Original Article – Medical Education

Seeing the Wood for the Trees: Approaches to Teaching and Assessing Clinical Pharmacology and Therapeutics in a Problem-based Learning Course[†]

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Abstract

For about 50 years, clinical pharmacology and therapeutics have been taught in the medical schools via traditional lectures and practical classes. During this time, significant changes have occurred in our understanding of medicine and basic sciences. Also the needs for our community have changed dramatically. The explosion of scientific discoveries, the use of new technologies in disease diagnosis, the availability of a wide range of therapeutic options, and the availability of knowledge to everyone via the Internet have necessitated new approaches for teaching medical and other health professional students. Finding information related to a topic has not become a priority in teaching, what has become more important is to teach undergraduate students how to think in addition to what to think. Applying information learnt and assessing its significance in real life situations has become mandatory. The aims of this paper were: (i) to discuss the model we used in introducing clinical pharmacology and therapeutics teaching in the undergraduate course at the University of Melbourne and the educational principles behind the model, and (ii) to discuss the new tools of assessment used in a problem-based learning (PBL) curriculum.

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Introduction

Over the last 3 decades, the rate of knowledge accumulation in drug development has been enhanced by advances in molecular modelling, the molecular genetics of drug action and the screening from natural sources for novel therapeutic agents. These advances mandate the need for a more adaptive and responsive educational structure to arm students with skills to access the rapidly moving knowledge base. Medical educators have also realised the need to teach undergraduate students "how to think" in addition to "what to think". With the widespread use of computers and web-based educational resources, finding new information has not become a priority in medical education, what is more important is to train medical students to become critical thinkers, able to use information learnt in clinical situations and apply common principles which underpin therapeutic decision making and selection of therapeutic agents.[1]

Enhancement of community awareness, the worldwide availability of access to the internet for self-education, and the emerging ethical and legal issues in relation to the changes in our life with availability of new therapeutic approaches such as organ transplantation, genetic engineering in disease management, stem-cell research and its potential therapeutic uses, have necessitated the need to restructure medical curricula and undergraduate medical training to fulfill these needs.[2,3]

The aims of this paper were: (i) to discuss the model we used in introducing clinical pharmacology and therapeutics in our curriculum at the University of Melbourne and the educational principles behind the model, and (ii) to discuss the new tools of assessment used with this structure.

The Teaching Model and Curriculum Design

It is obvious that a traditional curriculum, based on lectures and practical classes will not be able to stand up to emerging challenges.[4] A new educational approach that incorporates a number of principles is needed in the design of new medical curricula. The focus is not just creating a roadmap for the content components of the curriculum but to restructure the whole content and keep an emphasis on educational outcomes throughout the design.[5] These

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educational principles in our curriculum model are summarised below, with an emphasis on clinical and basic pharmacology and therapeutics components.

1. Focus on Key Principles

The problem-based learning (PBL) model adopted for our curriculum is similar to a large tree with a large stem and a trunk and well developed roots. The branches and the number of leaves on these branches are the fine details in the curriculum, while the key principles are the stem, the trunk and the roots. What does this model mean to students and our academics and clinicians helping in the development of the curriculum? The model means that the focus is on the main principles and key issues first. Fine details or the number of leaves on each branch can be increased depending on the amount of research and self-directed work made by each student. Leaves may fall and new leaves will replace them. This is very similar to obsolete and out-dated information that is replaced with up-to-date knowledge and new discoveries. Students and teachers have a responsibility for the growth and maturity of the curriculum (Fig. 1). The curriculum is dynamic and it is the responsibility of the students to learn how to keep their knowledge up-to-date and interact within the design placed in the curriculum. The curriculum is not just what the Faculty plans, it also includes what students learn, practise, believe in, test and use.
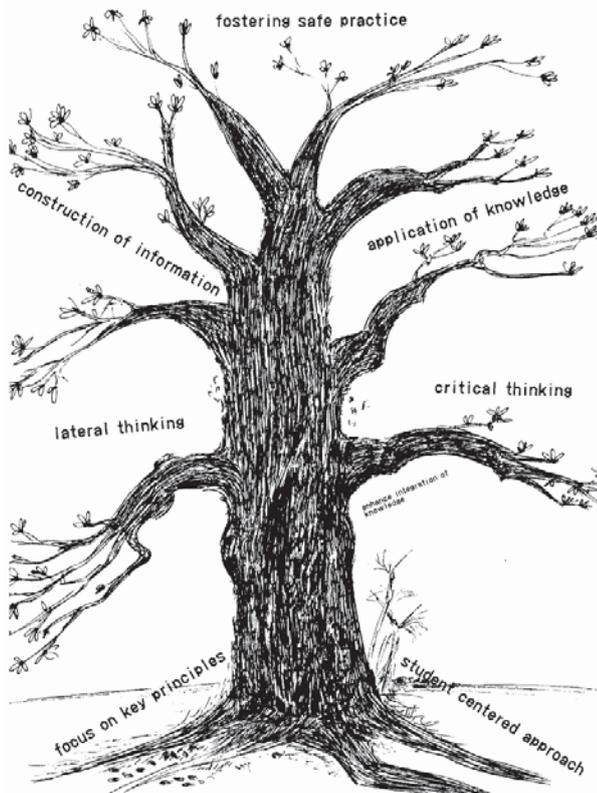

Fig. 1. The tree of curriculum design.

2. Enhance Integration of Knowledge and Construction of Information

In our curriculum, clinical pharmacology and therapeutics are integrated with basic sciences. This approach allows students to understand the interaction between these disciplines and pharmacology and helps in understanding the mechanisms by which drugs act and the scientific explanation for side effects, over-dose and toxicity, contraindications and aspects of drug interaction. This horizontal integration is introduced at each body system studied and is also accompanied by a vertical integration in which basic sciences, health practice and clinical medicine streams are represented throughout the course with a different emphasis depending on the stage of the course.

The educational objectives of our course are unlike the traditional instruction model that has been based on the assumption that knowledge can be transferred intact from the mind of the teacher to the mind of the learner. There is strong evidence that teaching and learning are not synonymous with this mode. Teachers may be able to teach and teach well but this does not mean that students have learnt or can apply what was taught in different situations.[6,7]

According to the traditional theory of learning, the learner's minds contain images that somehow represent copies or pictures of what the teacher presented, but this does not guarantee deep learning or the ability of the learner to debate, justify or apply information learnt. This theory has shaped the way classrooms are designed and courses are run, where students have to be seated to face the teacher, who is the sole source of knowledge to be taught.[8]

With the constructive theory of learning, the learner does not mirror and repeat what they are told or what they read. Learners, according to this theory, search for the meaning, collect information from a wide range of resources, comprehend what they have learnt, test the new knowledge, try to find relationships, organise the information learnt and construct this knowledge in their mind.[9] This theory constitutes part of the teaching philosophy of our new curriculum. This is particularly useful as the students discuss their learning issues in tutorial two (Table 1). Students should not underestimate the value of this session or spend the time reading or drawing a diagram or a flow chart they copied from a textbook. Instead, they should work together to construct the knowledge they came with. A scribe recording this information and facilitating this process will help the group to achieve their goals.

3. Encourage Application of Knowledge to Real Life Scenarios

Although factual knowledge is important for understanding of new concepts, knowledge on its own is not enough, particularly in situations that require dealing

Table 1. Summarises the Sequence of Steps Taken by Students as They Discuss a Problem-based Learning (PBL) Case in Tutorials 1 and 2*

Tutorial 1	**Tutorial 2**
1. Clarify unfamiliar terms in the trigger	1. Discuss learning issues and use new knowledge to explain issues raised in the problem
2. Define the problem(s)	2. Identify laboratory tests and other investigations that could help them to refine their hypotheses, assess any complications and possible causes
3. Brainstorm possible hypotheses or explanations	3. Analyse, evaluate and interpret the data provided from laboratory tests and other investigations
4. Synthesise mechanisms to explain their hypotheses	4. Refine their final hypothesis
5. Gather information that could help them to support or exclude each of their hypotheses	5. Discuss overall management goals, available options and factors that may interfere with each option
6. Refine hypotheses in the light of the information provided from history and clinical examination	6. Provide overall evidence from history, examination and investigations for their final diagnosis and construct a mechanism reflecting their learning outcomes from the case
7. Identity areas of deficiencies in their knowledge and define their learning issues	7. Discuss group performance and feedback from the tutor

*Each week students discuss a new PBL case. The case is discussed on two tutorials and each tutorial is 2 hours long.

with uncertainty. Furthermore, training students to use knowledge and apply it to a wide range of real situations enhances their competencies and their skills in mastering concepts learnt. The use of case scenarios provides students with the opportunity to: (i) use the case as a vehicle to drive learning of basic medical sciences in a clinical format, (ii) consider psychosocial issues in their assessment of the patient's problems, (iii) explore any contributing factors for patient's problems such as side effects of medications used, drug interactions, presence of risk factors, genetic, familial or environmental causes, (iv) design an enquiry plan that enables them to collect more information about the patient's problems, past history, past investigations, allergy, drug side effects, current medication, and social history, (v) interpret patient's symptoms, clinical signs, laboratory and other investigations and use the information in refining their hypotheses, and (vi) outline their management plan and available options.

4. Foster Critical Thinking, Self-directed Learning and the Use of a Wide Range of Resources

Self-directed learning is being responsible for one's own learning. This could be seen as a frustrating experience by some students and faculty teaching staff may become worried about their own discipline and whether students will grasp the objectives and details they would like to teach them. The aim of self-directed learning is not to compensate for deficiencies in the course or to fill gaps in the curriculum structure. The aim is to train students early in the course to be able to identify their learning needs, search for information from a wide range of resources such as textbooks, journal articles, multimedia CD-ROMs,[10] practical classes, lectures, seminars and educational websites.[11] Also to be able to use the information in cons-

tructing their learning and covering their learning needs.

5. Foster Safe Practice and Understand Community Needs

One of the key skills that we would like our students to develop during their undergraduate training is to be prepared for safe practice. This concept is usually diluted or ignored in most medical curricula and course designers usually focus on content such as causes of diseases, pathogenesis, clinical picture, investigations, differential diagnosis and management issues rather than addressing skills that are essential to their profession. Even the assessment tools are usually not expanded to include such skills. Although such content is important it is usually over-represented, leaving no time for students to develop their professional skills. There is evidence in the United States of between 44,000 and 98,000 deaths per year caused by medical errors.[12] There is also evidence that students in a good number of curricula learnt about professionalism as a set of attitudes and behaviours and how they need to communicate effectively with their patients and other members in the management care system, as well as their responsibilities towards the profession and the community needs. Although these bases are essential, there is a need to prepare students to be part of the healthcare system and develop their skills with a focus on minimising errors.[13]

For the development of clinical pharmacology and therapeutics in the curriculum, the following principles have been recommended:

- The focus should be on risk assessment of medications, not just learning about uses and mechanisms of action.
- Evaluation of hazards and side effects, contraindications and drug interactions before prescribing any medications.

- Thinking about what you would warn a patient who will use a particular medication, what investigations you might need to do before prescribing a high-risk medication, what follow-up is needed and what questions would you ask them in these follow-up visits.
- Adequate preparation of patients before discharge (patients usually do not recall being taught about side effects of their medications and they feel they were not prepared).
- Understanding high-risk medications that are commonly prescribed (e.g., antibiotics, narcotic analgesics, warfarin, glucocorticoids and hypoglycaemic agents) and measures needed to ensure safe practice.
- Understanding the risks of multiple prescriptions, particularly in the elderly.
- Understanding that changing medications or starting a new medication could trigger problems and what you need to do to ensure that administration is safe and without harm.

To place these principles into a learning plan, we developed a 6-step decision-making process to foster students' competency in clinical pharmacology and thera- peutics (Fig. 2).

6. *Enforce Staff Development and Excellence in Teaching*

The ability of teachers to facilitate students' discussion within small groups is one of the major determinants of the quality and success of PBL courses. A number of teaching skills are required in PBL tutors including: the ability to facilitate discussion and ask open-ended questions, knowledge about group dynamics, techniques of students' motivation, the ability to assess students' learning, organisational skills, and the ability to give constructive feedback and monitor group or individual progress during a semester or an academic year. Training in workshops to achieve these skills is mandatory for every PBL tutor before having their own group.[14]

Clinical tutors involved in the last 2 or 3 years of the course need to be aware of the overall structure of the curriculum, what students learnt in the early years, the overall educational philosophy of the course, teaching skills needed in PBL classes and how disciplines such as clinical pharmacology and therapeutics are integrated in the curriculum and the steps in the decision making for competency in clinical pharmacology and therapeutics (Fig. 2).
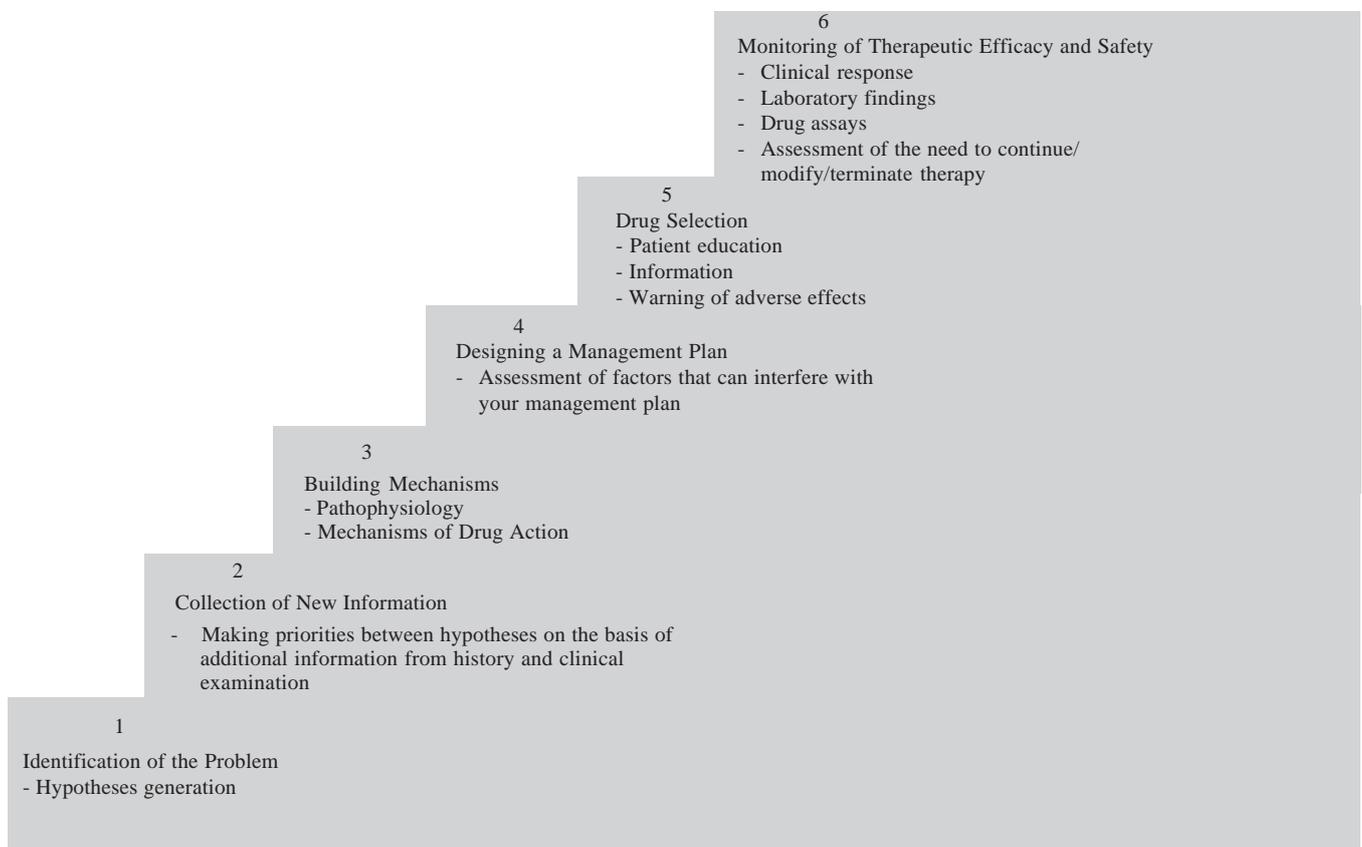

Fig. 2. The six steps in the decision-making process for competency in clinical pharmacology and therapeutics.

Assessment in a PBL Curriculum

With the introduction of PBL in medical and health professional education and a full shift from traditional lecture-based curriculum to student-centred programmes, many schools are currently reviewing their assessment tools and introducing new strategies that reflect the philosophy of the new curriculum. Aligning learning outcomes, student learning and teaching activities and assessment is vital for the success of university programmes and ensuring quality learning.[15] Medical educators and course designers need to first identify areas of competencies and skills to be examined and then select appropriate, valid and reliable tools that enable the assessment of each of these competencies.[16] The scenario-based multiple-choice questions (MCQs), extended matching questions (EMQs), PBL style of questions and objective structured clinical examination (OSCE)[17] have been used, among other tools, in formative and summative assessments to address these needs.

1. Scenario-based Multiple-choice Questions

Well-structured MCQs may demand a greater deal of analytical thinking,[18] enabling examiners to test a wide range of skills such as (i) analytical skills, (ii) integration of knowledge, (iii) problem solving skills, (iv) justification and clinical reasoning, (v) construction of mechanisms, and (vi) application of knowledge. The use of scenario as the stem of the question enables examiners to construct questions free from grammatical clues, imprecise terms, and trivialities or small print of textbooks.[16] The example below shows the use of scenario-based MCQs testing clinical pharmacology and therapeutics in an integrated fashion:

A 5-year-old child migrated with his family to Australia as a refugee from south Sudan. He bled excessively when injured. The most likely cause for his bleeding:

A. Vitamin B deficiency
B. Platelet sequestration
C. Increased serum bilirubin
D. Low serum protein, causing factor XIII deficiency/malfunction
E. Vitamin K deficiency

Answer: E

Further assessment revealed a protruding abdomen and a palpable liver below the right costal margin. He had bowed legs and a history of delayed walking. Which of the following laboratory investigation results would be expected with his presentation?

Item	Serum alkaline phosphatase	Serum Calcium (Ca^{2+})	Serum Phosphorus $(PO_4{}^-)$
A	Raised	Raised	Raised
B	Low	Low	Low
C	Raised	Normal	Normal
D	Low	Raised	Raised
E	Raised	Low	Low

Answer: E

2. Extended Matching Questions

EMQs are MCQs items organised into sets that use one list of options for all items in the set.[19] EMQs allow examiners to assess application of knowledge using 4 to 5 case scenarios addressing one theme but allow testing of deeper understanding of a wide range of issues related to that theme. EMQs could test students' knowledge about mechanisms of drug action, drug interaction, side effects of a group of drugs and decision making regarding the drug of choice in a number of case scenarios where a number of factors could affect the action plan and management options. The 2 examples below show the use of EMQs in clinical pharmacology and therapeutics assessment:

Theme: Drugs used in cardiovascular disorders

A. Angiotensin-converting enzyme (ACE) inhibitor (e.g., captopril)
B. Angiotensin receptor blocker
C. Spironolactone (aldosterone antagonist)
D. Beta-adrenoceptor antagonist
E. Digoxin
F. Dopamine
G. Amrinone
H. Intravenous nitroglycerin
I. Amiodarone
J. Triamterene
K. Isosorbide dinitrate

For each patient select the drug most likely to be recommended

1. A 58-year-old female presented with acute anterior myocardial infarction. Her blood pressure was 80/50 mmHg, pulse rate was 140/min, temperature was 36.7°C, and respiratory rate was 25/min. There were bilateral crepitations on respiratory examination. Her 12-lead ECG showed no arrhythmia but changes suggestive of massive acute anterior myocardial infarction (Answer F).

2. A 49-year-old female presented with shortness of breath and signs of heart failure. Her pulse was irregular. She had no treatment prior to her presentation (Answer I).

3. A 58-year-old male was treated with an ACE inhibitor for heart failure following myocardial infarction. Three months later, he developed cough and investigations including chest X-ray revealed no clues for the cause of his cough (Answer B).

3. PBL Style of Questions

These questions could test a number of educational objectives including: the ability to apply knowledge to real situations, hypothesis generation, weighing the evidence for and against each hypotheses, using evidence in refining the final hypothesis and construction of mechanisms that demonstrate integration of knowledge from physiology, pathophysiology, pharmacology and other disciplines.[20]

Mrs Hi Nee Guo, a 34-year-old cashier, was admitted to the intensive care unit with head injuries following a motorcar accident. Mrs Guo was conscious and able to give details about her accident to the admitting doctor. Further questioning revealed that she was on

lithium tablets for a bipolar disorder for over 3 months. Approximately 18 hours after the accident, she developed excessive secretion of urine, passing approximately 170 mL/h. Her urine osmolality wass 150 mOsmol/L and serum osmolality was 350 mOsmol/L. The registrar stopped intravenous fluids and asked the nurse to test Mrs Guo's urine osmolality 4 hours after the cessation of all intravenous fluids. Mrs Guo's urine osmolality remained constant at 150 mOsmol/L and her urine output remained high, approximately 168 mL/h.

A. List the likely causes for Mrs Guo's excessive urine production. Mrs Guo felt very thirsty. The registrar decided to treat Mrs Guo with 5 units of vasopressin intravenously. The registrar did a repeat test on Mrs Guo's urine. The results showed that urine osmolality increased to 300 mOsmol/L and urine output decreased to approximately 80 mL/hour.

B. What is your final hypothesis? Explain your reasoning.

C. Use your knowledge of physiology and pathology to describe the mechanisms underlying Mrs Guo's thirst, polyuria, low urine osmolality and the changes in her urine osmolality and urine output following vasopressin treatment. You may use flow diagrams, illustrations and dot points to explain your mechanism.

Conclusions

Significant changes have occurred in our understanding of basic and clinical sciences. The explosion of scientific information and the use of new techniques in diagnosis and the wide range of therapeutic options have necessitated the introduction of new teaching and learning strategies in medical curricula. The tree model of the curriculum which was described in this paper is student-centred and focuses on key principles and enhancement of integration across disciplines. Fine details or the number of the leaves on each branch can be increased depending on the amount of research and self-directed work made by each student. Leaves may fall and new leaves will replace them. This is very similar to obsolete and out-dated information that is replaced with up-to-date knowledge and new discoveries. Students and teachers have a responsibility to the growth and maturity of the curriculum. The curriculum in this way: (i) focuses on key principles, (ii) aims at enhancing integration of knowledge and construction of information, (iii) encourages application of knowledge to real life scenarios, (iv) fosters critical thinking, self-directed learning and the use of a wide range of resources, (v) fosters safe practice and understanding of community needs, and (vi) enforces staff development and excellence in teaching. The six steps in the decision-making process for competency in clinical pharmacology and therapeutics presented in our model aims at ensuring safe practices, enhancement of

integration of clinical pharmacology and encouraging students to apply knowledge learnt in a scientific pattern. Assessment in our model aims at assessing competencies and skills by using reliable and valid assessment tools.

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