplines (e.g., science, mathematics, chemistry, nursing, medicine, psycholo-
Problem-based learning (PBL) is beginning to be used more frequently in medical schools (17,18), and its use has been expanding in pharmacy, usually in individual courses (2,7,19-21). Although the definitions of PBL have varied, it is an educational method focusing on the acquisition, synthesis, and appraisal of knowledge by actively working through problems using facilitated (small groups with tutors/facilitators) and self-directed learning (22). Unlike the case study approach in which students apply information to a problem after they acquire the knowledge, with PBL the students are presented with a problem/case prior to being taught the concepts involved. They then must identify issues to learn/information needed to resolve the problem, obtain the necessary information, apply the information to the problem, and summarize what they have learned (17). Advantages of PBL include less use of memorization and studying simply for short-term recall, greater utilization of library resources, higher levels of student satisfaction, generally higher clinical ratings of PBL medical school graduates by their faculty supervisors, faculty satisfaction, greater faculty-student interaction, and less student boredom with school work (17,23). The potential disadvantages of PBL relate to cost, particularly with regard to faculty effort as facilitators/guides (24), efficiency of time utilization (e.g., approximately 18 percent less content per unit time is covered in a PBL vs. a conventional curriculum), and resources needed (e.g., available references, paper costs, etc.) (17). Personnel costs could be a prohibitive factor for PBL implementation when 10 or more small groups are used at a time and for class sizes reaching and exceeding 100 students (17), common in many schools of pharmacy. It has therefore been predicted that a “blending” of PBL and traditional educational techniques will be seen to a greater extent in the future.

BACKGROUND FOR PROJECT IMPLEMENTATION

A recent review emphasized the importance of knowledge structure in clinical problem-solving (25). Well organized knowledge structures have been suggested as necessary for guiding students’ problem-solving. This involves recognition of “patterns of information typically observed in clinical problems,” followed by “the underlying organization of relevant knowledge into hierarchies or clusters of related concepts and procedures.” (25) This latter description is similar to the concept map. Concept maps have been reported to assist faculty in developing PBL cases for students (12). Several advantages were described for the use of concept maps in conjunction with the development of PBL cases. Concept maps can provide a concise summary of possible learning issues, assist faculty in assessing whether case goals have been achieved by students, visually explain conceptual associations among disciplines, and assist faculty (and students) in identifying the basic principles that extend across disciplines (12). Concept maps can also facilitate problem-solving skills in students (8). It has been recommended that problem-solving instruction de-emphasize the process of problem-solving and instead focus on “the development of highly accessible and well-structured knowledge bases.” (25) Thus, the integration of concept maps with PBL exercises could be a logical and potentially beneficial educational strategy for enhancing meaningful student learning. However, no published reports were found which described the integration and utilization of concept mapping with PBL cases.

With the continued expansion and sophistication of technology, computerized PBL materials could serve as a substitute for facilitator-led group sessions, thereby reducing personnel requirements for schools with large class sizes. They could also be used to supplement traditional facilitator-led PBL experiences in small and large institutions, to allow students to review PBL material at their own pace and enter responses on the computer (26), and to incorporate video or multimedia experiences that would be difficult to demonstrate in person within individual groups. Since the facilitator’s role should primarily be to guide, pose questions to, and provide appropriate corrective feedback and support to students within PBL sessions (17), a computer program could simulate this process and function as an “expert” tutor or facilitator. Facilitator expertise has been reported to be advantageous for enhancing student learning with PBL, particularly when a problem lacks sufficient structure or when the students lack prior knowledge of a subject (27). Thus, the computer can serve as a consistent source of expertise with respect to PBL case content.

Problem-based learning cases have been used in three pharmacy basic science disciplines at WVU - pharmacuetics, medicinal chemistry, and pharmacokinetics - as part of a previously funded project by the U.S. Department of Education. This project used a “middle ground” approach to PBL (17, 25), in which small group problem-solving and case study analyses were incorporated into the basic sciences courses as a supplement to faculty directed instruction. Teaching of the basic sciences were integrated with clinically relevant examples, and students’ information retrieval skills and literature use were enhanced. Several integrated cases with accompanying comprehensive facilitators’ guides were written and utilized. The project was shown to enhance student learning and was favorably evaluated by pharmacy students. However, as previously noted by others, the personnel requirement was felt by some faculty to be problematic. The pharmacy class size at WVU at the time (BS program) was approximately 86 students and 10 small groups were used each semester. About 525 total facilitator hours were required each semester for the small group sessions and several of the facilitators would not have had teaching responsibilities in the involved courses if PBL had not been used. Thus, it was decided to initiate a project to computerize several of the PBL cases with integrated concept maps to illustrate key concepts.

PROJECT GOALS AND OBJECTIVES

The instructor goals for the project were to: (i) develop interactive computerized PBL cases integrating pharmacuetics and medicinal chemistry using clinically relevant problems, to allow for individualized, student-centered learning; (ii) evaluate the effectiveness of the computerized PBL cases vs. traditional facilitator-led PBL sessions; and (iii) develop, refine, incorporate, and evaluate concept maps as tools to enhance problem-solving and learning when used in conjunction with computerized PBL exercises.

The goals for the students were to: (i) demonstrate a thorough understanding of several basic pharmaceutical sciences (medicinal chemistry, pharmaceutics) concepts; (ii) apply the
basic sciences concepts learned in one discipline to other disciplines; (iii) use a logical reasoning process to apply basic sciences concepts to pharmacy practice or patient related problems; (iv) identify and use appropriate resources to collect the information needed to resolve the pharmacy practice or patient related problems; and (v) demonstrate effective interpersonal communication and team-building skills.

Each of the computerized cases developed had specific learning objectives (Appendix A). Some of the case learning objectives overlapped in order to reinforce the concepts involved and to help ensure student proficiency in achieving the associated outcomes.

COMPUTERIZED PBL CASE DESIGN AND DEVELOPMENT

A total of 16 PBL cases integrating pharmaceutics and medicinal chemistry with comprehensive written facilitators' guides were successfully used and evaluated by first professional year pharmacy students during the Spring 1995, 1996, and 1997 semesters. The use of these cases in small, facilitator led groups allowed the investigators to identify and compile the types of issues brought up by students during the PBL group discussions. Ten cases were selected from among those used during the facilitator-led PBL sessions in the Spring 1997 semester. The cases used during this semester focused on pharmaceutics and medicinal chemistry concepts. The cases selected consisted of problems involving the following drugs: Methicillin/Miconazole, Methotrexate, Trifluoperazine, Glycopyrrolate, Tetracaine, Dipivefrin, Cocaine, Erythromycin, Furosemide, and Propanolol.

Authorware Professional™ was the software used for case development. The computerized cases were structured in a manner that allowed students to complete all the steps in the PBL process (i.e., identify and clarify the problem, develop and rank hypotheses, state the goal, generate ideas to solve the problem, prepare a plan of action) normally performed in the facilitator-led small group settings (Appendix B). After viewing a problem scenario, students asked open-ended questions of the computer to clarify the situation. The computer was programmed to “match” keywords or phrases in the questions and either provide additional data in response, assist the students in resolving the questions themselves by guiding them through a series of prompts for which responses were needed (similar to what a facilitator might do during a group discussion), or refer them to references to find the needed information. All “unmatched” questions the students asked were automatically recorded by the computer to allow for future incorporation of new keywords. Students were asked to rank order hypotheses for the cause(s) of the problem, and they received feedback and obtained helpful hints as needed to arrive at a reasonable option(s). Students were also asked as part of the cases to state a goal for the case/situation, type in potential ideas to resolve the problem, and prepare a plan of action. Sound (e.g., narration in places where individuals are speaking, phones ringing, etc.) was also incorporated in selected parts of the cases.

For key basic sciences concepts in the cases, concept maps or portions of maps were incorporated within the case in the appropriate areas (see example in Appendix C). For assessment purposes, two versions of the computerized PBL cases were initially developed: Version 1 - computerized PBL cases without concept map material, and Version 2 - computerized PBL cases (identical in format and content to Version 1) with the addition of concept map material. To evaluate the effectiveness of the concept maps as learning tools, half of the students were assigned to use the Version 1 PBL computer cases and the other half used the Version 2 computerized cases.

Facilitator-led PBL cases that previously included graded written assignments also incorporated these writing assignments into the corresponding computerized cases to make the PBL experiences as similar as possible between students. For example, the tetracaine case required students to individually write down hypotheses and rankings of their likelihood, and to turn their written material in for grading. The computerized tetracaine case was designed so that students were unable to proceed into the hypotheses portion of the problem without a password. At that point, students were required to individually write down their hypotheses, rank order them, and turn them in. In addition, at selected points during each of the cases, the computer recorded students' choices or their responses to questions. These data were also used as a measure of the students' problem-solving abilities, in lieu of direct facilitator observations of the groups.

Student Audience/Place Used in Curriculum

The two courses in which the computerized cases were used and evaluated were Concepts in Pharmaceutics and Fundamentals of Medicinal Chemistry 1, both required courses that were taught at the time to first professional year BS degree pharmacy students. The first year students were not familiar with the drugs used in the cases and needed to research them as they worked through the sessions, which introduced them to the use of various reference sources. In the new six-year entry-level PharmD curriculum which admitted the first class in Fall of 1998, the majority of the computerized cases are being used in an integrated Pharmaceutical Care Lab during the Spring semester of year one. An additional case was used during the Fall semester of the second year curriculum and another case in the Spring semester of year two. This was done because these two cases meshed better with the new ability-based outcomes developed for the second year curriculum.

Implementation Process

To evaluate the extent to which the project goals and objectives were achieved, control and experimental groups of students were used. The control group consisted of the first year BS program pharmacy students during the Spring semester of 1997 and the experimental group consisted of the first year BS program pharmacy students during the Spring semester of 1998. Both groups received the same orientation to the PBL process, including a review of the problem solving steps that should be followed (Appendix B). Only the experimental group completed the computerized PBL cases. In addition to the computerized cases, these students also participated in a total of four facilitator-led sessions in small groups. The control group received only facilitator-led PBL sessions in small groups, on an approximately weekly basis, in their Concepts in Pharmaceutics and Fundamentals of Medicinal Chemistry 1 courses. For both the control and experimental groups, approximately two to three hours per week were set aside in these courses for conducting the PBL sessions. The control students received the same PBL cases/problems as the experimental group and served as a comparison or contrast to the experimental group with regard to their problem-solving skills, thinking abilities, and knowledge and application of basic sciences concepts.

The instructors were able to complete, utilize in class, and evaluate eight of the planned computerized cases for the experimental group—all except the cocaine and methicillin/micona-
zole cases. A facilitator-led session was used in place of the computerized methicillin/miconazole case, which was unable to be completed in time. The students also completed the first part of the cocaine case on the computer and worked through the remainder of the case via a written assignment. At present, the cocaine case has been completed and used during Spring 1999 and it is planned to completely revise the methicillin/miconazole case.

The students worked in groups of eight or nine during their PBL experiences in both the control (for all cases) and experimental (for the four facilitator led cases) classes. These small groups were balanced with regard to average GPA for the students in each individual group, those using the computer cases without concept maps and those using the computer cases with concept maps (computer cases without concept maps - mean group GPA = 3.44, computer cases with concept maps - mean group GPA = 3.33), and the male to female ratio, to the extent possible. During the eight computerized cases, experimental group students were assigned to work at the computers in groups of two or three (keeping within their larger group of eight to nine students). In order for different students to gain experience working together, the groups of two to three were rotated three times during the semester (i.e., four different groups of two or three worked together at the computer over the semester). In addition to one or two teaching assistants working in the computer labs, one or two of the instructors were also present as the students worked through each of the cases to assist with any computer-related problems and to “facilitate” any case related issues raised. In general, students required about 1 1/2 to three hours to complete each case.

The attitudes of control and experimental students toward the PBL sessions overall, their facilitators, and the individual cases were obtained through the use of surveys and evaluation forms. Students in both the control and experimental groups also completed an evaluation of each of the peers in their group; each individual student received a total of seven peer evaluations that were averaged into a score that counted for 15 percent of their overall PBL grade.

RESULTS

Evidence of Student Learning

The GPAs of the control and experimental group students at the beginning of their Spring semesters were comparable: average GPA = 3.37 (range = 2.3 - 4.0) for control group and average GPA = 3.39 (range = 2.2 - 4.0) for experimental group. Control group students received a total of 12 weekly quizzes over the course of the semester, six each in the Concepts in Pharmaceutics and the Fundamentals of Medicinal Chemistry I courses. The quizzes were staggered between the classes on alternate weeks. Similar to the control group, the experimental students also received a total of 12 weekly quizzes over the course of the semester, six each in the Concepts in Pharmaceutics and the Fundamentals of Medicinal Chemistry I courses. The quizzes were based on the learning objectives for the PBL case(s) completed during the previous week. The same quizzes were used for the Concepts in Pharmaceutics and the Fundamentals of Medicinal Chemistry I courses (with one exception for the Medicinal Chemistry course) for both the control and experimental groups (quizzes were not returned). The different quiz in the Medicinal Chemistry course tested similar concepts in both the control and experimental groups.

The average scores on the six quizzes in the Concepts in Pharmaceutics course ranged from 2.8 to 4.9 (maximum = 5.0 points) vs. 3.5 to 4.9 (maximum = 5.0 points) in the experimental and control groups, respectively. Analyses (t-tests) showed no statistically significant differences between the control and experimental groups for four of the quizzes ($P > 0.09$). Experimental students performed significantly better than control students for one quiz (means of 4.7 vs. 4.1, respectively; $P = 0.0004$) and significantly worse than control students for one quiz (means of 2.8 vs. 3.5, respectively; $P = 0.003$). Experimental group students complained that the concepts covered in this last quiz were not adequately reviewed by the computer program, although in fact: (i) the computer recorded data showed that many students skipped the section in the computerized case that contained the applicable material, and (ii) computer feedback recommended to the students that it be reviewed. This computer case will be revised based on the data obtained from the quiz to provide greater “tutorial” material for students desiring this information, and to also include the option for students to review the applicable information in several parts, as opposed to just one part, of the computer program.

The average scores on the six quizzes in the Fundamentals of Medicinal Chemistry I course ranged from 3.5 to 4.8 (maximum = 5.0 points) vs. 2.7 to 4.4 (maximum = 5.0 points) in the experimental and control groups, respectively. Analyses (t-tests) showed no statistically significant differences between the control and experimental groups for three of the quizzes ($P > 0.0001$; quiz 4 - means of 3.4 vs. 2.7, respectively, $P < 0.0001$; quiz 6 - means of 4.8 vs. 3.3, respectively; $P < 0.0001$). Quiz 4 was the quiz that tested similar, but not identical, concepts in both student groups. The quiz scores in both the pharmaceutics and medicinal chemistry courses indicated that the computerized cases were at least as effective, and in some cases more effective, than comparable facilitator-led cases for the objectives covered.

Comparing the 12 quiz scores between the students who used the computer cases with concept maps and those who used the cases without the maps, students in the group without concept maps scored higher on seven of the 12 quizzes (mean increase = 0.08 points out of five points total) and students in the group with concept maps scored higher on the remaining five quizzes (mean increase = 0.16 points out of five points). There was a maximum mean difference on an individual quiz of 0.31 points (out of five points total) in favor of the concept map group, and a maximum mean difference on a quiz of 0.15 points in favor of the group without the maps. The mean differences between the groups were not significantly different.

In addition to the quiz information, data were recorded during actual use of the computerized cases. These data were used as a measure of the students’ problem-solving abilities in lieu of direct facilitator observations for the experimental group. For the control group, facilitator evaluations of students constituted 60 percent of the students’ overall PBL grade (with written assignments and peer evaluations constituting the remaining 40 percent of the grade). For the experimental group, facilitator evaluations constituted 15 percent and data recorded from the computer cases constituted 45 percent (total = 60 percent) of the students’ overall PBL grade (with written assignments and peer evaluations again constituting the remaining 40 percent of the grade). The average overall PBL grades in the control and experimental groups were 87.4 percent and 92.6 percent, respectively ($P < 0.0001$). In general, students did very well on the computer case questions, with the
majority of students (over 50 percent) scoring 100 percent on each case. This is not completely unexpected, since the computer cases were designed to help students think through the material by posing questions and asking them to research information, with feedback provided. The computer also can remove a degree of the subjectivity that exists with facilitator evaluations. On the other hand, the facilitator evaluations included assessments of communication, team building, self-assessment, and group assessment skills that the computer recorded data lacked. This was compensated to an extent by the peer evaluations.

Student Attitudes

Attitudinal data was obtained for both the control and experimental groups. For the control group, students indicated from open-ended questions that the most important skills they acquired from the PBL sessions were communication skills/group interaction skills (N = 28), problem-solving skills (N = 22), and use of resources (N = 13). The majority of students felt that peer discussions facilitated their ability to solve problems (N = 77 positive comments), compared to 16 comments that peers hindered their ability. In response to the question of whether students preferred the PBL approach over traditional lectures, 51 replied yes, eight replied no, and six were unsure.

The experimental group students indicated that the most important skills they acquired from PBL were problem-solving skills (N = 41), use of resources (N = 30), and communication skills/group interaction skills (N = 16). Since the student groups were smaller during use of the computer cases, it is not surprising that somewhat fewer students felt that PBL enhanced communication and interaction skills. However, the significantly greater number of experimental group students who felt that problem-solving and resource skills were the most important skills acquired from PBL was interesting. Similar to the control group, the majority of experimental students felt that peer discussions facilitated their ability to solve problems (N = 74 positive comments), compared to 11 comments that peers hindered their ability. In response to the question of whether students preferred the PBL approach over traditional lectures, 54 replied yes, 10 replied no, and eight were unsure. In response to the question of whether students preferred the use of computer cases or facilitator-led cases, 29 students commented they liked both, 17 preferred the computer cases, and 37 preferred the facilitator-led sessions.

Table I summarizes the results from the survey asking specific questions about the computer cases. Students felt the cases promoted student-centered discussion, assisted them in taking responsibility for their own learning, were easy to use, and that they learned from the cases. The cases were often frustrated during the “Clarify the Problem” step of the computer cases, felt that they were occasionally rushed using the computer cases, and that the computer case feedback was sometimes vague. Correction of these problems should minimize these student frustrations. Students were neutral (mean = 3.0) in their opinions of whether the concept maps were a valuable addition to the cases (see discussion of these issues in “Changes Initiated and Follow-Up Data” section).

When students in the control and experimental groups were asked to indicate the case they learned the most from, the same cases appeared among the top four in both classes: fenfluramine (individual written case for both groups), propranolol (facilitator-led in control group; computerized in experimental group), levodopa/carbidopa (facilitator-led in both), and erythromycin (facilitator-led in control group; computerized in experimental group). Thus, the format used (facilitator vs. computerized) per se did not appear to affect student opinions about the cases.

Changes Initiated and Follow-Up Data

Since it required more time than initially anticipated to develop the computer cases, the eight completed cases were not thoroughly field tested prior to their use. Although each case was reviewed by one or two of the instructors and one or two graduate students (with suggested revisions incorporated in the cases), the complete cases were not reviewed initially to the extent desired prior to their use by the entire class. Despite this, there were no major technical problems encountered during student use of the cases. The problem encountered most frequently, and consistently the source of greatest annoyance to students (apparent from student comments during their evaluations and discussions with them), involved the “Clarify the Problem” step in each case. In this step, students typed in open-ended questions related to the case/problem in order to obtain additional information helpful to its resolution. The computer program was formatted in this way, as opposed to having students select from a menu of options, to most closely mimic activities in the facilitator-led sessions. The computer was pro-

Table I. Student attitudes regarding computerized cases

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computer offered constructive feedback.</td>
<td>3.4</td>
</tr>
<tr>
<td>2. Computer promoted student-directed discussion.</td>
<td>3.9</td>
</tr>
<tr>
<td>3. Computer assisted in clarifying situations without directly providing answers.</td>
<td>3.3</td>
</tr>
<tr>
<td>4. Computer allowed students to spend as much time as needed to grasp difficult concepts.</td>
<td>3.5</td>
</tr>
<tr>
<td>5. Computer encouraged students to ask questions and reflected questions back to the students.</td>
<td>3.4</td>
</tr>
<tr>
<td>6. Computer assisted students in taking responsibility for their own learning.</td>
<td>4.0</td>
</tr>
<tr>
<td>7. Computer programs were easy to use.</td>
<td>3.5</td>
</tr>
<tr>
<td>8. Computer cases contained the appropriate level of detail.</td>
<td>3.4</td>
</tr>
<tr>
<td>9. It was clear from the computer cases what the key concepts were that I was expected to learn.</td>
<td>3.8</td>
</tr>
<tr>
<td>10. Enough time was available during class sessions for computer use.</td>
<td>3.1</td>
</tr>
<tr>
<td>11. Computer served as an appropriate content resource when other avenues were exhausted.</td>
<td>3.1</td>
</tr>
<tr>
<td>12. The group size was appropriate for computer use.</td>
<td>4.1</td>
</tr>
<tr>
<td>13. Computer made cases fun to work through.</td>
<td>3.4</td>
</tr>
<tr>
<td>14. I learned from the computer cases.</td>
<td>3.9</td>
</tr>
<tr>
<td>15. The concept maps clarified relationships among key concepts.</td>
<td>3.0</td>
</tr>
<tr>
<td>16. The concept maps were a valuable addition to the computer cases.</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*Means based upon Likert score of 5 = Strongly agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly disagree.*
grammed to provide specific responses based upon key words entered. Since students were typing in free text, it was difficult for the instructors to anticipate in advance every possible way in which students might phrase a question. Thus, many times when students typied in questions, the computer replied that no information was available in the data base.

Beginning with the second computer case used (trifluoperazine), the computer was programmed to record any question a student asked that was “unmatched” by the data base. As part of the revision process, the lists of “unmatched” questions for each case were reviewed and the key words the students used incorporated into the data base. This should allow for much less student frustration; further, this will allow the data bases in the computer cases to become larger and result in fewer “unmatched” questions each year. For example, trifluoperazine was used this semester (Spring 1999) for the second time. The experimental group students (1998) asked a mean of eight “matched” questions and a mean of 24 “unmatched” questions per individual group during this case. However, five of the student groups asked between 40 and 50 questions that the computer failed to match, often with the same question phrased several different ways in an attempt to receive an answer. It is not surprising that several students became frustrated with this. In contrast, the 1999 students (using the revised case) asked a mean of 12 “matched” questions and only four “unmatched” questions per individual group. The most “unmatched” questions any individual student group asked was 16; in fact, only three groups asked over 10 “unmatched” questions. As with last year, these new “unmatched” questions will be added to the computer data base to further strengthen it for next year.

Other changes made with regard to the computerized cases this semester involve having larger student groups working at the computers, the scheduling of more time for computer use, clearer answers in some of the computer responses, and making the concept maps easier to read and simpler. Current students are assigned to work at the computers in groups of four or five, with two computers available to look at within each of the groups. This change was made based on the observation in the experimental class that some of the small groups of two or three did not function well. When one student in the two-membered groups went to look at a reference, the other student often just sat there doing nothing. With the larger groups, discussion can continue. Also, sometimes all two (or three) students in the smaller groups would be “stuck” on a topic. With the larger groups, the likelihood of this happening appears to be reduced. With regard to the time allotted, with the experimental students some cases had to be continued the following week since students could not complete the case in the two hours allowed per session (problems with use of the Health Sciences Center’s Computer Based Learning Center necessitated the scheduling of only two hour blocks). This year, three hour blocks per session were scheduled for computer use in the School’s new Center for Pharmaceutical Care Education. Further, some students asked this semester about being able to, on their own, review the cases again after their use in class. This was allowed this year. Wording in the feedback provided by the computer is being reviewed on an ongoing basis to clearly indicate correct and incorrect responses by students. Finally, the concept maps often used a small font that was difficult to read and some maps were fairly complex. It was noted during sessions that students often bypassed the maps because of this. This year, the font was changed to a larger, more readable size and large concept maps were subdivided into smaller ones. A brief quiz, specifically focusing on concept map mate-

rial, was also used during one of the cases this year.

Follow-up attitudinal data about the PBL sessions using an open-ended questionnaire were obtained from the Spring 1999 class of 67 first year, entry-level pharmacy students. These students only used the computerized cases with no facilitator-led sessions. With regard to the most important skills students believed they learned from the PBL approach, the most common skills mentioned by the 1999 students, similar to the previous class, included problem-solving skills (N = 40), use of resources (N = 23), and communication/group interaction skills (N = 14). Most students felt that peers facilitated their ability to solve problems (49 positive comments) compared to 11 comments that peers hindered their ability. A total of 46 students indicated they preferred the PBL approach over traditional lectures, four preferred lectures, and eight were unsure or liked both equally. Interestingly, when the 1999 class was asked whether a faculty or graduate student facilitator would be more or less attractive than the computer, 40 indicated they would prefer the computer, 12 indicated they would prefer a facilitator, and six would like a combination approach.

CONCLUSIONS

Only limited information exists in the literature regarding the use of computerized PBL cases in an attempt to achieve the benefits of PBL with less resource expenditures(26). The use of concept maps is also relatively new in pharmacy education. The computer cases were found to be successful in achieving the project goals. Students appeared to achieve the learning objectives to at least a similar extent through the use of either the facilitator-led PBL sessions or the computer cases. The savings with respect to personnel hours, particularly with continued use of the computer cases, is clear. For each two to three hour facilitator-led session, nine different facilitators were needed to work with the small groups, resulting in up to 216 personnel hours required each time the eight cases were taught. In contrast, assuming two instructors are present during use of the eight computerized cases (two sessions per week @ 3 hours per session), only 96 personnel hours would be required for the eight cases. Although a benefit for concept map integration was not demonstrated thus far, it is anticipated that making the maps more readable and usable will be valuable to students. Other revisions that continue to be made in the computer cases should continue to enhance them.

Two additional computer cases were developed during the past year. An introductory case, designed primarily to familiarize students with the problem-solving steps and navigation through the computer cases, involved antipyretic use for fever. A further case (breast milk excretion principles) was developed for the computer cases, involved antipyretic use for fever. A further case (breast milk excretion principles) was developed this summer so that use of some of the cases can be rotated during alternate years to minimize the likelihood of students in one year providing case “answers” to students the following year.

Finally, it is planned to make all of the computerized cases available to other interested schools/colleges of pharmacy via the Internet in the near future.

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References


APPENDIX A. COMPUTERIZED PBL CASE LEARNING OBJECTIVES

1. Tetracaine Case:
   a) Explain how functional groups can affect the water solubility of a drug.
   b) Identify the hydrolysis products of an ester and predict their water solubility in solutions of varying pH.
   c) Predict the pKa values of common functional groups such as amines, amines, and carboxylic acids.
   d) Describe whether, and how, temperature changes affect drug solubility.
   e) Explain the circumstances under which it is appropriate to resolubilize drug crystals in solution by heating.
2. Trifluperazine Case:
   a) Recognize basic nitrogenous within a drug’s chemical structure and predict that drug’s approximate pKa.
   b) Recognize and identify functional groups within a drug’s structure that are susceptible to air oxidation and photodegradation and predict likely routes of decomposition.
   c) Describe methods for minimizing the probability and/or extent of decomposition.
3. Erythromycin Case:
   a) Identify acetal and ester functional groups in a molecule.
   b) Describe whether these functional groups in a drug molecule are subject to degradation and, if so, identify the conditions under which the groups are susceptible to degradation and the products of the degradation reaction.
   c) Explain how an enteric coating works and the reason for its use in a product formulation, and identify whether specific products formulated with an enteric coat should be altered.
   d) Describe physical or chemical methods that can be used to minimize the degradation of drugs susceptible to acid-catalyzed hydrolysis in the stomach and the manner by which these methods accomplish this.
4. Methotrexate Case:
   a) Estimate the pKa values of chemical compounds.
   b) Predict the solubility of drugs based on the pKa(s) of the drug and the pH of the solution and the influence of solubility on drug (in vivo) distribution and elimination.
5. Dipiverine Case:
   a) Explain what a prodrug is and the potential advantages associated with administration of a prodrug.
   b) Recognize that esters are subject to hydrolysis and identify the products of ester hydrolysis.
   c) Identify functional groups in a drug molecule that are subject to oxidation, chemical decomposition, and photodegradation.
   d) Predict the relative lipophilicplicity of drug structures and the ester derivatives of those structures.
6. Glycopyrrolate Case:
   a) Explain how the chemical structure of a drug affects its absorption.
   b) Describe how different routes of administration may lead to different amounts of available drug.
   c) Explain how a drug’s dosage form or formulation characteristics affect oral absorption.
7. Propranolol Case:
   a) Describe the characteristics of a drug that could result in bioavailability changes when switching from an immediate release to a sustained release oral dosage form.
   b) Describe how drug is released from a bead-based, matrix design sustained release formulation and the factors controlling its release.
   c) Use product formulation information to determine how sustained release is achieved in a drug product.
   d) Explain how saturable first-pass metabolism influences unchanged drug levels in the plasma (i.e., bioavailability).
   e) Describe how changes in a drug’s bioavailability could
f) Characterize the relationship between the degree of
hydrophilicity of relatively low molecular weight drugs and
the likelihood that they will be renally excreted unchanged
vs. liver metabolized.
g) Describe the effects that impaired renal function can have
on a drug that is excreted unchanged by the kidneys.
h) Determine the relative lipophilicity of the beta receptor
blocking agents by examining their chemical structures, and
predict the extent to which they will be metabolized.
i) Identify the cardioselective beta receptor blocking agents
and describe the clinical significance of this property.

8. Furosemide Case:
a) Identify the pKa values of common functional groups.
b) Recognize specific functional groups that are most suscep-
tible to light-catalyzed photodegradation.
c) Describe what a color change in a tablet could indicate.
d) Identify methods that can be used to maximize shelf-life,
including how a drug is formulated, packaged, dispensed,
and stored.
e) Identify appropriate storage conditions for a drug product
based upon its formulation and stability characteristics.

9. Cocaine Case:
a) Identify the basic product characteristics of a sterile prod-
uct.
b) Identify factors important in the design and formulation of
sterile products.
c) Determine appropriate methods for formulating and prepar-
ing a sterile ophthalmic product.
d) Estimate drug product tonicity, pH, and shelf-life.
e) Choose an appropriate method for product sterilization,
given the drug’s chemistry.
f) Describe how the site of drug delivery influences product
formulation.

APPENDIX B.THE PROCESS OF REASONING AND
DECISION MAKING

When working through any of the steps listed, you may need to obtain
supplemental information from various sources. Be prepared to iden-
tify these sources and obtain the information.

Step 1 Identify and clarify the problem(s)
The key to this step is asking a series of questions and determining
their answers.
To identify the problem(s), ask:
1) What is wrong in this situation? [with this patient? with this
drug(s)? with this drug product(s)? with the use or handling
of the drug product(s)?]
To clarify the problem(s), ask:
1) What was the sequence of events leading up to the problem?
2) a. What specific factors are involved?
b) Which of these factors are relevant to the problem?
3) What are the relevant characteristics of the involved drug(s)
and drug product(s)? - such as:
   Chemical functional groups and properties
   (acid/base, reactivity)?
   Dosage form(s)?
   Route of administration?

Formulation(s)?
Pharmacokinetic (absorption, distribution,
metabolism, excretion) properties?
Manufacturing mode used?
3) What are the relevant characteristics of the involved
patient? - this can include, but not be limited to:
   Age and sex of patient?
   Other medical illnesses or conditions in patient?
   Other drugs taken by patient?
   Situational factors - such as noncompliance,
   patient beliefs or attitudes, etc.
4) How serious is the problem?
5) What is the time frame for resolving the problem?

Step 2. A. Develop hypotheses for the cause(s) of the problem(s)
Consider:
1) What kinds of conditions or circumstances could be possible
causes of a problem(s) of this type? - such as:
   Physical conditions?
   Chemical conditions?
   Patient factors?
   etc.
2) What are the predisposing factors to the development of the
problem(s) in this case?

Step 2. B. Determine and rank the likelihood of the hypotheses
Consider:
1) What additional information is needed to fully clarify or
   evaluate the hypotheses?
2) Which hypothesis best fits the available information?

Step 3. State the goal
Clearly identify what you hope to accomplish in the situation.

Step 4. Generate ideas to solve the problem(s)
In this step, it is important to “brainstorm” ideas for possible solutions
to the problem(s). Do not quickly dismiss or ignore ideas without giv-
ing sufficient thought to them.
Consider:
1) What procedures, methods or techniques have the potential
to accomplish the goal?
2) What procedures, methods or techniques have been used
previously in similar situations to solve the problem(s)?

Step 5. Prepare a plan of action
You need to determine which specific solution to select. Be prepared
to justify your selection if disagreement arises. In order to make your
selection consider:
1) What are the advantages and disadvantages of each poten-
tial solution?
2) Which of the possible solutions to the problem is/are the
most: logical? safe and effective? practical to implement?
cost effective? consistent with drug/dosage form con-
strainst? consistent with patient needs/desires/abilities?
consistent with the stated goal?
3) a. How will the solution be implemented? (Be specific)
b. What difficulties or obstacles could occur during
   implementation? How could these be overcome
   or by passed if they occur?

Adapted from: Wales CE, Nardi AH, and Stager RA, Thinking Skills: Making
APPENDIX C: EXAMPLE CONCEPT MAP FROM GLYCOPHYRROLATE CASE - INTERRELATIONSHIPS AMONG PHYSICAL-CHEMICAL PROPERTIES OF A DRUG AND PASSIVE TRANSPORT.