Teaching pharmacology to medical students in an integrated problem-based learning curriculum: an Australian perspective

Owen L WOODMAN[1], Agnes E DODDS[2], Albert G FRAUMAN[3], Mosepele MOSEPELE[2]

[1]Department of Pharmacology, Faculty of Medicine, Dentistry and Health Sciences;
[2]Faculty Education Unit, Faculty of Medicine, Dentistry and Health Sciences;
[3]Clinical Pharmacology and Therapeutics Unit, Department of Medicine, The University of Melbourne, Australia

ABSTRACT

The world-wide move away from the didactic teaching of single disciples to integrated Problem-based Learning (PBL) curricula in medical education has posed challenges for the basic sciences. In this paper we identify two major challenges. The first challenge is the need to describe a core disciplinary curriculum that can be articulated and mapped onto the new structure. We illustrate how the British Pharmacological Society (BPS) Guidelines are used to evaluate the curriculum coverage in the medical course at The University of Melbourne. The second challenge is to ensure that foundational concepts are given adequate emphasis within the new structure, and in particular, that students have the opportunity to pursue these concepts in their self-directed learning. We illustrate one approach to teaching important pharmacological concepts in an integrated curriculum with a case study from the first year curriculum at The University of Melbourne. Finally, we propose the features of an integrated curriculum that facilitates the learning of basic pharmacology in a situation where PBL and integration sets the curriculum framework.

RECENT CHANGES TO MEDICAL EDUCATION

The last two decades have seen a major shift in teaching methods in several large Australian medical schools. In line with global trends, curriculum planning groups have responded to the call for more relevant and engaging ways of teaching medicine[1]. These responses productively coincided with contemporary understanding of the need to encourage active and self-directed learning in all areas of tertiary education[2,3]. In particular, the previous, traditional shift from early scientific training to clinical experience in medical curricula is now seen as fragmented, resulting in students who were poorly motivated to study foundational disciplines[4]. Several medical schools in Australia now have made significant changes to the way they train future medical professionals[5], drawing on a better understanding of the durability of knowledge that is acquired by students who are active learners rather than passive recipients of didactic teaching. This change has encompassed the foundational disciplines as well as clinical training.

Three major structural changes are associated with this revolution in medical education. First, Problem-based Learning (PBL) is adopted as the major curriculum method. Then, within PBL curricula, basic science disciplines have been sysnthesised in a horizontal integration of the scientific curriculum around studying the major body systems, and a vertical integration of

[1] Correspondence to Prof Owen L WOODMAN.
E-mail owenlw@myriad.its.unimelb.edu.au
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clinical and basic sciences. Thirdly, several schools have moved to graduate entry, four-year courses for the degree of MBBS. Such restructuring means that curriculum designers must not only respond to the active learning environment, but also must organize their framework for organising teaching material more efficiently and effectively, while retaining the core scientific basis on which clinical medicine is built.

In this paper, we describe how The University of Melbourne developed a curriculum framework for active learning and for the integration of basic and clinical sciences, and in particular, the place of pharmacology in this framework. Incorporating these changes into the medical curriculum involved teaching pharmacology within a vertically and horizontally integrated PBL-based program of study. We illustrate our use of PBL for the teaching of pharmacology with a case study that demonstrates one approach to teaching important pharmacology concepts interactively. Finally, we propose the features of an integrated curriculum that facilitates the learning of basic pharmacology in a situation where PBL and integration sets the curriculum framework.

STRUCTURE OF THE MBBS AT THE UNIVERSITY OF MELBOURNE

The School of Medicine at the University of Melbourne introduced a new medical curriculum in 1999. It remains an undergraduate degree, but has a dual entry pathway for graduates and undergraduates. Undergraduate entry students enter from school and complete a six year program, including a research year leading to the degree of Bachelor of Medical Science. Graduate entry students make up one third of the local intake and complete their degree in four and a half years. They enter in the second semester of the first year, and do not complete the extra research year.

The first two and a half years of the degree are pre-clinical. Students take two subjects during each 14 week semester for five semesters**.** The main science subject has two PBL tutorials at the beginning and end of each week. Five lectures and at least one practical class are delivered between the two tutorials, giving students resources for their independent study.

PROBLEM-BASED LEARNING

The rationale for relying on Problem-based Learning in medical programs has been presented in many scholarly papers over the past 15 years. Especially useful are two review papers by Albanese and Mitchell[6] and Norman and Schmidt[7]. The arguments in favour of a PBL-based curriculum model that encourages self-directed learning and motivates students through the use of relevant clinical scenarios are now widely accepted.

Problem-based learning comes in a variety of forms. At Melbourne, the system of 'progressive disclosure' is used for paper-based cases in tutorial groups of 11 students with a non-specialist tutor (usually a basic scientist, but sometimes a clinician). The cases are quite detailed, with complex descriptions that encourage students to deal with the information as it unfolds (following the Harvard model)[8]. In the first tutorial students are given a short scenario, followed by the progressive disclosure of the patient's history, physical examination findings and investigation results. Students spend the week between tutorials researching a set of agreed learning issues. In the second tutorial students apply the knowledge and understanding gained from their self-directed study to the problem. They are given further information on the patient's progress and the results of investigations. This information is used to finalize their hypotheses and to resolve outstanding questions. At the end of the second tutorial students are given the patient's prognosis and follow-up treatment. It is at this point that many drugs are introduced, but there is little time to investigate the reasons for their prescription.

VERTICAL AND HORIZONTAL INTEGRATION

While PBL has been discussed, advocated and evaluated to such an extent that it forms the major topic of research and writing in medical education, the issue of vertical and horizontal integration has received much less attention. However, it is the move to integration of both kinds that has the largest impact on teachers from the basic science disciplines[9-11].

A horizontally integrated curriculum combines input from all the relevant scientific disciplines, with each making a contribution to students' understanding of a major body system (eg cardiovascular). This requires each discipline to organize the presentation of key content with novel emphases (for example, dealing with drugs in relation to a disease of the cardiovascular system, rather than as a particular class of drugs). Thus disciplinary teachers also have to work to a timetable

that is different from that in a traditional approach to topics. Such new challenges can only be met by planning involving scientists and clinicians from all contributing disciplines.

Few accounts explain how to incorporate disciplinary content into such an integrated curriculum. One of the few by Sivan, Iatridis and Vaughn reported on the integration of pharmacology into a problem-based learning course at the Indiana School of Medicine[12]. These authors concluded that it is possible to successfully integrate core pharmacological knowledge into a PBL curriculum, although the course they describe concentrates blocks of pharmacology teaching into one section known as 'Systemic Function and Drug Action'. In the more common body systems approach adopted by the University of Melbourne, each learning block has a theme of one or two major body systems. In such a framework, pharmacology cannot stand as something to be taught on its own. It must be taught within the synthesized whole system.

At Melbourne, a broadly-based introductory subject known as 'Principles of Biomedical Science' is followed by four 'body system' subjects: nutrition, digestion and metabolism is the first block, followed by cardio-respiratory and musculoskeletal, neuroscience and endocrine, and the final subject is organized around microbiology and pathology. Pharmacology must find its place as one discipline represented in the analysis of each of these body systems, but as a discipline that informs and is informed by all the other disciplines (eg, physiology, biochemistry and pathology).

CHALLENGES FOR TEACHING PHARMACOLOGY IN AN INTEGRATED CURRICULUM

The challenges involved in teaching pharmacology in an integrated curriculum include the need to ensure that a core disciplinary curriculum can be identified and mapped to the new structure, and that students are introduced to key scientific concepts and information in an order that builds from a sound scientific base to the more clinically applied knowledge. Even more importantly, foundational concepts must be given sufficient emphasis in students' self-directed learning to allow them to construct a knowledge-base that can be available to them as a resource when they are engaged with clinical problems.

Identifying the curriculum The clinical pharmacology and therapeutics over-arching objectives within our course are to understand mechanisms of action of specific therapeutic agents and to apply these into clinical settings. This approach seeks to provide a practical and rational prescribing skill base by the end of the final semester of the course. This hopes to enable the future prescriber to define the patient's problem, define the therapeutic objectives, to check the effectiveness and safety or appropriateness of the preferred agent for that individual patient, to provide the patient with information, instructions and warnings and to initiate and monitor treatment, in line with WHO prescribing guidelines. In addition, the course aims to provide skills to access information sources (print-based and in electronic format) for new and emerging therapeutic agents. The media used for these aims include incorporation of therapeutic and prescribing issues in the PBL cases/tutorials and in electronic prescribing modules, developed by the Australian National Prescribing Service. Identifiable therapeutic areas include hypertension and cardiac failure, drugs in disease and therapeutic drug monitoring, peptic ulcer disease/reflux and bowel disturbance, diabetes, Parkinson's disease including drug-induced movement disorders, metabolic bone disease, COAD and asthma, pain, headache and vomiting, ischaemic heart disease, dermatologic drugs and anti-rheumatic drugs.

The British Pharmacological Society (BPS)[13,14] has identified generic core objectives applicable to most areas of therapeutics, and has constructed a list of "core drugs and therapeutic problems for the medical curriculum". For these drugs graduates are expected to have an understanding of mechanism of action, contra-indications and side effects.

The general mechanisms of action of drugs at a molecular, cellular and organ level are considered as drugs acting on the different body systems. This is readily dealt with in a systems based curriculum, and we have identified systems and related drugs appropriate for the pre-clinical years. Appendix 1 maps our curriculum to the BPS drug list and identifies the number of PBL tutorials, and accompanying lectures or practical classes where those drugs are discussed.

As the Appendix shows, some systems have been very well covered, specifically, cardiovascular, respiratory, nervous and locomotor systems, together with drugs used to treat psychiatric and infectious disease. However, the drugs acting on the gastrointestinal and endocrine systems have been largely neglected, in particular as a subject for lectures. This concentra-

Appendix 1. Frequency with which selected drugs are included in different teaching formats (The drugs are listed as they appear on the BPS website. http://www.bps.ac.uk/)

Commonly used drugs	Drugs	Lectures (n)	PBL Tutorial 1 (n)	PBL Tutorial 2 (n)	Practical Classes (n)
System	Drugs				
Gastrointestinal system	antacids		1		
	alginates				
	H2-antagonists			1	1
	proton pump inhibitors			1	
	misoprostol	1			
	codeine				
	loperamide				
	sulphasalasine				
	corticosteroids				
	laxatives				
	antispasmodics				
	spironolactone				
	metreonidazole				
Cardiovascular system	thiazide diuretics	2		2	
	loop diuretics	1		3	
	potassium-sparing diuretics	1			
	β-adrenoceptor antagonists	4		2	2
	calcium channel blockers	4	2	1	
	ACE inhibitors	1	2	1	
	AT1-antagonists	1			
	α-adrenoceptor antagonists	1			1
	methyldopa	1			
	nitrates	1	1	1	1
	digoxin	1		1	
	adenosine				
	amiodarone	1	1		
	lignocaine	1			
	aspirin	1		1	
	clopidogrel	1			
	thrombolytics	1		1	
	heparins	1		3	
	warfarin	1		3	
	statins		1	1	
Respiratory system	oxygen		3	1	
	β-adrenoceptor agonists	1	4	3	1
	cromoglycate	1			
	ipratropium	1	1	1	
	theophylline	1			1
	corticosteroids	1	3	4	
Nervous system	L-dopa	1			
	Dopa decarboxylase inhibitors	1			
	bromocriptine	1			
	anti-muscarinic drugs	1	1		
	anti-convulsant therapy		1		

System	Drugs	Lectures (n)	PBL Tutorial 1 (n)	PBL Tutorial 2 (n)	Practical Classes (n)
	sumatriptan			1	
	anti-emetics				
	pizotifen				
	betahistine				
	benzylpenicillin				
	corticosteroids				
Psychiatric disease	Benzodiazepines	1	2		
	tricyclic antidepressants	1			
	SSRIs	1	1		
	MAO inhhibitors	1			
	antipsychotic drugs	1	2	2	
	lithium	1			
	procyclidine				
	propranolol				
	disulfiram				
	chlordiazepoxide				
	methadone	1			
	nicotine	1		1	
	cannabis	1	1		
	amphetamine	1			
	ethanol	1			
	cocaine	1			
Infectious disease	penicillins	1	3	1	
	cephalosporins		1		
	tetracyclin	1	1	1	
	trimethoprim			2	
	aminoglycosides	1	1	1	
	macrolides				
	chloramphenicol				
	fusidic acid				
	quinolones		1		
	antituberculosis drugs			1	
	antifungal drugs	1		1	
	antiviral drugs			2	
	antimalarial drugs		1	1	
Endocrine system	insulin	1		1	
	sulphonylureas		1	1	
	metformin				
	thyroxine				
	propranolol			1	
	carbimazole			1	
	bisphosphonates				
	calcium			1	
	vitamin D				
	corticosteroids			1	
	glucose				

Commonly used drugs	Drugs	Lectures (n)	PBL Tutorial 1 (n)	PBL Tutorial 2 (n)	Practical Classes (n)
System	Drugs				
Renal disease	immunosuppressants				
	corticosteroids				
	erythropoietin			1	
Locomotor system	aspirin	1		1	
	paracetamol	1	4	1	
	NSAIDs	3	3	1	
	penicillamine	1			
	gold	1			
	sulphasalazine	1			
	methotrexate	1	1		
	colchicine	1			
	allopurinol	1			
	corticosteroids	2	1		
	calcium				
	vitamin D				
Surgery, anaesthetics & intensive care	opioid analgesics	1	2	1	
	local anaesthetics		1		

tion is largely explained by the emphasis on those drugs most commonly used in the clinical setting. It does, however, raise the question of just how comprehensive students' pharmacological knowledge is at the time they enter the clinical setting for the last three years of their training. In addition, tabulating the appearance of a drug in a PBL case does not reveal the depth to which students' are encouraged to investigate its actions and uses. For example, paracetamol and NSAIDs are often listed in the first PBL tutorial, reflecting their common use. Students become familiar with their prescription, but unless such drugs are integral to the clinical condition around which the case is built students will not spend independent study time on investigating their action.

Teaching fundamental concepts Nevertheless, other areas of basic pharmacology need greater consideration in regard to placement within a 'systems based' course. For example "the receptor as a target of drug action and related concepts such as agonisms, antagonism, partial agonism and selectivity". Those basic principles of pharmacodynamics are universal and clearly not unique to any specific body system. Where then should they be taught? Our approach has been to first introduce the basics of drug-receptor interactions as part of a series of lectures on cell signalling, at the beginning of the first year when students are also being introduced to the other scientific disciplines. In this way students, having learned the concepts of signalling between and within cells, can then consider how drugs may target cells to produce an effect. After that concept has been introduced, methods of quantification of drug actions can be explored and the concepts of agonism and antagonism covered. These basic concepts are taught before any consideration of pharmacotherapeutics. Thus, pharmacodynamics of specific agents can be considered as those drugs are introduced in relation to their actions on different body systems.

Taken together, Tab 1 and Appendix 1 demonstrate that the majority of concepts and detailed information seen by the BPS as essential for medical education are covered at some point in the pre-clinical years. However, while this overview answers the question of *what* is taught, it does not address the issue of *how* important basic principles are taught.

CASE STUDY: USING PROBLEM-BASED LEARNING TO TEACH BASIC CONCEPTS

In a similar fashion to pharmacodynamics, pharmacokinetics requires consideration for each agent.

Tab 1. Frequency with which core knowledge is addressed in different teaching formats.

Core Knowledge and Understanding	Lectures (n)	1st PBL Tutorial (n)	2nd PBL Tutorial (n)	Prac Classes (n)
Basic Pharmacology (Pharmacodynamics)				
- the receptor as a target of drug action and related concepts such as agonism, antagonism, partial agonism and selectivity	4			
Clinical Pharmacokinetics				
1. the mechanisms of drug absorption, distribution, metabolism and excretion				
2. the concepts of volume of distribution, clearance and half-life	3	1	1	1
Factors that determine variation in drug response				
- pharmacokinetic handling of drugs	3	1	1	

However, students also need to appreciate the underlying principles of drug absorption, metabolism and excretion. Although these principles were not directly related to any particular system, the decision was taken to locate them in the Gastrointestinal system for a number of reasons. The subject, 'Nutrition, Digestion and Metabolism' is taught early in the course (in the second half of first year), giving the opportunity to lay the conceptual foundations early, and it deals with the absorption and malabsorption of nutrients, and excretion, allowing drugs to be dealt with as another group of foreign compounds.

It was seen as important that these principles form an integral part of the enquiry-based learning of PBL. To encourage this, a PBL case was written to highlight issues in clinical pharmacokinetics, and this case was supported by five lectures delivered in the same week as students were working on the case. There were two lectures on pharmacodynamics, two on the Pharmacokinetic behaviour of drugs and one on Variability in Drug Action. There was also one practical class (a computer based practical on pharmacokinetics). Thus, students were given a set of basic concepts to support their own learning of the issues arising from the case.

There are significant challenges in writing a case that focuses on pharmacokinetics within a systems based curriculum. While there are very many drugs that can be used to illustrate pharmacokinetic principles, PBL cases tend to focus on the underlying physiology and pathology, rather than the behaviour of a drug that may be used to treat the disease. This poses a particular problem in the pre-clinical years, where students are not directed towards management issues. A writing team of three pharmacologists, one clinically trained medical educator and one emergency physician canvassed a wide range of options. Ultimately the team chose to use as an example a drug that has a narrow therapeutic range, important potential drug interactions and zero order kinetics (phenytoin). In so doing we were able to deal with issues such as routes of administration, absorption and metabolism but the underlying disorder (epilepsy) did not relate to systems being studied (gastrointestinal and hepatobiliary). The case therefore had to be written to direct students away from the underlying pathology and towards the pharmacological therapy, in exactly the opposite approach to that taken for other cases in the subject. The decision to include a case not directly related to the system-based framework of the curriculum is one of the problems that has to be addressed in medical curricula wishing to move to problem-based learning and horizontal integration. The 'problem trigger' and a summary of the information provided to tutors to guide students are given below.

"Out of the blue" One afternoon, Tony Spiteri, a 30 year old man, is brought to the Emergency Department of a suburban Melbourne hospital by ambulance. His pregnant wife, Angela, accompanies him. She is crying. She says, "we were just watching TV and suddenly he went stiff and then his arms and legs started jerking. He went blue and froth started coming out of his mouth. I thought he was going to die. He kept shaking for about three minutes and he's been really sleepy since. He's told me that he has epilepsy and that he used to have fits, but he hasn't had one since I met him. He takes these tablets every day to stop them." She hands you a bottle of phenytoin 300 mg tablets.

Tutor Notes (summary) This case encourages

discussion about drug administration, absorption, distribution, metabolism and elimination. Important concepts are therapeutic range (or index), drug toxicity, drug interactions and adherence. It provides the opportunity to reinforce the principles of first aid for the fitting patient, the bio-psychosocial consequences of epilepsy and long term medication, the medico-legal responsibilities of medical practitioners and issues related to self-medication.

For the first part of the first tutorial, students address a set of questions common to all our cases: identifying the presenting problem, generating hypotheses and formulating mechanisms to explain those hypotheses. When students have completed this part of the tutorial (about 30 minutes later), they are given more information about Tony. This information deals with the administration of diazepam and phenytoin. Questions within the case guide students to think about the drugs chosen, the route of administration and the doses used. These questions are more specific than usual in a PBL case and are designed to focus attention explicitly on kinetics.

To steer students away from information-gathering and hypothesis testing about epilepsy, the case provides the diagnosis and strong clues within the history that Tony's fits may related to poor adherence with his medication. This is done to ensure that students do not spend their study time between tutorials on the nature of epilepsy.

The second tutorial introduces the potential for drug interactions, when Tony requires treatment for symptomatic gastro-oesophygeal reflux. Students use knowledge acquired from the lectures and their own study to tackle this issue.

EVALUATION OF STUDENT LEARNING WITH EPILEPSY CASE

In the first two years of the new curriculum, each PBL group was asked to complete an evaluation of the problem of the week. This evaluation was delivered on-line and each group was asked to discuss the questions, reach consensus and submit the answers on the tutorial room computer. Data were collected via a server on an excel spreadsheet and were available for quantitative and qualitative analysis. Tab 2 shows the number of groups identifying six learning issues. These learning issues were not made available to students until the end of the Friday tutorial, at which time groups could evaluate the issues they had chosen for study during the week against the faculty learning objectives.

Tab 2. Number of PBL groups out of 14 who identified 6 learning issues in the epilepsy problem.

Learning issue	Groups (*n*)
Determinants of drug route of administration	10
Determinants of drug dose	12
Determinants of drug dose frequency	8
Reasons for monitoring some drugs and not others	12
Drug absorption, distribution and elimination	14
Mechanism of action of phenytoin and diazepam	13

As shown in Tab 2, all 14 groups who responded to the evaluation identified 'drug absorption, distribution and elimination' as a key issue. Most groups[13] also identified 'mechanism of action of phenytoin and diazepam' as one of the major learning issues. Eleven of the 14 groups agreed that the case contained the right amount of information, and was either 'interesting' or 'very interesting'. However, in response to the question 'what other issues would you have liked to cover' seven groups mentioned that they wanted to spend more time on understanding epilepsy, reflecting a desire to follow the clinical case in more detail, as is often the case with students in PBL.

When asked for general comments about the problem, four groups said that they found the first tutorial very technical, and 'dry', and another group added the comment.

It would have been more interesting if it was more integrated with the Nutrition, Digestion and Metabolism syllabus, although we recognize that with a relevant disease we wouldn't have had the time to cover the pharmacology stuff.

The mixture of learning issues reported by the groups demonstrates the desire of students to focus on the clinical condition, even when that is not a major component of the problem. This is understandable, as one of the major aims of PBL is to motivate medical students by the use of real clinical conditions. Thus we were satisfied that the case had directed the students to the desired learning issues and deflected most students from investigating epilepsy (which is covered later in the course), even if some students expressed frustration at not being able to follow the clinical scenario in more detail.

CONCLUSION

PBL-based curricula are designed to engage students in a search for knowledge in the service of understanding the full gamut of a clinical condition, from the basic physiology and molecular structures to the action of pharmacological agents on those structures. The aim is to make students curious about the drugs they will prescribe, rather than to teach algorithms and protocols divorced from the fundamental concepts. Only by understanding the basics will students be able to ask important questions such as 'Why this dose?' 'Why this frequency?'

In the pre-clinical years, however, the emphasis is on an understanding of the underlying science and not on management issues. This can present difficulties for the teachers of pharmacology in particular, since it is logical to introduce drugs and their effects as part of management.

The task of embedding pharmacology in an integrated medical curriculum is not a simple one. As we have demonstrated, it involves the close cooperation of pharmacologists with their fellow scientists from other disciplines as well as with educational designers and clinicians. It is possible, however, to gain the benefits of integration without sacrificing student learning of fundamental concepts of the discipline as well as their application in the clinical setting.

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