Outcomes-Based Integrated Hybrid PBL Curriculum

Anne Marie Whelan, Susan Mansour and Patrick Farmer

College of Pharmacy, Dalhousie University, 5968 College Street, Halifax, Nova Scotia, Canada, B3H 3J5

In 1995 we identified several goals for curricular change: increase accountability; lead practice; improved patient health care; increase graduates' communication skills; and improve graduates' problem solving. We developed an outcomes-based integrated hybrid problem-based learning (PBL) curriculum. The curriculum includes integrated PBL units, organized primarily by body system and disease states, a four-year skills laboratory, a three-year critical appraisal series, and practice experiences. The integrated PBL process simulates pharmacy practice and encourages students to develop and practice life-long learning skills. Students are assessed both in each curricular component and comprehensively. Evaluation of the curriculum includes evaluations by students, results of an annual progress examination, and several graduate, preceptor and employer surveys. The College has achieved complete curricular change with the first class graduating in the spring of 2001. Interim curricular evaluation results indicate students achieve levels of knowledge and skills similar to, or better than, those achieved previously.

INTRODUCTION

The College of Pharmacy at Dalhousie University in Halifax, Nova Scotia, Canada is responsible for the pharmacy education of Canada's three Maritime provinces. The entry to practice degree is a Bachelor of Science degree requiring one year of prerequisite undergraduate study followed by four years in the professional program. In 1995 the College critically reviewed all of its programs and structures with the assistance of Dr. Lynn Curry of CurryCorp, based in Ottawa, Ontario as a facilitator. A transition team, comprised of 15 people representing faculty, staff, students and stakeholders, was established to oversee and facilitate the review and subsequent changes. Five working groups (Undergraduate Curriculum; Faculty Development; Management; Research, Scholarship and Graduate Studies; and Communications) similar in composition to the transition team, were established to aid the work. Each working group had specific goals, objectives and time lines.

In light of a desire to adopt strategies to facilitate more active learning and in response to the introduction in Canada of accreditation standards and process, the Undergraduate Curriculum Working Group conducted an in-depth review of the undergraduate pharmacy program. This led us to develop a unique outcomes-based integrated hybrid problem-based learning (PBL) curriculum that would achieve optimal outcomes within financial and other resource constraints. In the fall of 1997 we welcomed the first class to the program. We believe this curriculum is the first of its type in an entry-level pharmacy program. An overview of the processes used to develop and evaluate this innovative program is presented in this paper.

GOALS OF THE INNOVATION

Broad goals for curricular change included five fundamental improvements desired within the curriculum: *(i)* increase accountability by making the curriculum outcomes-based; *(ii)* increase the ability of the curriculum to lead practice; *(iii)* direct the curriculum toward improved patient health care; *(iv)* increase graduates' communication skills; and (v) improve the problem solving ability of graduates.

CHANGE PROCESS

Six general steps taken to achieve curricular change were to: *(i)* define the outcomes expected of pharmacy graduates at Dalhousie; *(ii)* determine the type of pharmacy degree; *(iii)* review and select a curricular design; *(iv)* develop the individual components of the curriculum; (*v*) develop student assessment methods that complement curricular design; and *(vi)* develop an overall curricular evaluation plan. An iterative decision making process known as facilitated deliberative inquiry (FDI) was used to involve many constituents(1,2). For us this was an effective means of achieving consensus on changes.

Defining Curricular Educational Outcomes

The first step in the change process was to define the specific educational outcomes that students would be expected to meet upon graduation. Several documents were reviewed by the Undergraduate Curriculum Working Group (AACP CAPE Educational Outcomes, 1994; Curriculum Outcome Analysis Preliminary Report, Faculty of Pharmacy, University of Toronto, April 1995; Competencies Required at the Point of Entrance to Pharmacy Practice in Canada, a summary of the Invitational Conference to Establish Outcome Standards for Canadian Pharmacy Education, June 1995). Outcomes developed at the Dalhousie College of Pharmacy national Invitational Conference to Establish Outcome Standards for Canadian Pharmacy Education, June 1995, with some modification

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[1]Manuscript based on the portfolio submitted to the 2002 Council of Faculties Innovations in Teaching Competition. [2]Parts of this material have been presented at *(i)* the Association of Faculties of Pharmacy of Canada Annual Meeting in Saskatoon, SK, Canada on June 25, 2000; and *(it)* the PBL 2002 A Pathway to Better Learning Conference in Baltimore, MD on June 20, 2002. *Am. J. Pharm. Educ,* 66, 302-311(2002); received 6/18/02, accepted 7/8/02.

Table I. Major [a] expected curricular outcomes of the Dalhousie College of Pharmacy

1. Contribute to client's need to maintain or re-established a state of well-being by meeting medication related and health needs
   - 1.4 Identify, solve, prevent medication related problems
     - 1.4.1 command of relevant disease knowledge
       - 1.4.1.1 normal anatomy, physiology, biochemistry
       - 1.4.1.2 describe the pathophysiology of a specific disease
     - 1.4.2 Command and application of relevant pharmaceutical knowledge
       - 1.4.3.2 relate the chemical/biochemical structure of drugs to their therapeutic action
     - 1.4.3 Assess and evaluate treatment including alternative and complementary options
     - 1.4.4 Develop a pharmacy care plan
   - 1.5 Provision of specific patient care
     - 1.5.1 communicate with client and other care professionals as appropriate
2. Contribute to decision making regarding the safe, effective and efficient use of drugs
3. Manage the business and practice environment of pharmacy
4. Continuously improve professional competence through a commitment to life-long learning
5. Contribute to the renewal and advancement of the profession
6. Skills, abilities and values to be demonstrated in all areas

[a] Each major outcomes has various elements. Examples of elements of Outcome #1 are shown.

best suited the needs of the College. In February 1996 these outcomes were accepted as the "Expected Curricular Outcomes of the Dalhousie College of Pharmacy." The six major outcomes are listed in Table I, showing as an example some of the elements of Outcome 1. The *Revised Educational Outcomes for a Baccalaureate Pharmacy Graduate in Canada* developed by the Association of Faculties of Pharmacy of Canada (AFPC) were subsequently adopted by the College(3).

Determining Type of Degree and Curricular Design

After choosing our desired curricular outcomes we debated which of a Baccalaureate and/or Doctorate in Pharmacy would best meet these outcomes. We concluded that a Bachelor's degree was the most appropriate.

In identifying the most appropriate curricular design to meet the Expected Curricular Outcomes of the Dalhousie College of Pharmacy, we considered several goals to be important: (*i*) the need for better integration of basic science with practice; (*ii*) enhanced student ability to apply knowledge to real world situations; *(iii)* better clinical functioning; and *(iv)* enhanced problem solving ability.

Taking the approach of building a pharmacy curriculum on the foundation of expected curricular outcomes allowed us to consider less traditional methods of curriculum organization and delivery. Problem-based learning seemed best suited to meet our needs and desired outcomes. "In this approach, the student takes on a patient problem, a health delivery problem, or a research problem as a stimulus for learning in the areas, subjects or disciplines that are appropriate for the student at the time. In doing this, the student exercises or further develops his problem-solving skills."(4) Thus, we selected PBL as the primary structure of the curriculum using patient cases as the focal point to integrate learning of various pharmacy disciplines.

Although the primary focus of the curriculum is small group PBL units, we recognized the need for complementary educational components such as laboratories for practice-based skills, a critical appraisal series and practice experience rotations. An overview of the organization of the curriculum is shown in Appendix A.

Our curriculum is hybrid in that it allows for these complementary educational components as well as a maximum of three hours per week of plenary classes to discuss certain difficult concepts and supplemental material associated with the PBL units. The hybrid nature of the curriculum also allows some flexibility in delivery methods of certain content material. For example, in year two, pharmacokinetics is offered in a non-PBL format such that students receive a lecture course accompanied by skills lab and critical appraisal. Additionally, we have designed a PBL curriculum that is faculty-directed in that faculty define the learning objectives for each case in each unit. The students receive these learning objectives at the end of each case.

Developing Curricular Components

Each educational component is comprised of several specific elements. We will focus on the PBL units, each of which is comprised of several cases. As the elements of the PBL units were developed, general (Table II) and then specific learning objectives (see the end of the case in Appendix B) were identified to provide opportunities for students to attain the particular knowledge, skills and abilities needed to achieve the curricular outcomes. The evolution of a particular outcome from general to specific objectives can be tracked through the curriculum as demonstrated below:

Specific Curricular Outcome. 1.4.3.2: Relate the chemical/biochemical structure of drugs to their therapeutic action.
PBL Unit Objective: What are the structural requirements for activity? (SAR)
Specific PBL Case Learning Objective for Case 3 in PHAR 2020.03. Analyze the medicinal chemistry of the drug classes used to treat glaucoma.

1. Integrated Hybrid PBL Units

PBL units begin with discrete subject/discipline units in the first year for each of the preclinical medical sciences, ranging in length from three weeks of microbiology to seven weeks of biochemistry. Students use a problem-solving approach incorporating hypothesis generation for these units(5). While students are immersed in these subjects additional activities include only a skills laboratory and a few hours a week in a community volunteer program. The PBL units in the second, third and fourth years are organized by disease state and body system and integrate pathophysiology, review of pharmacology, pharmacotherapeutics, medicinal chemistry, biopharmaceutics, pharmaceutics, and behavioral and administrative pharmacy in the context of a patient case. The integrated nature of the cases serves to illustrate clearly to the students the interconnections between the various disciplines and their importance

Table II. Overall PBL case approach and objectives for PBL units

1. Therapeutics: Each case situation must be approached from the perspective of pharmaceutical care as discussed in the Pharmaceutical Care (PC) Skills Lab and each student must learn how to use this approach independently. There are a minimum number of guiding questions in each case as it is assumed that students will use the PC approach. Thus, students must consider drug-related problems, outcomes (goals) of therapy, all nonpharmacologic and pharmacologic therapies, therapy of choice for the particular patient, pharmacy care plans, and monitoring. Students also need to understand the disease states in order to choose an appropriate therapy and thus must consider pathophysiology, signs and symptoms, etiology and epidemiology for each situation. Students are reminded that although individuals will have specific learning issues, all students are required to complete their own basic readings on the subject areas.
2. Pharmaceutical Sciences: Since Therapeutics is supported by the pharmaceutical sciences, including biopharmaceutics, medicinal chemistry natural products chemistry, pharmaceutics and pharmacokinetics, students are expected to develop pertinent Learning Issues in these disciplines as well. Whenever a new class of drugs or a new dosage form appears in a case, students should ask themselves such questions as
   - To what pharmacologic class does the drug belong?
   - What is its mechanism of its action?
   - What are the structural requirements for activity? (SAR)
   - How selective is its action? Does the drug have any side effects that are predictable from its structure? What effect does structure have on side effects, selectivity?
   - Are there other drugs that work by the same mechanism?
   - How are these drugs metabolized? Does the metabolism of these drugs affect therapy?
   - Based on an understanding of the route of administration of a particular drug, how does the dosage form impact upon the therapeutic objective of the drug?

to practice. The use of patient cases with a problem solving process that heavily integrates the pharmaceutical care model assists students' application of knowledge to real patients and better prepares them to function in a clinical environment. Students gain understanding of the patient's problem and identify appropriate pharmacotherapeutic recommendations with the aid of a tutor. The pharmacy-specific problem solving approach used in years two to four is shown in Appendix C.

Role of Tutors. PBL tutorial groups consist of approximately eight students and a tutor. The role of the tutor is to help the students through the process of self-directed learning. This role requires that tutors guide the student in learning as opposed to dispensing information to the student(6). The tutor must have coaching, modeling, and facilitation skills(6), as well as being able to activate students in their learning(7). All tutors attend a two-day standardized tutor training program modified from a program developed by the Faculty of Medicine, Dalhousie University(5) to provide tutors with the skills and knowledge they would need to fulfill their role. Additional workshops are developed as needed to provide additional training and support. In addition, a peer assessment program is in place whereby each tutor is observed by a peer and receives feedback for enhancing performance and skills. The majority of our tutors are non-experts. That is, they have no specific expertise in the subject areas being covered in the PBL units. For example, most of our tutors are non-academic pharmacists, graduate students, and nurses. In addition, the tutors play a major role in assessing the performance of the students in the tutorials (this is discussed further in section: Developing Student Assessments).

Role of Faculty. The introduction of this novel curriculum meant not only a new way of learning for the students but also a new way of "teaching" for faculty members. In addition to the more standard lecturing, faculty must also serve as case and tutor guide authors, resource experts, student assessors and, on occasion, tutors. Faculty determine the main focus of the patient cases by the issues that are included as well as by determining the learning objectives of the cases. A comprehensive tutor guide is prepared for each case to aid the tutors in facilitating their groups. The tutor guides are not provided to the students. The role of resource expert involves being available to the students individually or by group to address issues on which they have done some preparation but require guidance depth or understanding.

A faculty development program was established to aid faculty in understanding PBL and enhancing the skills they would need for these new roles. Perhaps most challenging for the faculty was the writing of cases that integrated pharmacy content, followed the intended curriculum outcomes and addressed specific learning objectives. Case writing workshops were held to help faculty members understand the basics. Several approaches to writing cases were then tested and an integrated case writing approach has evolved. As integrated cases require collaboration by a number of faculty members, the most efficient approach is the initial drafting of the case by the therapeutics expert followed by additions and modifications from medicinal chemistry, biopharmaceutics and pharmacokinetics, pharmaceutics, and pharmacy administration faculty. This maximizes the relevance of the pharmaceutical science and administration material presented. Cases vary in length from one to five days although most are formatted for three days. Case three from the Topical Products (Eye and Ear) unit in year two (Appendix B) is a five-day case which illustrates:

- how the case is constructed so students progressively learn about a disease state and its management over the course of several days;
- the integration of several content areas so students learn the relevant information about a topic *(e.g.,* review of anatomy/physiology of eye, pharmacology of eye medications, pharmaceutics of eye drops, pharmacokinetics of
- application of products to the eye, therapeutics of glaucoma medications); and
- practical application of knowledge to a patient case.

To aid faculty members with these new responsibilities an extensive curriculum manual was designed, collated and provided to all faculty members. The manual provides such information as an overview of the curriculum, curriculum outcomes, case writing guidelines, multiple choice question writing guidelines, tutor orientation information and a sample case and tutor guide. All faculty members also participated in a tutor training program.

Role of Students. As is obvious from the above description, students are not passive learners. They take a very active role in their daily learning especially in the PBL units, and as can be seen by a typical weekly timetable (Appendix D) students have considerable time for self-directed learning. The tutorials in the PBL units are two hours in length. When students receive the first page of the case *(e.g.,* Day One, Page One of the case shown in Appendix B) they must apply their prior knowledge, hypothesize, problem solve (using the process shown in Appendix C) and identify their learning needs. In this way, a list of learning issues is generated. All students in the group are responsible for a significant quantity of general background reading in addition to these specific learning issues. The specific learning issues are assigned by the group to individual students at the end of tutorial. Once the students have gone as far as they can they will be given the next page until they work through all the pages for a particular day.

The students assigned learning issues then locate information related to the learning issues by examining primary, secondary and tertiary literature sources. Students usually then format the information and citations to the literature into typed handouts to be given to their group mates to aid in their learning. The handouts vary in length and complexity depending on the case and particular learning issue. At subsequent tutorials, students pass out their handouts for the group to follow as the student leads the discussion on the content and application of the content back to the case. Students are encouraged to use overheads or write on the whiteboard to illustrate various points. Students are also expected to incorporate prior learning where appropriate and integrate learning from the various subject areas as they apply to the case *[e.g.,* how altering a dosage form (pharmaceutics) may alter the release/absorption (pharmacokinetics) of a drug, and thus the expected safety and efficacy (therapeutics)].

Once all the learning issues are discussed, the process begins again and the first page for the second day of the case is distributed. As shown by the case (Appendix B), Day 2, Page 2 consists of guiding questions. These are inserted by the case authors for the students to use as a stimulus for learning if the authors feel that the students may not readily identify the areas easily by themselves (especially in some of the pharmaceutical science areas). As the students progress into years three and four of the curriculum the use of guiding questions decreases as the students become more familiar with the problem solving process and recognize that comprehensive student learning is expected, as applicable, with every case. Not all cases will have all pharmacy disciplines covered; students gradually learn to recognize what is necessary to gain a thorough understanding of the topic area.

In some PBL units students are given additional assignments to supplement their learning. For example, in the nutrition unit they complete an assignment on calcium wherein they calculate their own calcium intake over the course of a week, as well as work through a hypothetical post-menopausal patient case regarding osteoporosis.

2. Complementary Curriculum Components

The critical appraisal series is a novel course that focuses on applied statistics, sourcing of drug information and critical evaluation of the literature. Application of skills in this series meshes with the particular area being studied in the PBL units at any one time.

Skills laboratories run throughout the four years of the curriculum and provide learning opportunities for the various pharmacy related skills such as written and verbal communication, compounding of medications, sterile preparation of medications, computer usage, use of various devices and many others. Activities are developed that provide opportunities for application of the material learned in the PBL units. Skills labs also prepare students for their various practice experience rotations. For instance, students learn sterile technique in second year skills lab prior to a technically oriented rotation in hospital pharmacy where they will see this technique in practice.

Practice experiences begin in the first year with one-half day/week spent in a health related community volunteer agency. Following the second year, students complete a two-week rotation in each of a community and hospital pharmacy with the goal of introduction to the more technical and administrative functions of pharmacy. Students complete four weeks following the third year in a clinical community pharmacy rotation. During the second term of the fourth year students spend six weeks in each of clinical community and hospital pharmacy rotations.

Developing Student Assessments

The importance of establishing that students are achieving the desired outcomes is self-evident. However, methods to achieve this in a PBL curriculum presented new challenges. Students learn in a variety of manners in this curriculum so each element had to be examined and the best methods of student assessment determined. It is essential that student assessments include methods of measuring content knowledge as well as higher order skills, such as critical thinking and problem solving and skill development. A comprehensive assessment plan was developed that included assessments for each curricular component as well as more global assessment methods. To minimize competition and enhance cooperative learning, we also decided that grading for all components of the curriculum would be pass or fail. No letter or number grades are recorded on the student's official transcript.

1. Student Assessments Used in the Integrated Hybrid PBL Units

Most PBL units have a midterm and final examination that includes questions from all pharmacy disciplines integrated into that unit. Students are expected to be able to incorporate and apply material learned previously. Questions may be multiple choice, short answer, or essay. Some units also incorporate the use of written assignments, and lab assessments when a science lab accompanies the unit. Questions increase in complexity as the students progress through the curriculum. For example, in year two students are just beginning integrated units using the pharmacy-specific problem solving approach. Therefore questions used at this stage are relatively straightforward, yet test both knowledge and application of both the content and the pharmaceutical care approach. By years three and four students are expected to have integrated the pharmaceutical care approach into their thought process and be able to integrate previous learning and various pharmacy disciplines when answering the questions. Thus, some questions test at the higher levels of analysis, synthesis and evaluation.

A tutor assessment report at the end of each unit provides an assessment of student performance in the PBL tutorial groups and addresses use of reasoning, knowledge acquisition

Table III. Mean scores, number of students and type of curriculum each year of the progress exam

Year of exam	First-year	Second-year	Third-year	Fourth-year
1998	PBL [a] 61.57 (N=60) [b]	Trad[c] 65.92 (N=25)	Trad 76.57 (N=23)	Trad 83.42 (N=12)
1999	PBL 60.68 (N=44)	PBL 68.69 (N=59)	Trad 78.60 (N=10)	Trad 82.69 (N=14)
2000	PBL 57.05 (N=42)	PBL 68.20 (N=45)	PBL 73.33 (N=58)	Trad 77.67 (N=12)
2001	PBL 57.95 (N=60)	PBL 63.44 (N=55)	PBL 73.51 (N=47)	PBL 75.63 (N=56)

[a] "PBL" designates students enrolled in the PBL curriculum.

[b] N = number of students in class who wrote the exam and volunteered to participate in the study. Students in the PBL curriculum were required to write the exam while those in the traditional were not.

[c] "Trad" designates students enrolled in the traditional lecture-based curriculum.

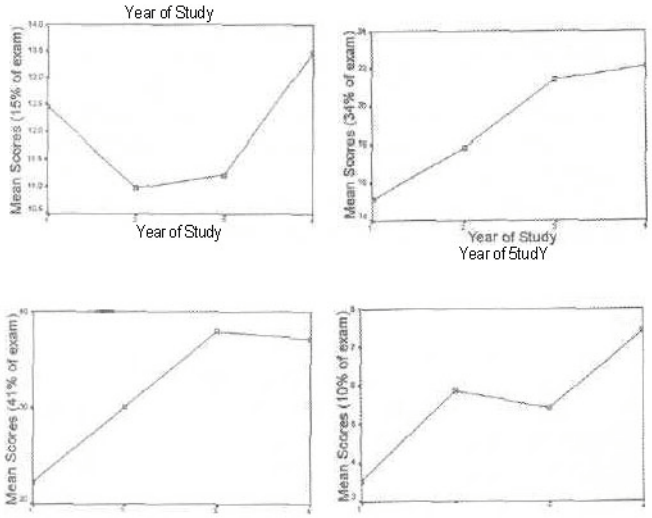

Fig. 1. Student performance by subject category.

and integration, group skills and self-assessment skills. The tutor assesses the student's ability to self-assess and this is included as part of the tutor's assessment. Once completed, the assessment is discussed by both the tutor and student. If both agree with the assessment, the form is signed, a pass or fail assigned by the tutor and the form becomes part of the student's records at the College. The student must receive a "pass" on this assessment in order to successfully complete the PBL unit. A mid-unit assessment provides the opportunity for students to rectify any potential weaknesses.

2. Comprehensive Student Assessment

Annual Progress Examination. A bank of multiple-choice questions was developed including questions from all pharmacy and biomedical disciplines. This bank is enhanced each year. Approximately 50 percent of the questions test at higher levels of learning (analysis, synthesis, evaluation). A single 100-item examination is administered simultaneously each spring to all students in the program. Students are required to write the examination to proceed to the next year. The results are used to assess eligibility for the Dean's List.

We recently analyzed the data from the classes of 1998-2001 which include students enrolled in the lecture-based and PBL-based curricula. The data presented here are from those students who wrote the exam and agreed to have their results used in curriculum research. As can be seen in Table III, the mean scores on the examination increase each year as the students proceed through the curriculum. Student performance by category is depicted in Figure 1. The mean scores in the biomedical sciences gradually declined after year one but then increased in year four. This may be attributed to the students not being assessed directly on this material in years two and three but being forced to relearn and integrate the material for their clinical practice experience in year four. The scores in the pharmaceutical sciences steadily increased from year one to year three and then leveled out, most likely reflective of the fact that the students are continually exposed to and assessed on this material in years two through four. The mean scores in clinical pharmacy steadily increased from year one to three and then leveled out. Again, this is most likely due to continued exposure to and assessment of this material through years two to four. The mean scores in pharmacy administration increased at the end of year two and end of year four. This may be due to this content being learned principally in years two and four. Thus, interim analysis of cumulative results from four years' experience with the progress examination suggest that: *(i)* students do progress in overall knowledge as they proceed through the curriculum; and (*ii*) retention of knowledge appears to be at least partially related to the year in which the knowledge is learned in the curriculum.

Objective Structured Clinical Examination (OSCE). In 2001, a six station OSCE (four standardized patient stations, one standardized physician station and one written station) was administered as a pilot to the fourth-year students just prior to the end of their last academic term and accounted for a portion of the skills lab mark for that year. The OSCE cases were developed based on content learned over the four years of the curriculum and were intended to evaluate many of the expected curricular outcomes we felt were not easily assessed by written examinations (primarily elements of Outcomes #1 and #6). As the small number of stations raises issues of reliability, we intend to continue to develop and expand the examination.

Developing Curriculum Evaluation

When developing the comprehensive evaluation plan we wanted to ensure that we were: (*i*) obtaining regular feedback from the students; *(ii)* assessing the degree to which students acquired knowledge and skills; *(iii)* assessing the ability of the students to apply their learning to the work site; and *(iv)* monitoring their overall performance after graduation(8).

1. Student Evaluation of the Curriculum Structured Student Evaluation of Curriculum While at the College. Students evaluate each component of the program as it is completed through the use of standardized evaluation forms. The results of these are reviewed by the curriculum committee and any issues identified are addressed. Students also complete a standard end-of-the-year evaluation form. As part of this they are asked to rate their perceived preparedness to meet the *Expected Curricular Outcomes of the Dalhousie College of Pharmacy.*

At the end of each PBL unit, course or skills lab, students evaluate the faculty involved using a modified version of the Dalhousie University approved "Student Ratings of Instruction Questionnaire/Comment Sheet" following stated policies and

procedures. Faculty are provided with the results and use these in self-analysis and as part of reappointment, promotion and tenure. At the end of each PBL unit, students evaluate their tutors using a standardized form. These are reviewed by the director of the College and any concerns identified are addressed confidentially with the tutor.

Fourth-Year Curriculum Discussion and Feedback. With the first class completing the PBL program in the spring of 2001 a structured feedback session was facilitated by the head of education. All 64 of the students in the class attended and were divided into 11 groups of approximately six to facilitate the process. Students felt that the PBL curriculum empowered them to be more active, self-directed learners with greater confidence in their researching and communication skills. Their major concerns were the minimal use of lectures and the lack of content perspective provided by faculty. The students perceived the integration of material in cases as relevant and applicable to practice but felt they may be missing the basic concepts of some content areas. Since this feedback session provided valuable information not obtained so completely elsewhere we plan to continue with these sessions annually.

Educational Experience and Preparation for Practice: A Survey of Graduating Students and Graduates. This research survey was designed as a method of curriculum evaluation intended to compare the PBL curriculum with the former lecture-based, traditional curriculum. A 24-item questionnaire was designed which asks students questions regarding demographics, College of Pharmacy experience, pharmacy practice experience and educational preparation. In addition, students were asked about their opinions on their overall educational experience and learning methods. It is administered at time of graduation and again one year after graduation.

Interim data analysis is complete for the classes of 1998 to 2001 at time of graduation. In terms of educational experience, graduates were asked to rank how well they feel Dalhousie prepared them to perform the 50 activities that comprise the desired educational outcomes. The students of the PBL curriculum perceived themselves to be better prepared in 16 activities than the students of each of the other classes. No significant difference in perceived preparedness for practice was found in 15 activities. Of the remaining 19 activities, the PBL students perceived themselves as equal to or better prepared than various of the other classes. Notably, the PBL students did not perceive themselves to be less well prepared than the other three classes in any activity. Although we recognize this is not an objective measure of student learning we felt it important for our students to assess themselves on the desired curricular outcomes as this is part of life-long learning. We have also used the results to identify areas of the curriculum in which the students do not perceive themselves to be well prepared for practice. For example, students indicated that they felt least prepared to perform the activities in the area of "Contribution of Decision Making Regarding Safe, Effective and Efficient Use of Drugs." We can use these results as we re-examine the relevant areas of the curriculum.

The majority of respondents in all graduating years appeared to be satisfied with their education and overall experience at Dalhousie College of Pharmacy. The class of 1999 (primarily lecture-based curriculum) appeared to be least satisfied comparatively. At time of graduation, approximately two-thirds of all respondents in all years would select Dalhousie again to pursue a pharmacy degree. The most common reason for not selecting Dalhousie again was cost of the program. With regards to the PBL curriculum as a factor for choosing Dalhousie University, five of 36 respondents in the class of 2001 said this would be the main reason for selecting Dalhousie (the most common reasons were: "admissions favors Maritime residents" and "personal reasons"). Only three of 10 respondents stated that the PBL program would be the reason for not selecting Dalhousie again. In addition, the Class of 2001 ranked PBL tutorials and self-directed learning as more important to their development of competence as a pharmacist than the classes of 1999 and 2000 (both of these classes had some PBL units in their curricula).

2. Student Performance as an Evaluation of the Curriculum

Annual Progress Examination: Comparison of Lecture-Based and PBL-Based Curricula. In addition to the other purposes already mentioned, the progress examination was also intended to evaluate the curriculum and determine if the knowledge learned by students in the traditional and PBL curricula is equivalent. Results to date from this research study suggest that there are no consistent differences in performance between students in the PBL curriculum and those in the traditional curriculum.

Objective Structured Clinical Examination. As mentioned previously, the OSCEs were administered to the fourth-year students for the first time in the spring of 2001. As we continue to expand the use of the OSCEs, the results will be incorporated as a component of the overall curriculum evaluation.

Pharmacy Examining Board of Canada Examinations. Upon graduation from a Canadian College of Pharmacy students must successfully complete national examinations in order to become licensed as a pharmacist in most provinces in Canada. Starting in 2001, the exam was comprised of a multiple choice section and an OSCE. Results from those graduating from the PBL-based curriculum have been compared against those from the lecture-based curriculum on the multiple choice question section only to identify if there are any major changes in Dalhousie College of Pharmacy's ranking in pass rates and faculty averages. The rankings in both the pass rate and faculty average improved in 2001 (the first class to graduate from the PBL curriculum). At this point it is not possible to attribute this improvement solely to the change in the curriculum, however, we believe the results are indicative of the positive influence the PBL curriculum has had on the learning of the students.

3. Application of Learning to Practice

Preparation for Clinical Clerkship: A Survey of Dalhousie College of Pharmacy Preceptors. This research project consists of a 35-item survey which gathers fourth year clinical preceptors' opinions on how prepared students are for the activities required of them during the clinical rotation. The six major activities that are required of the students were broken down into 50 components *(e.g.,* the activity "Drug Information Request" was broken down into 12 components such as "Clearly identify the problem," "Consult generalized resources for background knowledge," etc.) Surveys have been mailed to the preceptors of the classes of 2000 and 2001 and interim data analysis has been completed. Preceptors perceive no differences in the students' overall preparation for clinical clerkship in knowledge, skills, attitudes, and ability to apply knowledge and skills in a clinical practice setting. Data collection will continue with the preceptors of the class of 2002.

4. Monitoring Performance after Graduation

An 18 item research survey of Dalhousie pharmacy graduates' supervisors/employers was administered to identify supervisors'/employers' perceptions of the level of preparedness

of graduates in their first job following graduation. Surveys have been mailed to supervisors/employers of the graduates of the classes of 1998, 1999 and 2000. Supervisors/employers were asked to rank how well they feel Dalhousie prepared students to perform the 50 activities that comprise the desired educational outcomes. We will not have feedback from supervisors/employers of graduates of the PBL curriculum until 2003.

REFLECTIONS

Having had experience with two graduating classes from this integrated PBL curriculum we feel that the transition has been successful. Some aspects have been particularly effective while others require modification.

Outcomes-Based Focus

Focusing our curriculum on outcomes allowed us to think critically about curricular content and to ensure that learning opportunities are directly related to achievement of these outcomes. This ensures student attainment of the appropriate knowledge and skills. We are striving to track comprehensively the fit of each curricular component with the outcomes by developing a tracking system that is easy to access, interpret and alter as needed. Student assessment and curriculum evaluations were designed to link directly to achievement of the outcomes.

Problem-Based Learning

Our hybrid PBL curriculum incorporates a minimum number of classes and permits a few content areas to be learned in a more traditional manner. Permitting a minimal number of classes provides structure to undergraduate students while allowing them the flexibility of focusing in depth on areas of pertinence. The use of some lecture-based classes also recognizes and supports different learning styles. This approach also helps ease the anxiety of faculty with regard to control of student learning.

While we wished to increase our students' ability to function effectively in practice, we may not be able to easily measure our success in this regard. However, students problem solve weekly and apply their knowledge to plausible real world situations. Additionally, tutors assess these skills in the tutorial performance assessments and faculty test the ability of students in their regular examinations. Achievement will also be measured through our ongoing curriculum evaluations which will assess the transfer of skills and abilities to pharmacy practice.

We believe we must attend to certain student role issues in order to achieve optimal results. For instance, there is a student tendency to prepare thoroughly for only one learning issue to be "presented" to the remainder of their group of students. This is a dangerous tendency for two reasons: (*i*) students learn well only material they present; and *(ii)* the PBL tutorials can become a series of mini-lectures by non-experts, rather than a discussion and application of knowledge common to all students. To counteract this, tutors must be vigilant and ensure that their assessments of students address this issue. Additionally, faculty need to be vigilant in assessing individual students thoroughly.

As expected, students report that they find it difficult to know when to stop researching or studying, especially in their early years. While faculty-set learning objectives help to some extent, students typically do develop the ability to identify an appropriate depth of knowledge over the first few years. We have found it important to tell junior students explicitly that they will develop this capability.

Students also still tend to study for assessments such as examinations, so it is critical that assessments both by tutors on tutorial process and by faculty via exams reinforce the importance of not simply memorizing information but applying it to cases. Students also reported in the initial years that they felt a lack of clinical perspective in the cases because they have very little experience of actual practice. Thus, clinical faculty often provide case wrap-up sessions during class time so students can benefit from the clinicians' experience and put the case into an appropriate perspective.

Advantages of using non-content-expert tutors are that they are less likely to "teach" and more likely to facilitate a learning process; they bring a different perspective to the students and often stress real world importance; and they believe in the process of PBL and transmit that to the students. On the other hand, the tutors require intensive and on-going training in Socratic teaching, feedback and assessment; there has been a reallocation of financial resources; and there is an additional administrative burden of recruitment, retention, training and assessment.

Integration

Integration has eliminated redundancy in the curriculum. We have chosen not to integrate some subject areas, either due to our inability to integrate them effectively within the constraints of a four-year curriculum, or due to a belief that some were more appropriately studied separately in detail.

With an integrated curriculum, faculty work across disciplines much more effectively than in the previous discipline-based curriculum. Informal faculty discussions across disciplines with regard to learning and teaching occur spontaneously while faculty are discussing various cases or units.

Additionally, more formal curriculum discussions have been requested at which all faculty participate to ensure sharing of information. This degree of sharing did not take place in the traditional curriculum and when sharing did occur, it was generally within disciplines. Artificial turf barriers, while never a particular problem in this College, have been minimized and this allows the content of the curriculum to be transparent to all faculty as well as students. Faculty seem to feel a greater sense of responsibility to all areas of the curriculum.

While faculty experts are identified and available to students for each discipline represented in a case, students often cannot distinguish which faculty person might be the most appropriate to address a particular question. This suggests that students are successfully integrating the material and understanding its relevance to the patient case in question. Additionally, some faculty have observed that students will question more frequently what they read in a text in light of what they have learned or reasoned out by approaching the issue from a different (often a science) perspective.

Future Directions

Over the five years since the curriculum began, we have made minor modifications to improve the flow of learning and assessment. Several such modifications will take place over the next year, including combining several short units to make longer units.

Student assessment mechanisms have been and will continue to be modified. Initially, due to human resource constraints, we used primarily multiple choice questions on

examinations. However, faculty recognized the necessity to incorporate other types of assessments and have done so. Self and peer assessment are important components of a PBL program as well as critical skills for pharmacists. We provide workshops in both of these areas in the students' first year, and include self-assessment ability as part of the tutor assessment of the students. However, students have not developed this skill. We are currently developing a new system of self and peer assessment for which we are also designing a research study. Progress examinations and OSCEs are two important overall assessments. A triple jump examination will also be incorporated over the next year.

From the results of the annual progress examination, we see that student knowledge in the area of biomedical science appears to drop in years two and three of the curriculum. In order to facilitate students' application of this knowledge during those years, we need to incorporate questions about this content into the unit examinations. Additionally, in order to assist the students in retaining their knowledge of disease states and drug therapy learned in early units, we have begun to incorporate more of these disease states and treatments into both subsequent cases and examinations. We will also continue to work towards examinations that integrate disciplines to encourage students' ability to integrate these areas.

CONCLUSION

We are proud of having successfully implemented an entire integrated PBL curriculum. Using outcomes to design a curriculum, assess student performance and evaluate the curriculum is a feasible approach that has ensured that we have increased the accountability of our curriculum. Initial indicators show successful achievement of our goals.

Acknowledgments. The authors would like to thank the faculty and students of the College of Pharmacy for their patience, commitment and enthusiastic support during the development and transition to the revised curriculum. Additionally, transition team members and working group members, together with our facilitator. Dr. Lynn Curry, deserve particular mention. The process could not have succeeded without the cooperation of practitioners in the region. Financial support was received from the Dalhousie Pharmacy Endowment Fund, and Dr. Patrick Farmer was the beneficiary of a three-year Canadian Foundation for Pharmacy/Apotex Theme Grant.

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APPENDIX A. OVERVIEW OF CURRICULUM, COLLEGE OF PHARMACY, DALHOUSIE UNIVERSITY UNDERGRADUATE PHARMACY PROGRAM

Program year	Class	Learning Method
First	PHAR 1070.03 Skills Lab I	SklLab; Tut; Lect
	PHAR 1080.00 Community Experience Program	PracExp
	ANAT 1040.03 Basic Human Anatomy	Lect; Tut
	MICR 1050.03 Microbiology and Immunology	Lect; Tut; SciLab
	CHEM 2442.03 Organic Chemistry	Lect
	PHYL 1400.06 Human Physiology	Lect; Tut
	BIOC 1040.06 Biochemistry & Molecular Biology	Lect; Tut; SciLab
	PHAC 1470.06 Basic Pharmacology	Lect; Tut
Second	PHAR 2010.03 Critical Appraisal Series -1	Lect
	PHAR 2015,03 Topical Products (Dermatologicals)*	Lect; Tut
	PHAR 2020,03 Topical Products (Eye & Ear)*	Lect; Tut
	PHAR 2025.03 Respiratory*	Lect; Tut
	PHAR 2030.03 Infectious Diseases 1*	Lect; Tut
	PHAR 2040.03 Gastrointestinal Disorders*	Lect; Tut
	PHAR 2050.03 Nutrition**	Lect; Tut
	PHAR 2060.03 Pharmacy Administration I	Lect; Tut
	PHAR 2070.03 Skills Lab II	SklLab
	PHAR 2081.03 Practice Experience I	PracExp
	PHAR 2082.03 Practice Experience II	PracExp
Third	PHAR 3010.03 Critical Appraisal Series II	Lect
	PHAR 3020.03 Women's Health Issues*	Lect; Tut
	PHAR 3030.03 Infectious Diseases II*	Lect; Tut
	PHAR 3040.06 Cardiovascular Diseases*	Lect; Tut
	PHAR 3050.03 Pain and Rheumatology*	Lect; Tut
	PHAR 3055.06 CNS and Behavioral Disorders*	Lect; Tut
	PHAR 3060.03 Endocrine Disorders*	Lect; Tut
	PHAR 3070.03 Skills Lab III	SklLab
	PHAR 3080.03 Practice Experience III	PracExp

Program year	Class	Learning Method
Fourth	PHAR 4010.015 Critical Appraisal Series III	Lect
	PHAR 4020.03 Neoplasms*	Lect; Tut
	PHAR 4030.03 Liver Diseases*	Lect; Tut
	PHAR 4040.03 Blood&Immune Mechanism Disorders*	Lect; Tut
	PHAR 4050.03 Genitourinary Disorders*	Lect; Tut
	PHAR 4060.03 Pharmacy Administration II	Lect; Tut
	PHAR 4070.015 Skills Lab IV	Lect; Tut
	PHAR 4080.045 Practice Experience IV	SklLab
	PHAR 4085.045 Practice Experience V	PracExp

Key: Lect - lecture; SklLab - skills laboratory; PracExp - practice experience; Tut - problem-based learning tutorial; SciLab - science laboratory.
* Multidisciplinary PBL units consisting of pharmaceutical sciences, pharmacotherapcirtics, and pharmacy administration.
** Includes 3-week block of pharmacokinelics.

APPENDIX B. CASE THREE FROM THE TOPICAL PRODUCTS (EYE AND EAR) UNIT IN YEAR TWO*

Day One, Page One

George Carter is a 50 yo African Canadian male who is a sales representative for a pharmaceutical company, and spends a lot of time on the road driving, both day and night. He has recently been diagnosed with primary open angle glaucoma in both eyes as identified by mild visual field loss and increased intraocular pressure (IOP) of 32 mm Hg. His father[1] also had glaucoma but George had not talked about it much with him and his father is now deceased. Upon diagnosis George's ophthalmologist, Dr. Brown, gave him a prescription for timolol 0.5% (gtt i, o.u., b.i.d.). When George had his prescription filled he came to your pharmacy which is new to him. The pharmacist on duty asked him a number of questions and seemed to be particularly concerned about whether or not he suffered from asthma or heart disease. George reported that his only health problem is that he suffers with hay fever every summer for which he takes various antihistamines which work quite well for him.

George called you a few days after starting the timolol. He tells you that your colleague spent a great deal of time talking to him and gave him a lot of information. However, he has noticed a stinging and slight redness that goes away after about 5 minutes. He wonders if this is **a** normal effect of the therapy and says that the stinging occurs every time he uses the drops. He asks you what he should do.

Day One, Page Two

You determine that George has an appointment with his ophthalmologist in 2 weeks time and that the stinging is quite mild. You believe that his reaction is not allergic in nature and counsel him to continue using the drops until his next appointment.

Day Two, Page One

George continues with the timolol for the full 2 weeks and returns to his ophthalmologist today. His IOP has decreased to 25 mm Hg. Dr. Brown has explained to George that he would like the IOP reading to be lower than 25 mm Hg. To try to achieve this, the ophthalmologist prescribes a trial of Timpilo 2® (gtt *i,* o.u., b.i.d.) and asks him to make another appointment in one week's time.

You are on duty when George brings in his new prescription and find that he is quite confused about the purpose of the new prescription, why he has to go back in another week, and generally about how to use this new medication. "Dr. Brown said something about 2 drugs mixed in 1 bottle but I didn't quite catch what he said."

Timpilo :

When reconstituted, Timpilo 2® contains pilocarpine HCI 2% and timolol maleate 0.5%.

When reconstituted, Timpilo 4® contains pilocarpine HCI 4% and timolol maleate 0.5%.

Both products are dispensed in two-chambered vials: one chamber holds concentrated solutions of the drugs at pH 3.7; for Timpilo 2®, the second chamber holds a sterile diluent with pH 8.0, while for Timpilo 4®, the second chamber holds a sterile diluent with pH 9.0. Both products also contain benzalkonrum chloride, dibasic sodium phosphate dodecahydrate (Na2HPO4 10 H2O) and monobasic sodium phosphate dihydrate (NaH2PO4 2 H2O).

Day Two, Page Two

Guiding Questions:

1. Does the combination of timolol and pilocarpine make sense based on mechanism of action?
2. Why is Timpilo® dispensed in a two- chambered vial? Why is Timpilo 2® supplied with a diluent at pH 8.0 while the diluent supplied with Timpilo 4® has pH 9.0? What determines the ideal pH for eye drops? What other physicochemical properties are important for eye drops? Explain.
3. What instructions would you give the patient on how to use this product?
4. What is the role of benzalkonium chloride in this product? How does it act?
5. What is the role of the sodium phosphate salts in this product? Why are two necessary? Explain how they work,
6. Diagram the possible absorption pathways of an ophthalmic drug following topical application to the eye.
7. Is pilocarpine available in other dosage forms? Describe the advantages and disadvantages of the various types of dosage forms available for eye products, including pilocarpine.
8. How can systemic side effects from eye drops be minimized? Would all applied drugs be affected to the same extent?
9. What anatomical feature of the eye impacts upon the accessibility of systemically administered drugs to the eye?
10. How can iris color impact upon the pharmacokinetics of a drug instilled into the eye?
11. What contraindications are there to the formulation of benzalkonium chloride in a product? What is the chemical basis of these? What alternatives might be used?

Day Three, Page One

George is very pleased with your information and thanks you profusely for your time. He comes in after his next visit and tells you that while the Timpilo® has brought his IOP down to 21 mm Hg, he finds he is experiencing blurred vision. He is very concerned about this as he depends on being able to drive as part of his job. Dr. Brown has told him to remain on the same medication for another few days but that he will call in a new prescription for him to start in a few days. In the meantime he suggested that George not drive.

Dr. Brown calls you the next day to tell you that he has decided to discontinue George's pilocarpine but keep the timolol and add a new drug. He is considering adding one of the following agents: Propine®, Alphagan®, Trusopt® or Xalatan® and asks if they are all covered on George's insurance plan.

Day Four, Page One

After your discussion, Dr. Brown decided to add Azopt® to the timolol and this was successful for George for some time. Over the next few years, however, it was necessary to try George on a variety of the other agents, with some success. George has recently celebrated his

53rd birthday and has gone for his 6 month checkup with Dr. Brown. Today his IOP has risen again, and Dr. Brown considers using echothiophate.

Day Four, Page Two
Guiding Question:
What are the treatment options for George at this point?

Day Five
Eventually George has laser surgery which helps significantly. He continues to use timolol on a regular basis and his IOP is controlled at about 19 mm Hg. His visual field remains moderately affected. As a result of the care that you have provided to George over the last few years and your understanding of his needs with respect to his glaucoma, he has had his wife and children bring all their prescriptions to your pharmacy as well.

Learning Objectives
The student will be able to:

1. Illustrate and label the anatomy of the eye.
2. Explain the pathophysiology of acute/open-angle glaucoma & identify monitoring parameters.
3. Recommend appropriate drug therapy for open-angle glaucoma.
4. Describe the mechanisms by which drugs used to treat glaucoma provide therapeutic effect.
5. Analyze the medicinal chemistry of the drug classes used to treat glaucoma.
6. Explain important adverse effects, contraindications and drug interactions of the above drugs.
7. Provide counseling advice on issues associated with the pharma ceutical treatment of glaucoma.
8. Analyze the effect of pharmaceutics/biopharmaceutics principles of ophthalmic preparations (isotonicity, pH, particle size) on drug therapy.

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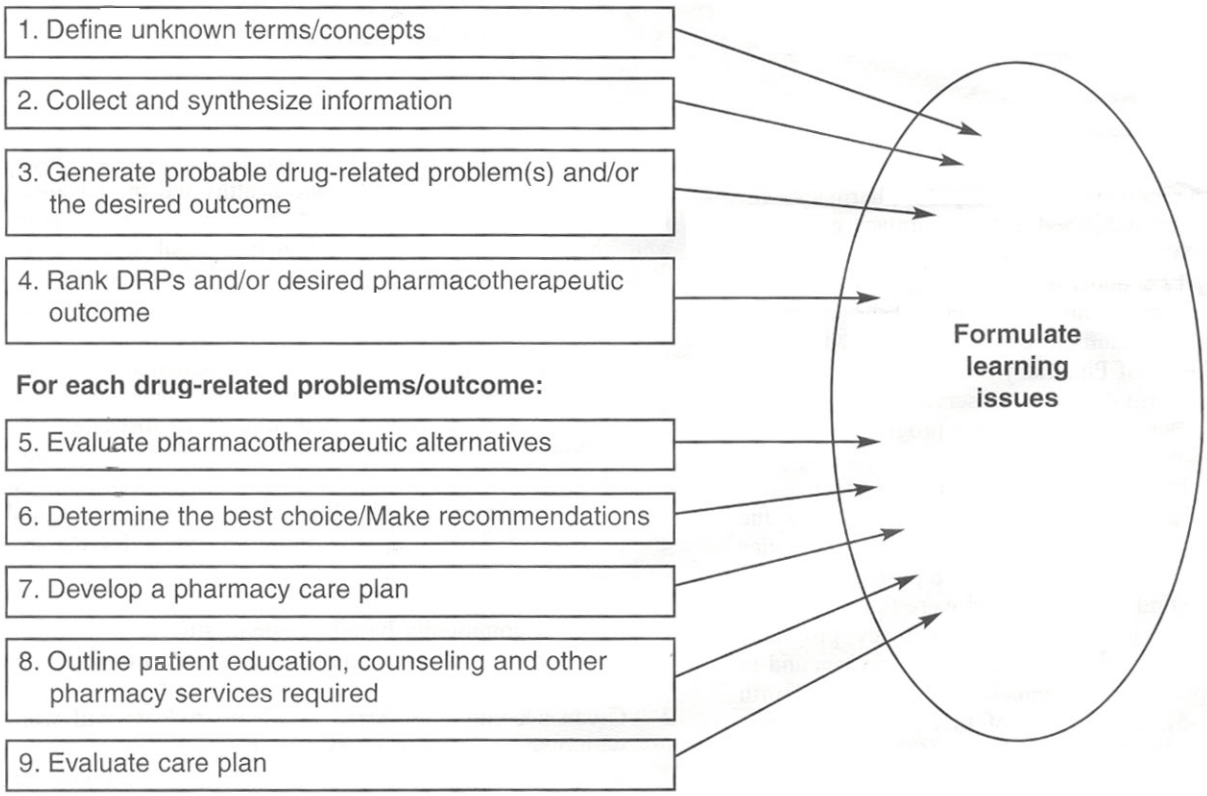
APPENDIX C. PHARMACY SPECIFIC PROBLEM SOLVING APPROACH



APPENDIX D. A TYPICAL WEEK [a] IN YEAR THREE (2001-2002)

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Lab Class 9:30-10:30	Laboratory Section 01 8:30-11:30		Critical Appraisal Class 9:30-11:30	
Class 10:30-11:30		Class 10:30-11:30		Class 10:30-11:30
Tutorial 12:00-2:00	Laboratory Section 02 12:30-3:30	Tutorial 12:00-2:00		Tutorial 12:00-2:00

[a] Lab/tutorials are assigned for students. Students will be notified of their sections when each unit begins.