Original Article

Facilitation of Students' Discussion in Problem-based Learning Tutorials to Create Mechanisms: The Use of Five Key Questions

Samy A Azer,[1] *MBBCh, MPH (NSW), PhD (Syd)*

Abstract

Without the appropriate facilitation of discussion in a problem-based learning (PBL) course and the use of specific educational tools that enhance cognitive skills, students might deprive themselves of achieving the deep learning experience expected to take place in a PBL course. One of the educational tasks in PBL is the creation of mechanisms for hypotheses made by the students, based on their knowledge of the basic sciences and the psychosocial issues raised in a particular case scenario. The whole task is student-constructed and should enhance their ability to explain the scientific basis of the symptoms and clinical signs of the patient enlisted in the case. Because students usually discuss the case without enough prior related knowledge, they might find it difficult to address different aspects of their mechanisms. These gaps in knowledge may be considered part of their "learning issues". In tutorial 2 (a PBL case is usually discussed in 2 or 3 tutorials at the maximum; each tutorial is 2 hours long), students should be able to build a comprehensive mechanism reflecting their deep understanding of the problem. However, students might not be able to integrate information learnt and their mechanisms might show a number of shortcuts and/or lack integration of information, and the flow of the pathophysiological changes may not be logical. This manuscript describes 5 key open-ended questions in PBL tutorials to facilitate students' discussions as they create their mechanisms.

Ann Acad Med Singapore 2005;34:492-8

Key words: Medical education, Pathophysiology, PBL tutors

Introduction

An important aspect of problem-based learning (PBL), particularly in the early years of the undergraduate medical, physiotherapy, nursing and dental courses, is teaching basic science in a clinical format.[1,2] This approach should enhance students' skills to develop reasoning strategies, use information in relevant situations, generate hypotheses for problems identified and build mechanisms. Mechanisms are usually described as diagrammatic flowcharts illustrating a sequence of events. The main aim of including mechanisms in a PBL template is to encourage students to use knowledge learnt and information provided in the case scenario, including psychosocial issues, to explain how a hypothesis suggested by the group could explain the patient's problems.[3] During this process, the group might discover that they are unable to provide a thorough explanation and that they lack information in areas such as physiology, anatomy, pharmacology, microbiology, pathology, biochemistry or pathophysiological changes. The group may choose to include these deficiencies in their knowledge as part of their "learning issues" list.[4]

However, building mechanisms is not an easy process and the students usually find it difficult to start their mechanisms or link them back to the information provided in the case scenario. Even in tutorial 2, after they have completed their learning issues and attended a few lectures, some groups struggle to build a good mechanism that integrates related information learnt to explain the pathophysiological processes in the case, the patient's symptoms and the clinical signs elicited in the case. Several factors could have contributed to this difficulty:

- Early in a PBL course, students find it challenging to develop their mechanisms. They are usually uncertain about what exactly constitutes a good mechanism and

[1] Faculty Education Unit (FEU)
Faculty of Medicine, Dentistry and Health Sciences
University of Melbourne, Australia

Address for Reprints: Dr Samy A Azer, Faculty Education Unit (FEU), Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Victoria, Parkville 3010, Australia.
Email: samy@unimelb.edu.au

how detailed their mechanisms should be.

- Most students are trained in high school to adopt a rote learning style rather than a learning style that encourages the application of knowledge, elaboration, reflection, critical thinking and integration.[5]
- In PBL, most tutors are not experts in the disciplines related to the case. Despite having been trained in interactive workshops on the facilitation of group discussion, some tutors find it difficult to ask appropriate open-ended questions that enhance the discussion on mechanisms.
- Textbooks, lectures, and other resources are usually discipline-based and do not help students to integrate information as they create their mechanism.[6]
- Building mechanisms requires a number of skills such as integration, a deep understanding of the basic sciences related to the case and the use of logical flow as they describe the pathophysiological changes related to the patient's problems described in the case scenario.
- The group might find it difficult to convey to the scribe where the mechanism should start and how it should progress.
- There are no guidelines in training workshops or textbooks for tutors and students to help them learn what constitutes a good mechanism.

The aims of this paper are (1) to evaluate the educational objectives of mechanisms in PBL – tutorial 1 versus those of tutorial 2, and (2) to discuss the use of 5 key open-ended questions to enhance group discussion of mechanisms.

Why are Diagrammatic Mechanisms Useful to Students' Learning in PBL Tutorial One?

Although there are a reasonable number of studies and review papers covering the rationale and educational objectives of PBL courses,[1,7,8] there are no papers in the literature discussing the educational objectives of mechanisms in a PBL curriculum and how tutors can facilitate group discussions of mechanisms. It is important that we use mechanistic tools to foster integration across disciplines, depth in learning and an understanding of the scientific basis for the patients' symptoms, clinical signs and laboratory findings, as well as the possible role of psychosocial issues in the case.

PBL cases are usually discussed in 2 or 3 tutorials, depending on the structure and design of the curriculum.[9] Each tutorial is 2 hours long. Each case usually begins with a trigger text or a scenario, which is often presented to the students without any prior preparation. A series of images, a 2- to 3- minute video clip or a cartoon may accompany the trigger text. In tutorial 1, students work in small groups of 10 students:

Step 1: Clarify key information in the trigger text and accompanied trigger images.

Step 2: Define problems in the trigger (problem formulation), and retrieve their own knowledge in relation to the identified problems.

Step 3: Generate a list of hypotheses for each problem.

Step 4: Develop an enquiry strategy on their hypotheses.

Step 5: Read further information provided with the problem of the week (e.g., medical history).

Step 6: Use the new information to support or exclude each of their hypotheses (group their hypotheses under 3 headings, less likely, most likely and to be excluded).

Step 7: Create mechanisms to explain their hypotheses.

Step 8: Identify areas of gaps in existing knowledge.

They may negotiate and refine their learning issues throughout tutorial 1.[9,10] Between tutorial 1 and tutorial 2, students work independently and look for information which addresses each of the learning issues identified in tutorial 1. Students may use resources such as textbooks, journal articles, websites and computer-aided learning (CAL) programmes in this process.[11] In tutorial 2, about 3 days after tutorial 1, the students' groups reconvene to discuss their learning issues. They discuss the knowledge they have acquired and relate the new information to issues raised in the problem. They then discuss laboratory investigations that might help to confirm their final hypothesis. They may discuss the progress provided in the case, usually cultural, ethical or psychosocial issues related to the patient. At the end of tutorial 2, students develop a comprehensive mechanism covering the patient's problem, clinical signs and laboratory findings.

It appears that the goals and educational objectives of creating diagrammatic mechanisms in tutorial 1 are not exactly the same goals and objectives of developing a comprehensive mechanism in tutorial 2 (Table 1). The scenario below summarises key information from the trigger and history findings from a PBL case.

An Example of a PBL Case Scenario

Ms Linda Hart, a 42-year-old librarian, is brought to the emergency department of a local hospital by ambulance at 4 am. She is pale and vomiting fresh blood. Although drowsy, she is oriented and able to answer your questions. Linda gives a history of vomiting large amounts of fresh blood at her house, before arriving at the hospital. Last night she started vomiting repetitively after binge drinking. Thirty minutes later, the vomitus became bloody. Immediately on arrival to the emergency department, the nurse tells you that Ms Hart's blood pressure is 100/60 mm Hg (on lying flat), her pulse rate is 105/min and regular, her respiratory rate is 20 per minute and her temperature is

Table 1. Aims and Objectives of Mechanisms in PBL in Tutorial 1 versus Tutorial 2

Tutorial 1	Tutorial 2
No prior knowledge about the case and its contents.	Students collect information from textbooks, computer-aided programmes, lectures and practical classes related to their learning issues and the case.
Building a mechanism helps students to identify areas of deficiencies in their knowledge.	Building a mechanism helps students to integrate information learnt, apply knowledge and address a patient's presentation and clinical signs.
Mechanism may be broad and may include several hypotheses.	Mechanism is usually focused around the final hypothesis.
Mechanism is usually superficial, not detailed and may contain short cuts.	Mechanism should be comprehensive, detailed, and reflect integration of knowledge with no short cuts.

36.5° C. The registrar inserts a large intravenous line in her forearm vein and she is commenced on Haemaccel intravenously. Ms Hart gives you a history of recurrent headaches, for which she takes aspirin tablets from time to time. Recently, she has experienced abdominal pain and indigestion. Her bowels are regular but she noticed that her stools have become black and soft over the last few hours. She has 2 tattoos on her back. She has been drinking a bottle of white wine a day for the last 10 years, but has increased her consumption since the death of her husband and son in a motor car accident under a year ago. Due to her alcohol problem and feelings of depression, she was seen by a psychologist 6 months ago and was advised to attend counselling sessions regarding her alcohol problem. However, she refused to attend.

Students identified haematemesis (vomiting blood) as one of the main problems: Their hypotheses for the problem were:

- Bleeding from an ulcer in the stomach (possibly caused by aspirin).
- Bleeding from oesophagus (oesophageal varices).
- Bleeding from a tear in the oesophagus (caused by repeated vomiting).
- Bleeding from a cancer of the oesophagus/stomach (cancers may ulcerate and bleed).

Due to uncertainty and lack of information, students might find it difficult to develop a mechanism explaining their hypotheses. Students may tend to develop a "backward reasoning" approach.[12] Using this approach, students begin by asking what could possibly cause Ms Hart to vomit blood. They might suggest, "Bleeding from oesophagus, stomach and duodenum". They then consider a new question: "What caused bleeding from these structures? Was it mechanical damage to the lining tissues? Was it bleeding from abnormal blood vessels in the oesophagus or the stomach?". The scribe adds this new information to the whiteboard. As the group places these items in their mechanisms and thinks about the preceding question they continue to develop their mechanism (Fig. 1). During this process, the group discovers that they lack information in

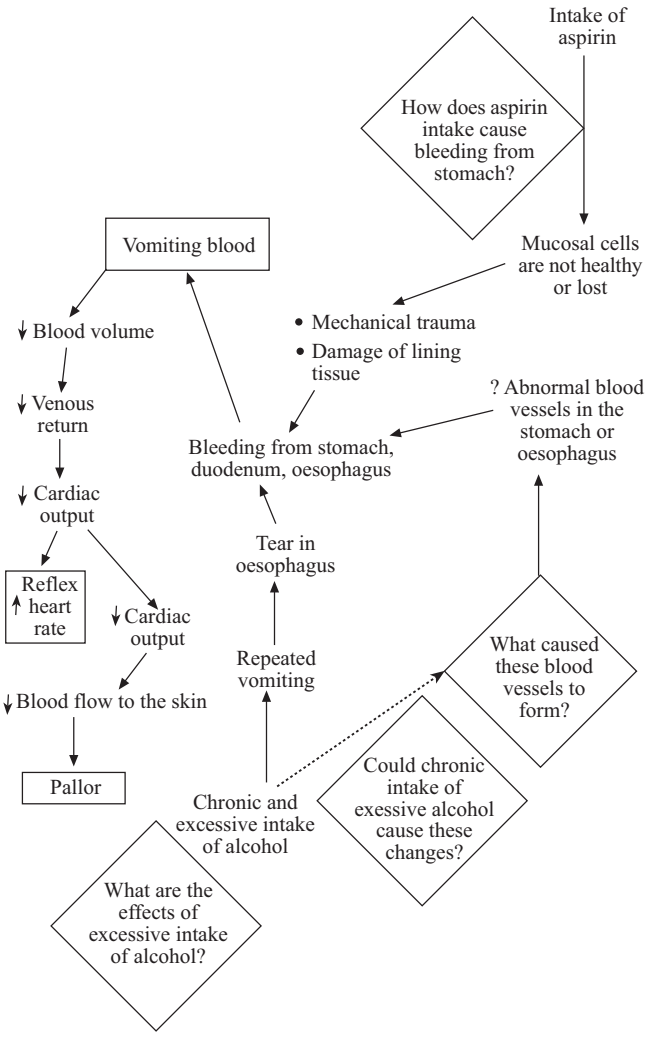

Fig. 1. An outline of a mechanism developed by students in tutorial 1 explaining vomiting blood, increased heart rate and pallor.

4 areas and they add them to their "learning issues" list: (1) What are the effects of excessive intake of alcohol? (2) Could chronic intake of excessive alcohol cause these changes? (3) How does aspirin intake cause bleeding from the stomach? (4) What caused these blood vessels to form? (These are illustrated as diamonds in Figure 1.) It is important to note that groups vary in their approaches and

not all groups will necessarily use "backward reasoning".

Thus, the development of diagrammatic mechanisms in tutorial 1 is useful and facilitates the achievement of these educational goals:

- Enhance students' reasoning skills.
- Encourage students to apply previously learnt information to a novel case.
- Enable students to identify areas of gaps in their knowledge and define their learning issues.
- Prompt students to realise the need for a grasp of the basic sciences to better understand a clinical context.
- Foster communication skills, peer-peer interaction, and the ability to make links, use logic and clarify areas of confusion.

Why is Creating Mechanisms Useful to Students' Learning in Tutorial 2?

At this stage, students have researched their learning issues using textbooks, journal articles and appropriate web sites, attended 4 or 5 lectures and possibly used a CAL programme related to the case. They should be able to use and integrate information to build a comprehensive mechanism (Fig. 2). Therefore, in contrast with tutorial 1, the goals for developing mechanisms in tutorial 2 are:

- The integration of knowledge across disciplines and the consideration of psychosocial issues in the case scenario.
- To allow students to appreciate the role of contributing factors and any risk factors mentioned in the case history.

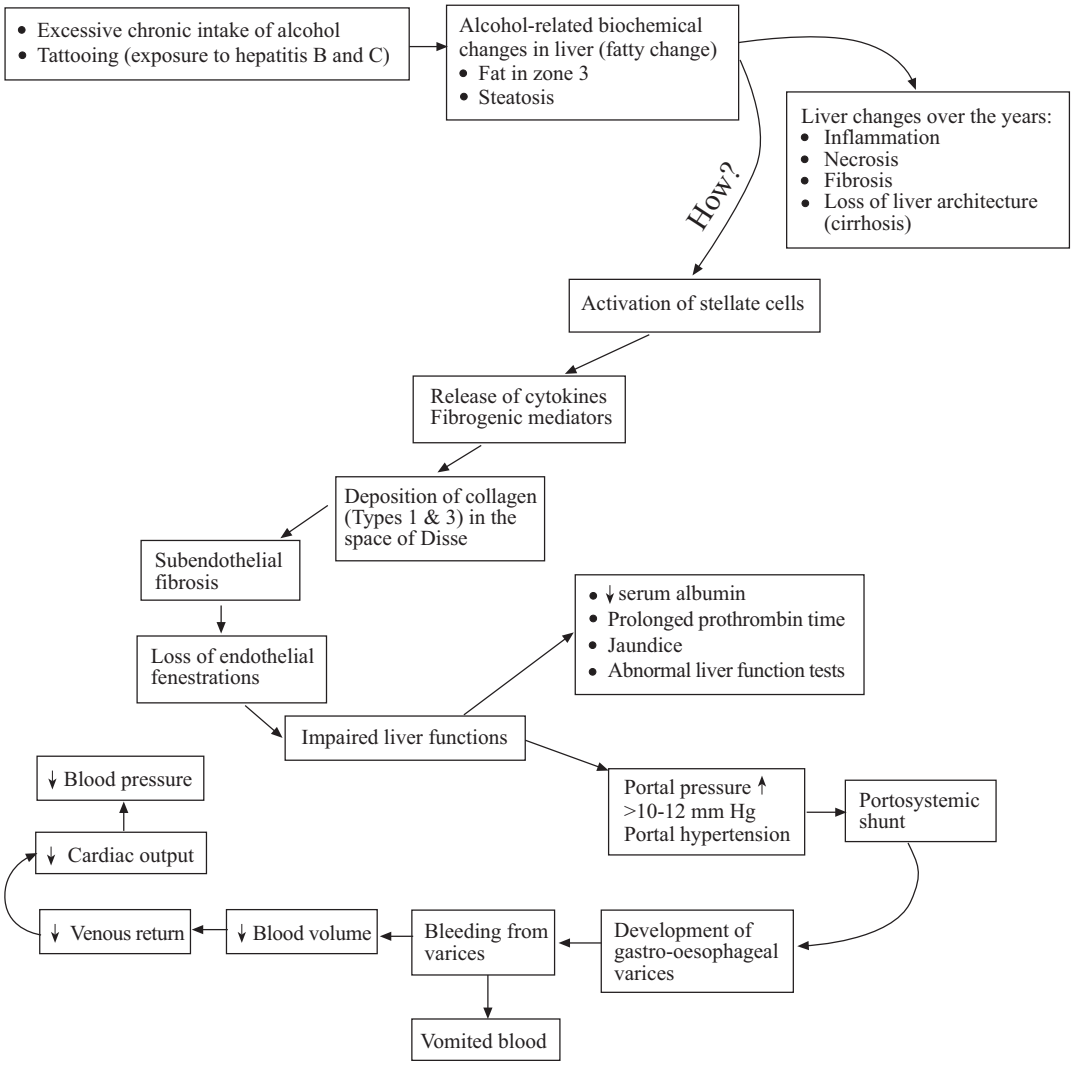

Fig. 2. Outline of mechanism created in tutorial 2.

- To encourage students to reflect on the scientific basis of a patient's presenting problems, clinical signs and laboratory changes.
- To enhance students' skills in organising pathophysiological changes in body systems and at the cellular level, with no short cuts or missed steps.

These goals cannot be achieved unless tutors are trained in facilitating group discussion so that students realise the significance of reviewing their mechanisms and utilising the information gained from different resources, such as textbooks, web sites, lectures, practical classes and CAL programmes.

Training PBL Tutors to Facilitate the Discussion of Mechanisms

In the context of major curriculum change, a staff development programme has a crucial role to play.[13] Hands-on training workshops present an opportunity for tutors to explore new skills in teaching and how to use group facilitation effectively. Successful group facilitation necessitates that tutors possess several skills including active listening, critical reflection, and the ability to create a healthy environment that allows every member in the group to participate in the discussion and to ask open-ended questions that enhance group discussion.[14] Open-ended questions should have a purpose, allow depth in learning, enable the group to work on a task and add new information to the whiteboard, motivate students to discover new challenges and foster their deep understanding of concepts discussed. However, most PBL tutors are not experts in the disciplines related to cases. They usually find it difficult to ask good open-ended questions that can drive the students' discussions and help them to build sound mechanisms. In order to boost the tutors' skills in this area, tutors need to be trained in refresher workshops, particularly in these areas:[16,17]

- How to encourage groups to keep their ground rules;
- How to explain the different roles members in the group may undertake;
- How to guide their groups to practise debating of issues rather than arguing;
- How to help the group work as a team;
- How to use open-ended questions effectively to facilitate discussion; and
- How to provide constructive feedback to the group.

The use of open-ended questions may help groups to work as a team on a task and construct their mechanisms (Table 2). This approach can be introduced in the workshop with the aims of teaching the PBL tutors to:

- Use mechanisms in PBL;
- Understand the uses of mechanisms in tutorial 1 and tutorial 2;

Table 2. Five Key Open-ended Questions to Enhance Students' Ability in Creating Their Final Mechanism

Q1. Have you considered contributing factors for your hypotheses? • Possible environmental factors. • Genetic background and family history. • Possibility of exposure to infectious agents. • Risk factors for vascular problems e.g., obesity, high blood pressure, high blood cholesterol/triglycerides, family history, diabetes. • Medications, allergies. • Psychosocial issues.
Q2. Have you considered explanations using your knowledge in basic sciences? • Anatomical, biochemical or physiological explanations, microbiological information and pathological changes. • Does your mechanism cover key issues at body system and cellular levels?
Q3. Does the flow of the mechanism explain the patient's problems and clinical signs with no short cuts? • Pathophysiological changes are placed in order. • No shortcuts. • The flow is logical.
Q4. Does the mechanism reflect the information provided in the case? • Age and background of the patient. • Medications. • Previous illness.
Q5. Have you addressed the target of your mechanism? • E.g., abdominal pain (as the problem) caused by a peptic ulcer (your hypothesis).

- Understand the different components of a mechanism;
- Realise that there is no one way for creating a mechanism but that students might need their support during this process;
- Practise how to use the 5 key open-ended questions to facilitate the discussion of mechanisms; and
- Practise how to give constructive feedback to students using the 5 key questions.

Such sessions in a workshop should be carried out by a PBL educator. The educator should:

- Provide participants with clear objectives for the session;
- Encourage participants to work in small groups and create a mechanism;
- Encourage participants to discuss the main challenges they face (as non-experts) in the construction of a mechanism;
- Use role-play in implementing the 5 key open-ended questions; and
- Provide feedback to participants on their performance.

Over the last 2 years, I have run 4 refresher workshops titled "Challenges Facing PBL Tutors" at the Faculty of Medicine, Dentistry and Health Sciences. Each workshop was attended by 12 to 14 tutors from a wide range of

Table 3. Response of Participants to the Workshop Evaluation Form

Issue	Participants' response* (n = 51)
1. The workshop was relevant to my needs.	4.61 ± 0.53
2. Overall, the workshop was worthwhile.	4.58 ± 0.49
3. The workshop has improved my understanding of how PBL works.	4.45 ± 0.67
4. The workshop has increased my confidence as a PBL tutor.	4.62 ± 0.63
5. Group facilitation: enhancing students' skills in creating mechanisms.	4.24 ± 0.83

* The mean ± SD of responses for each item in the questionnaire. The information provided was kept confidential and participants were not asked to provide their names or any clues about themselves.

backgrounds including Basic Biomedical Sciences and Physiotherapy. The aim of this workshop was to enhance the facilitation skills of PBL tutors in challenging areas such as the facilitation of mechanisms in PBL tutorials. Fifty-one tutors completed an evaluation questionnaire at the end of the workshop "Challenges Facing PBL Tutors", which I ran during 2002 and 2003. Participants were asked to rate a number of general issues about the PBL training workshop. Responses were on a scale of 5 (strongly agree) to 1 (strongly disagree). Table 3 summarises the mean ± SD of responses for each item in the questionnaire.

Why Does the Use of 5 Key Open-ended Questions Help PBL Tutors Facilitate the Discussion of Mechanisms?

- The questions are not focussed on subject matter, but rather the key components of a mechanism.
- The questions are suitable for the creation of any mechanism regardless of the body system.
- The approach is easy to use and it does not require tutors to remember scientific content.
- The questions help students to improve their mechanisms and consider the big picture as well as the essential details.
- The approach is practical and meets the philosophy of PBL.

Conclusion

Developing diagrammatic mechanisms in PBL tutorials offers students a number of educational benefits. We need to realise that the educational objectives achieved by developing mechanisms in tutorial 1 differ from those achieved in tutorial 2. The development of diagrammatic mechanisms in tutorial 1 aims to enhance students' reasoning skills, encourage students to apply previously learnt information to a novel case, enable students to identify areas of deficiency in their knowledge and define their learning issues, prompt students to realise the need for a grasp of basic sciences to better understand a clinical context and to foster communication skills in the group, peer to peer interaction, and the ability to make links and use logic. In comparison, developing mechanisms in tutorial 2 aims to integrate knowledge across disciplines and emphasise the significance of psychosocial issues in the case scenario, allow students to appreciate the role of contributing factors and any risk factors mentioned in the case history, encourage students to reflect on the scientific basis of a patient's presenting problems, clinical signs and laboratory changes and to enhance students' skills in organising pathophysiological changes at a body system and cellular level with no short cuts. The use of the 5 key open-ended questions offers an excellent opportunity for PBL tutors to better facilitate the discussion of mechanisms and provide constructive feedback to students as their teachers. PBL tutors should be trained in workshops to master this skill.

Acknowledgements

I would like to thank our PBL tutors of semesters 1 to 5, at the Faculty Education Unit, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Victoria, Australia, who provided me with useful feedback in our weekly briefing/debriefing meetings and updated me on the progress of their groups. I would also like to thank our students, who kept me engaged with PBL and their learning needs.

REFERENCES

1. Barrows H, Tamblyn R. Problem-based Learning: an Approach to Medical Education. New York: Springer,1980:10-38.
2. Norman GR, Schmidt HG. The psychological basis of problem-based learning: a review of evidence. Acad Med 1992;67:557-65.
3. Guerrero AP. Mechanistic case diagramming: a tool for problem-based learning. Acad Med 2001;78:385-9.
4. Patel VL, Groen GJ, Norman GR. Effects of conventional and problem-based medical curricula on problem solving. Acad Med 1991;66:380-9.
5. Bransford JD, Brown AL, Cocking RR. How People Learn: Brain Mind, Experience, and School. Washington, DC: National Academy Press. National Research Council, 2000:6-50.
6. Azer SA. Do recommended textbooks contain adequate information about bile salt transporters for medical students? Adv Physiol Educ 2004;28:36-43.
7. Albanese M, Mitchell S. Problem-based learning: a review of literature on its outcomes and implementation issues. Acad Med 1993;68:52-81. Erratum in: Acad Med 1993;68:615.
8. Vernon DT, Blake RL. Does problem-based learning work? A meta-analysis of evaluative research. Acad Med 1993;68:550-63.
9. Azer SA. Problem-based learning: A critical review of its educational objectives and the rationale for its use. Saudi Med J 2001;22:299-305.
10. David T, Patel L, Burdett K, Rangachari P. Problem-based Learning in Medicine: A Practical Guide for Students and Teachers. London: Royal Society of Medicine Press Ltd, 1999:4-22.
11. Hmelo CE, Lin X. Becoming self-directed learners: strategy development

in problem-based learning. In: Evensen DH, Hmelo CE, editors. Problem-based learning. A research perspective on learning interactions. New Jersey: Lawrence Erlbaum Associates Publishers, 2000:227-50.

12. Patel VL, Groen GJ. Knowledge-based solution strategies in medical reasoning. Cognitive Science 1986;10:91-116.
13. Evans PA, Taylor DC. Staff development of tutor skills for problem-based learning. Med Educ 1996;30:365-6.
14. Maudsley G. Roles and responsibilities of the problem based learning tutor in the undergraduate medical curriculum. BMJ 1999;318:657-61.
15. Wilkerson L. Tutors and small group in problem-based learning: lessons from the literature. In: Wilkerson L, Gijselaers WH, editors. Bringing Problem-based Learning to Higher Education: Theory and Practice. New Directions for Teaching and Learning. Number 68. San Francisco: Jossey-Bass Publishers, 1996:23-32.
16. Azer SA. Becoming a student in a PBL course: twelve tips for successful group discussion. Med Teach 2004;26:12-5.
17. Allen DE, Duch BJ, Groh SE. Strategies for using groups. In: Duch BJ, Groh SE, Allen DE, editors. The Power of Problem-based Learning. Virginia: Stylus, 2001;59-68.