AMEE Medical Education Guide No. 15: Problem-based learning: a practical guide

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SUMMARY *This practical guide for health professions teachers provides a perspective of one of the most important educational developments in the past 30 years. Problem-based learning (PBL) is a continuum of approaches rather than one immutable process. It is a teaching method that can be included in the teacher's tool-kit along with other teaching methods rather than used as the sole educational strategy. PBL reverses the traditional approach to teaching and learning. It starts with individual examples or problem scenarios which stimulate student learning. In so doing, students arrive at general principles and concepts which they then generalize to other situations. PBL has many advantages. It facilitates the acquisition of generic competences, encourages a deep approach to learning and prepares students for the adult learning approach they need for a lifetime of learning in the health care professions. It is also fun. PBL helps in curriculum planning by defining core, ensuring relevance of content, integrating student learning and providing prototype cases. There are also drawbacks associated with PBL. Students may fail to develop an organized framework for their knowledge. The PBL process may inhibit good teachers sharing their enthusiasm for their topic with students and student identification with good teachers. Teachers may not have the skills to facilitate PBL. The problem scenario is of crucial significance. It should engage the students' interest and be skilfully written. While the medium selected for presentation of the scenario is usually print, other media may be used. The clinical tasks carried out by the student may replace the problem scenario as the focus for learning. Students are supported during the PBL process by tutors and/or study guides. The amount of support required is inversely related to the students' prior learning and understanding of the PBL process. A range of additional learning resources and opportunities may be made available to the students, including textbooks, videotapes, computer-based material, lectures and clinical sessions. Tutors require group facilitation skills, an understanding of the PBL process and knowledge of the course and of the curriculum in general. They need special personal qualities and it is preferable if they have expertise in the content area. While special assessment processes have been developed to assess students learning by the PBL method, the general principles of assessment apply to PBL courses and a mixed menu of assessment methods needs to be employed. Curriculum design involves a skilful blend of educational strategies designed to help students achieve the curriculum outcomes. PBL may make a valuable contribution to this blend but attention needs to be paid to how it is implemented.*

Introduction

PBL is one of the most important developments in health professions education in the latter part of the twentieth century. "Some argue" suggested Boud & Feletti (1991) "that it is the most important development since the move of professional training into educational institutions". Since it was first developed by Howard Barrows at McMaster (Barrows & Tamblyn 1976), new medical schools throughout the world have adopted PBL as the educational and philosophical basis of their curricula and traditional schools have included it within their portfolio of teaching methods or have converted their undergraduate programmes to PBL.

In the UK the General Medical Council (GMC) has advocated a problem-oriented approach in its recommendations for basic medical education (GMC 1993). "Medical schools are well aware of the merits of the learner-centred and problem-orientated approaches and are striving towards their adoption, moves which are strongly encouraged."

However, PBL is also a matter of some controversy. Is it a significant development or a passing fad? Is PBL appropriate only in new medical schools or has it relevance in traditional schools? Indeed, what is PBL? Can PBL be introduced in any part of the curriculum?

One difficulty in discussions about PBL is that there is a great deal of confusion about what is meant by the term. Indeed, the term is often misused and misapplied in practice. There is also doubt or lack of clarity about the educational underpinnings of PBL. The role of the teacher in PBL is very different from the role of the teacher in the traditional curriculum and this role change may seem threatening to some teachers in the health professions. It is often thought that PBL is difficult to organize and expensive to implement in terms of time and resources.

The aim of this booklet is not to produce a critical review of the research evidence for and against PBL and its role in the undergraduate medical curriculum. A number of reviews have been published with this as their objective (Albanese & Mitchell, 1993; Vernon & Blake, 1993). Rather it is presented as a practical guide on PBL for teachers in the healthcare professions. It provides the educational background necessary for teachers to understand the approach and hints on the application of PBL to the reader's own course or curriculum.

The questions for individual teachers is not whether to implement a PBL curriculum or not, but rather the extent to which they should introduce PBL into their own teaching (Harden *et al.*, 1984). Where should their course be on the continuum between problem-based at one end of the spectrum and an information-gathering approach at the other?

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If you are not already committed to PBL, this booklet will:

- make you aware of the nature of PBL;
- highlight the advantages and limitations of PBL;
- help you to consider the range of approaches to PBL and which approach may be most appropriate for your own situation;
- provide you with hints for implementing PBL.

If you are already committed to PBL, the booklet will provide you with a deeper understanding of PBL and help you to place the approach you have adopted within a broader framework of approaches to PBL.

What is PBL?

Some definitions

Confusion and misunderstanding often exist about what PBL is. The term PBL is employed to convey different concepts and with different meanings.

It is helpful to think of PBL as active learning stimulated by, and focused round a clinical, community or scientific problem. "The principal idea behind problem-based learning is . . . that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve" (Boud, 1985). It is not simply the opportunity to solve problems, but rather learning opportunities where solving problems is the focus or starting point for students' learning. "Student work on the problem" suggested Ross (1991) "is explicitly used to get students themselves to identify and search for, the knowledge that they need to obtain in order to approach the problem". Students on presentation of the problem have two objectives: solution of the problem and learning related to the problem.

This relationship between the problem and the knowledge gained is emphasised by Boud & Feletti (1991). "This [PBL] turns the normal approach to problem solving found in university and college programmes on its head. In the normal approach, it is assumed that students have to have the knowledge required to approach a problem before they can start on the problem; here, the knowledge arises from work on the problem".

Albanese & Mitchell (1993) suggest that "PBL at its most fundamental level is an instructional method characterised by the use of patient problems as a context for students to learn problem-solving skills and acquire knowledge about the basic and clinical sciences". Barrows' explanation (1985, p. 15) provides further insights into the process. "The basic outline of the PBL process is: encountering the problem first, problem solving with clinical skills and identifying learning needs in an interactive process, self-study, applying newly gained knowledge to the problem, and summarising what has been learned."

Dolmans (1994) describes PBL as follows: "Faculty objectives are translated into a problem, usually consisting of a set of phenomena in need of some kind of explanation. Students analyse these problems, attempting to understand the underlying principles or processes through small-group discussion. During discussion, questions which remain unanswered are identified. These questions or learning issues serve as a guide for independent and self directed learning."

PBL may be though of as:

- an approach to learning and to curriculum design with a number of specified features; Walton & Matthews (1989), for example, describe it as a syndrome with eight features. Charlin *et al.* (1998) have identified seven educational principles as to how students learn in PBL;
- a specific educational approach based on the relationship between concepts or principles and examples or problems;
- a range of approaches—a genus with different species (Barrows, 1986) or a continuum (Harden & Davis, 1998);
- an umbrella term that involves any learning experiences in which problems are solved. Many would disagree with this definition, however, and would wish to see some of the features, for example those described by Walton & Matthews (1989) or by Charlin *et al.* (1998), included before calling the approach PBL.

An approach to learning and curriculum design with a number of specified features

Some authorities recognize the complex nature of the learning process which occurs in PBL and have found it helpful to regard PBL as a syndrome. Some essential ingredients were identified at a symposium on the topic attended by some of the world experts in PBL (Walton & Matthews, 1989). The acronym PROBLEM identified the key features of PBL:

Problems

"Problems provide the key units for structuring relevant learning"

Since Shoemaker developed learning in a functional context with radio technicians in 1960, educationists have appreciated the benefits of learning in a real or simulated task environment. Shoemaker's students more rapidly became effective and efficient radio technicians when trained by exploring radios that were broken than by traditional methods.

Resources

"Information for self-learning"

Students are given access to a range of resources—teachers, other health professionals, their peers, the library, basic science and clinical departments and so on—and are helped to discover the proper use of these information sources.

Objectives

"The learning objectives are planned by teachers, but with student input"

The problem scenarios, together with the curriculum documents, are a statement of faculty aims and objectives. Through identification of learning issues by students in the PBL process these aims and objectives are refined and expanded by students, facilitated by a tutor.

Behaviour

"Students' behaviour progressively mirrors that of the doctors"

In PBL students are confronted with clinical situations and are engaged in critical reasoning and decision making. They

do this as members of a small group or team. Since most health care professionals work in teams, and often in multi-professional or interdisciplinary teams, these skills should prove useful after graduation or post basic training.

Learning

"Active and student-directed; peer- and tutor-monitored"

In an experiment by Godden & Baddeley (1975), marine divers were asked to memorize information on shore and underwater. When tested, they remembered the information significantly better in the environment in which they learned it. Learning in context as in PBL assists students to organize their long-term memory for ready retrieval (Kriel *et al.*, 1986).

Examples

"Establish rules and lead to higher concepts"

Students are prompted by appropriate examples towards higher order thinking.

Motivation

"The excitement of discovery"

Students start, in PBL, with a problem that is designed not only as a focus for their teaching but also to arouse their interest in the topic. Whitehead (1932) describes the 'rhythm of education' and identifies three stages in education; romance, precision and generalization. The romance of learning, the excitement of discovery, is provided by the problem scenario.

Self-directed learning and self-assessment

"Developing the learning habit"

Learning does not end with basic training in the health professions, but continues for life. By developing self-directed learning skills, PBL facilitates the production of lifelong learners. PBL aids the development of students' assessment and criticism of themselves. In the process of PBL students have to identify what they need to learn. This promotes the habit of self-assessment essential for self-directed learning where there is no tutor, teacher or end-of-term assessment to inform students of their progress.

Charlin *et al.* (1998) defined seven criteria for student learning in PBL based on educational principles. The core principles are:

- the problem acts as a stimulus for learning;
- it is an educational approach, not an isolated instructional technique;
- it is a student-centred approach.

The student learning must involve:

- active processing of information;
- activation of prior knowledge;
- meaningful context;
- opportunities for elaboration/organization of knowledge.

A specific educational approach based on rules and examples

In the traditional approach to education, rules and principles are presented first. Students then apply these to clinical problems or examples of the rules and principles in action. In a problem-based approach the order is reversed. Students tackle problems or examples first and in doing so discover the rules and principles for themselves.

PBL is not a new concept, but has its origins in programmed learning, a form of learning package popular in the 1960s. Programmed learning was based on the behavioural psychology theory of stimulus–response. Evans *et al.* (1960) in "The RULEG system for the construction of programmed learning sequences" advocated starting the course of instruction from a generality or rule (RUL) and moving towards a statement of specificity or an example (EG), hence the RULEG approach. However, some programmers preferred to start with the examples and move towards an understanding of the underlying principle by working out the principle from the examples—an EGRUL approach. They found that this helped students learn just as well as, if not better than, the traditional approach (Gagné & Brown, 1962; Foord, 1964; Markle, 1964). In PBL in the health care professions, scenarios are selected as the examples and by actively working on these problems, students are expected to arrive at general principles (Harden & Davis, 1998). The scenarios may be related to a clinical, community or scientific problem.

Bordage & Lemieux (1991) believe the provision of prototype cases is important. They arrived at this conclusion after contrasting the diagnostic and clinical reasoning skills of experts and novices. Their findings indicate that the expert has in mind a prototype case with which he compares and contrasts the patient in front of him at the time. "We tend to tie the solving of new clinical challenges to how they resemble or differ from certain prototype cases." The importance of PBL is that the skilful selection of problem scenarios can provide students with prototype cases.

A range of approaches

PBL has developed, since it was first employed in McMaster University in the 1960s, into "a genus for which there are many species and sub species" (Barrows, 1986). "Each addresses different objectives to varying degrees." Barrows identifies the more important learning objectives as:

- structuring knowledge for use in clinical contexts;
- developing an effective clinical reasoning process;
- development of effective self-directed learning skills;
- increased motivation for learning.

Different PBL methods address these objectives to varying degrees. We have described different approaches to PBL based on the relationship between the two elements in PBL, the problem and the learning derived from a study of the problem. The 'EGRUL' model provides a basis for understanding the relationship between the problem and the lessons learned. It also gives an insight into the continuum that exists between a fully problem-based curriculum at one end of the spectrum and an information-orientated curriculum at the other (Harden & Davis, 1998).

The PBL continuum is presented as eleven steps, which are summarized in Table 1. As one progresses along the

Table 1. Problem-based learning — a continuum (reprinted from Harden and Davis, 1998)

	Terminology	Description	Example
1. 	Theoretical learning.	Information provided about the theory.	Traditional lecture. Standard textbook.
2. 	Problem-orientated learning.	Practical information provided.	Lecture with practical information. Protocols or guidelines.
3. 	Problem-assisted learning.	Information provided with the opportunity to apply it to practical examples.	Lecture followed by practical or clinical experience. Book with problems or experiences included.
4.	Problem-solving learning.	Problem-solving related to specific examples.	Case discussions and some activities in practical classes.
5. 	Problem-focused learning.	Information is provided followed by a problem. The principles of the subject are then learned.	Introductory or foundations courses or lecture. Information in study guide.
6. 	Problem-based mixed approach.	A combination of problem-based and information-based learning.	Students have the option of an information orientated or problem-based approach.
7. 	Problem-initiated learning.	The problem is used as a trigger at the beginning of learning.	Patient management problems are used to interest the student in a topic.
8. 	Problem-centred learning.	A study of the problem introduces the student to the principles and rules specific to the problem.	A text provides a series of problems followed by the information necessary to tackle the problems.
9. 	Problem-centred discovery learning.	Following the presentation of the problem students have the opportunity to derive the principles and rules.	Students derive the principles from the literature or from work undertaken.
10 	Problem-based learning.	The development of the principles includes the generalisation stage of learning.	The investigation of patients with thyrotoxicosis is extended to a more general understanding of thyroid function tests.
11 	Task-based learning.	The problem is the real world.	A set of tasks undertaken by a healthcare professional are the basis for the 'problem' presented to the student.

continuum the relationship between the 'RUL' and 'EG' changes with increasing importance being placed on the examples and with the examples becoming the focus for the learning. The final stage is 'task-based learning' (TBL), a development of PBL where the focus is the tasks undertaken by a doctor rather than a written simulation (Harden *et al.*, 1996).

Why should you be interested in PBL?

Some advantages of PBL

PBL has now been in use for more than 25 years and brings many real benefits to health professions' education. If used appropriately it could result in several advantages for your teaching programme:

- *Relevance*: Relevance of curriculum content is facilitated by structuring student learning round common clinical problems. PBL helps to eliminate much of the irrelevant and outdated teaching currently cluttering undergraduate or basic training programmes.
- *Identification of core*: The PBL approach, through its identification of core, has the potential to make an important contribution towards the reduction of information overload that overburdens many of our students.
- *Generic competences*: The approach contributes to the acquisition of generic competences or personal transferable skills such as problem solving, communication and team working, essential for all graduates of higher education (Allen, 1992). It thus helps develop education for capability, another important trend in health professions education which enables graduates to 'hit the ground running' on entering their first step on the career ladder.
- *Student centred*: The PBL process involves the student taking more responsibility for his or her learning, a feature that is thought to prepare students for learning in later life. The speed of developments and of innovation in patient care and in health care delivery requires all health professionals to make a commitment to keeping up to date through lifelong learning. PBL helps to prepare students for the adult learning approach they will need to employ later, in the continuing education phase of their professional life. There is some evidence in the area of the management of hypertension that graduates of a PBL curriculum may be more up to date than their peers (Shin *et al.*, 1993). The move away from passive learning and rote memorization, towards a more active approach in which the student is actively engaged in the learning process, can improve understanding and retention of what has been learned, by promoting a deeper approach to learning. Identification of learning issues by students enables them to set their own goals and take decisions regarding relevant content. This is a major asset of the PBL process.
- *Integration*: Integration has been shown to bring real benefit to student learning (Schmidt *et al.*, 1996). PBL is an important educational strategy for integrating the curriculum.
- *Motivation*: PBL is fun and rated enjoyable by both students and staff. Teachers in traditional curricula are familiar with the spectre of listless students, switched off by the information overload which has been a feature of undergraduate medical education for at least the past 100 years. Courses that depend largely on information gathering will direct students' learning styles towards rote learning of facts and information. One of the most widely accepted merits of PBL is its ability to motivate or remotivate students by freeing them from rote learning. Moreover, the clinical setting of the scenario is motivating for students.
- *Deep approach to learning*: PBL encourages a deep approach to learning. During the PBL process, students interact with the learning material more than in an information-gathering or theoretical approach. Concepts are related to everyday experience and evidence is related to conclusions. These are features of the deep approach to learning. If, as teachers, we wish to foster deep as opposed to surface learning in our students then we can use PBL as a tool or strategy.
- *Constructivist approach to learning*: PBL facilitates a constructivist approach to learning. When generating learning issues, students make use of existing or prior knowledge to identify what they still need to learn. Dewey (1929) proposed that learners construct personal, conceptual schemata or frameworks for organizing and retrieving information. The process of learning involves activating appropriate schemata and organizing new learning within the framework. PBL involves this constructivist approach to learning.
- *Prototype cases*: The scenarios in PBL may in many instances be considered by students as prototype cases as discussed above. In general, "the literature on the principles of adult learning indicates that people learn

best when they are ready and motivated to learn, involved in setting goals and deciding on relevant content and when they participate in decisions affecting their learning" (Westberg & Jason, 1993). All of these features are aspects of PBL.

Some disadvantages of PBL

The advantages of a PBL curriculum have been well articulated by those who have adopted it into their teaching and learning programmes. In an editorial, Norman (1998) suggested that "For too long PBL has been viewed as a self-evidently 'better' approach to health sciences education, despite an accumulation of evidence that the outcomes are not much different". Hemker (1998), writing from the perspective of a teacher in the Biochemistry Department in the Medical Faculty at Maastricht University, identified three objections to PBL:

- PBL makes it very difficult for students to identify with a good teacher. In PBL the teacher serves as a facilitator rather than acting as a role model. This may deprive students of the benefits of learning from an inspirational teacher. The use of PBL, however, does not necessarily exclude the opportunities for this to happen.
- PBL does not motivate staff to share knowledge with the students. Staff are denied the fun of sharing their processes of understanding with their students and of 'getting a buzz' out of teaching. On the other hand, many staff find it rewarding and stimulating, working within a PBL context.
- The knowledge acquired through PBL tends to remain unorganized. Organization of knowledge in traditional courses comes from students being introduced to a topic by experienced teachers able to distinguish between what is important and what is unimportant. The use of study guides may overcome this potential disadvantage.
- PBL requires competences many teachers do not possess. Teachers in medicine tend to teach as they themselves were taught using traditional approaches (Irby, 1996). Staff development programmes must be sufficiently robust to meet these challenges.
- Concern has also been expressed about the cost of implementing a PBL programme. PBL, however, is not necessarily more expensive than traditional approaches (Nieuwenhuijzen *et al.*, 1997; Sefton, 1997).
- PBL may be time consuming for students, particularly if they need to identify educational resources for themselves. The use of study guides, which identify the most appropriate learning material, will minimize this potential drawback.

Despite these concerns it is likely that PBL has a role to play in your teaching, even if it is not the panacea envisioned by some enthusiasts. The strategies for implementing PBL described in this booklet may help you overcome some of the potential problems with regard to PBL.

What approach to PBL should you adopt?

The question for the individual teacher is which of the range of approaches to PBL should be adopted in your teaching. This will depend on a number of issues:

- *Outcomes of the course*: The curriculum outcomes will influence the educational strategy to be adopted (Harden *et al.*, 1999). If the philosophy of the curriculum and the course outcomes emphasize factual recall of information, the most appropriate approach is likely to be situated at the information-orientated end of the continuum with a passive approach to learning. In courses where problem solving or application of knowledge is an intended outcome, an approach towards the problem-based end of the continuum may be more helpful with active learning promoting deeper understanding and higher order thinking.
- *Students and staff*: The successful implementation of PBL requires staff who are motivated and trained in this method of teaching. Student induction in the PBL process is also crucial for its successful implementation. Students need training in the appropriate use of the educational resources that are provided for them, such as electronic databases or 'drop-in' facilities in a clinical skills centre. Traditional teaching, if delivered well, is almost certainly likely to be better than PBL implemented badly.
- *Availability of resources*: The availability of resources will influence the approach to PBL to be adopted. Problem-based strategies tend to require a range of educational resources such as textbooks, computer-based material, videotapes and models. Space availability is also an important consideration. Implementation of PBL with small groups of students needs space for the small groups to meet and space is required for educational facilities such as a computer suite or learning resource area. A more information-orientated approach requires more teaching space in the form of lecture theatres.
- *Learning context*: PBL has been found to be difficult to implement in the clinical setting, although the literature contains examples of successful PBL experiments in hospitals or ambulatory care (Petrusa & Allensworth, 1985). TBL is an educational strategy that is particularly useful in the clinical context.
- *Activation of prior knowledge*: PBL builds on the students' prior learning. Although Barrows argues that even high school pupils have sufficient learning and everyday experience to learn by PBL, many teachers prefer to select approaches in the middle of the continuum when they feel prior knowledge is insufficient to support PBL or TBL.
- *Promotion of group skills*: PBL approaches that encourage small-group activities help to promote outcomes such as team working and communication skills.
- *Student choice*: There may be advantages in offering students a choice of learning strategies. In some circumstances this may be possible. Parallel PBL and traditional tracks have been offered in medical schools such as Harvard and New Mexico although many have moved to offering only a PBL programme. Distance learning courses make it possible to offer more easily a choice of information-gathering or PBL approaches to learning. Individual students are able to select their preferred learning approach (Rogerson & Horton, 1998).

The PBL process

The details of how the PBL process is implemented differ from institution to institution. However, the general

principles remain the same. Students are not regarded as passive vessels to be filled with facts by lecturers or teachers. They actively learn for themselves using the problem as a focus for their learning.

A number of identifiable stages or steps in the PBL process have been described. This begins with the problem scenario, which is often presented cold to the students; that is, they have not prepared themselves through previous study of the scenario.

Students, either working individually or more usually in groups, read through the scenario and identify unfamiliar terms or concepts. They inquire into the problem situation. Some group members may be able to clarify areas of uncertainty or plug knowledge gaps for others during this stage. From their prior learning, the group determines underlying mechanisms and develops possible explanations for the problem scenario. Further information about the scenario may be made available to the students if they request it; for example, in a clinical scenario, the results of patient investigation may be provided if requested. The additional information may be available on cards or may be provided by the tutor.

The group will encounter gaps in their understanding and identify these as the learning issues associated with the individual problem scenario. These learning issues should relate to the learning objectives previously identified by faculty. Some schools choose to assist the students in the process by providing a set of learning objectives identified by faculty which helps them to relate their work on the problem to overall course objectives.

Following this first stage there is a period for individual study. Students tackle the learning issues through accessing a range of educational resources.

When the group meets again, students share what they have learned and apply the learning to the problem scenario. The student group may be able to explain fully the phenomena identified in the problem scenario at this stage but they may also identify further learning issues which require another period of individual study. The group learning is then synthesized to explain the observations in the problem scenario. During this step students organize prior and new learning around the problem scenario. This aids retrieval of what has been learned when a similar problem or situation is encountered later in professional practice.

The final vital step in the PBL process is to generalize the learning to other situations in which such knowledge, skills and attitudes would be applicable; for example, an understanding of inflammation in a wound-repair scenario is broadened to a general understanding of the inflammatory process in other situations.

Individual medical schools have organized PBL in different ways: for example, the Harvard six steps approach emphasizes generalisation of what has been learned (Table 2). The Maastricht seven jump approach includes brainstorming (Table 3). Other medical schools, such as Liverpool, Glasgow and Manchester, have adopted different approaches (Bligh & Wilkinson 1997). Whichever approach is adopted, however, the basic concept is the same—through active involvement, students move from the example or problem towards the rule, principle or concept and then generalize their learning to other contexts or settings.

Table 2. Harvard Medical School Six Step Method

(1)	Group receives the written problem scenario without the opportunity to study it beforehand
(2)	The student group defines the problem
(3)	The study group identifies the learning goals
(4)	Students work independently to achieve the learning outcomes
(5)	The student group is reconvened. The students build new learning on to prior knowledge. Students review whether they have met faculty learning objectives. Further individual work and group meetings may be required to achieve this
(6)	The group synthesizes and summarizes their work. The students generalize from the specific problem scenario to other situations

Table 3. Maastricht Medical School—the seven steps in PBL

(1)	Students, working in a group, clarify the text of the problem scenario
(2)	Students define the problem
(3)	Brainstorming is used to identify explanations for phenomena observed in the problem scenario
(4)	The group reaches interim conclusions about the problem
(5)	The group formulates the learning objectives
(6)	Students work independently to achieve the learning outcomes
(7)	The student group reconvenes to discuss the knowledge acquired

The problem and its presentation

In this section we look at what makes a good problem scenario and the medium used to present it.

What makes a good problem scenario?

The selection of problem scenarios for use in PBL has often been a matter of intuition or serendipity. It is, however, a matter of importance. The design of appropriate problem scenarios ensures that students cover a pre-defined area of knowledge or learn a set of important concepts, ideas or techniques. The problem should lead students to a topic or field of learning and so meet faculty learning objectives (Ross, 1991). The role of the problem scenario (Margetson, 1998) is to act either as a 'convenient peg' on which to hang knowledge acquisition or as the focus of a 'growing web' of understanding in practice.

Dolmans *et al.* (1997) have identified seven criteria for effective problem design. The criteria, which are based on what is currently known about the nature of learning, are:

(1) *Learning outcomes*: The learning issues likely to be identified by students through study of the problem are consistent with faculty learning objectives. A problem scenario may address different categories of learning outcomes including scientific understanding, an understanding of health promotion or ethical issues. In a system-based programme, the scenario may address learning related to the different systems.

(2) *Phase of the curriculum*: The problem should be consistent with the phase of the curriculum and stage of student learning. It should enable students to build on and activate prior learning.
(3) *Relevance and motivation*: The problem scenario should be relevant to the students' future practice as health-care professionals and if not, should be of sufficient intrinsic interest to motivate the students and encourage them to spend more time on self-study.
(4) *Integration*: The problem scenario should present basic science concepts in the context of a clinical problem to encourage integration of knowledge. Such integration has been shown to improve clinical diagnosis (Schmidt *et al.*, 1996).
(5) *Cues*: The problem scenario should contain cues to guide the student and to stimulate discussion. It should further encourage students to elaborate and to search for explanations.
(6) *Open problem*: The problem scenario should not be so complete or closed that it is difficult to sustain discussion or that no further explanation is needed.
(7) *Student activity*: While all problems should be designed to promote active involvement by students in acquiring the necessary information, some problems may be constructed which will require more work by the student; for example, more detailed library searches or a small piece of investigative work.

Considerations in the choice of medium

Problems are usually presented to students in print. However, other media may be used. Newspaper clippings, audio-tape, videotape and computer simulations may all be used. In TBL, the real-life task carried out by the student provides the learning stimulus (Aspegren *et al.*, 1998).

A number of factors need to be taken into account when selecting the most appropriate medium to present the problem to students. These factors have been identified by Harden (1983) in the context of patient management problems but several are also relevant to PBL. These are:

- the ability to communicate the necessary information;
- ease of use;
- ease of production.

Newspaper clippings. Newspaper clippings may be used as PBL triggers. In the International Medical University in Kuala Lumpur in Malaysia an article 'Curbing Prostatic Disease' was used to focus student learning about the anatomy of the prostate, the diseases that affect it and their pathophysiology, and diagnostic tests for disease of the prostate.

Audio-tape triggers. The problem may be presented on an audio-tape. At the University of Newcastle, New South Wales, an audio-tape of a simulated emergency call to a general practitioner regarding an elderly patient who has collapsed was used as a trigger for learning about initial management and differential diagnosis of the collapsed patient.

Videotape. Videotapes may also be used. At the University of Dundee Medical School, a videotape of a patient during labour is used to introduce the problem to multiprofessional groups of nursing and medical students in a session where the learning objectives relate to the mechanism of labour and the role of doctors and midwives during labour. Situations such as breaking bad news, dealing with the bereaved or confrontational situations all make useful stimuli for a problem-based approach to learning which can be presented to students on videotape.

Computer. The computer may also be used to deliver PBL. 'PC Challenges' is a computer simulation in which a group or an individual is presented with a time-dependent simulation of patients with cancer-related pain (Harden *et al.*, 1998). Students have to manage the patient with the aim of discharging the patient from hospital with the pain controlled. This can be used as a vehicle for PBL. Students can take 'time out' from the management of the patient to look at what they already know that can help them and what they need to know and learn. They may obtain further information about managing patients with cancer-related pain on-line or in an accompanying text 'HELP'—Helpful Essential Links to Palliative Care (CME, 1995).

SACARA is a problem-based computer programme designed to update nurses on the topic of wound management (Davis *et al.*, 1998). Clinical scenarios are presented to cover common problems relating to a range of commonly occurring wounds. Help files can be accessed when further theoretical or scientific information is required to tackle the problem. Through group discussion or individual consideration of a series of questions, nurses arrive at management decisions which they can then compare with those of experts. They are then given feedback on their management.

Tasks as part of the health professionals' daily activities. The problem may be presented as a simulation using the range of media identified above or as a task undertaken by a doctor—TBL (Harden *et al.*, 1996). In TBL, the tasks carried out by the student, trainee or practitioner are used as a focus for learning. In TBL in dentistry, the following tasks served as a focus for learning during the first postgraduate year (CME, 1989):

(1) handling a patient with caries and undertaking the necessary restorations;
(2) undertaking treatment of a patient with a periodontic problem;
(3) handling a case of acute dental pain;
(4) undertaking treatment of an endodontic problem;
(5) management of a patient needing partial or complete dentures;
(6) undertaking minor surgical procedures (e.g. tooth extraction, root extraction, etc.).

These tasks relate to the competences the dental vocational trainees are expected to master during the training year such as communication with patients or their relatives, diagnostic skills, treatment planning, implementing treatment, prescribing, referral and management of other members of staff.

In a study guide for junior hospital doctors working in Paediatric units in the UK, produced for the Scottish Council for Postgraduate Medical and Dental Education by the Dundee Centre for Medical Education, the learning is focused round normal children and various examples of sick children the junior doctors might be expected to see (CME 1996).

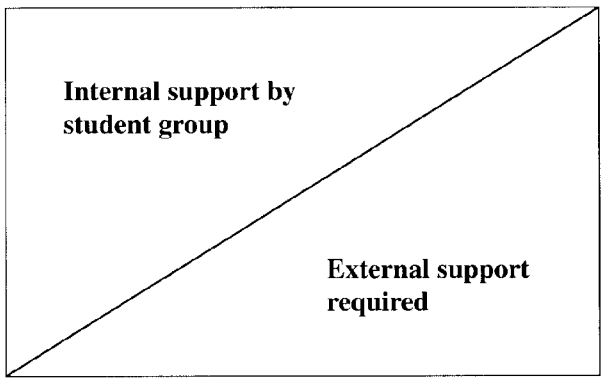

Figure 1.

Facilitating PBL

The extent to which facilitation is necessary

In PBL, students require a measure of support. This may be supplied through a facilitator in a PBL group or through supportive resource material provided, for example, in a study guide. The amount of external support required is dependent on the prior learning of the students and on their understanding of the PBL process. Internal support may also come from other members of the group through a collaborative learning process in which students learn from each other. Where there is a high level of internal support the need for external support is reduced (Figure 1). The greater the internal student support in terms of prior learning and experience with the PBL process, the less external support is required.

Where the level of prior learning is lower, greater external support is required. This support may come from the group facilitator (or tutor) or from material pre-prepared by faculty. In some situations a faculty facilitator may not be required but this is likely to be exceptional. Duek *et al.* (1996) studied tutorless groups and concluded that "the reliance on a tutorless format may not be appropriate when other sources of structure are absent from the curriculum". Students have sometimes been used as group facilitators.

The process of facilitation

If learning is the active construction of meaning, teaching can then be defined as the facilitation of learning. Nowhere is this definition more apt than in PBL. Here, "the teacher serves as both a monitor and stimulus to the process by asking leading questions, challenging thinking and raising issues or points that need to be considered. The teacher attempts to help students help themselves in the educational process" (Barrows & Tamblyn, 1980). These authors see the teacher's role in PBL as that of a guide, helping "the student develop skills in scientific reasoning, self-study and self-evaluation". They recommend that teachers should respond as an information source to a direct enquiry "only after they are sure that students have exhausted their own logic or information base and feel that the information provided will facilitate further work with the problem at the time, without sacrificing the value of self-study".

There are several different types of competence associated with group facilitation in PBL. These are:

(1) skills in facilitation of the small-group learning;
(2) an understanding of the programme for the week or for the course, including the ability to help the student relate the work on the problem to the learning opportunities during the week or course;
(3) an understanding of the overall educational programme and the ability to help students place the work undertaken in tackling the problem within the overall framework of the curriculum and the overall learning outcomes for the curriculum. This includes an appreciation of the stage of learning of the students and what they have already studied;
(4) Schmidt & Moust (1995) found that personal qualities of facilitators, "such as the ability to communicate with students in an informal way, an empathetic attitude and the creation of an atmosphere in which the open exchange of ideas is facilitated", seem to be important in promoting student learning. Qualities also helpful include a "willingness to become involved with students in an authentic way and the skill to express oneself in a language understood by students";
(5) perhaps one of the most contentious issues in PBL is whether the group facilitator should be an expert in the content matter related to the problem. Some argue that such competence frequently distracts from the tutor's role of facilitator. Others believe that subject-matter experts who have also been appropriately trained in facilitation skills are likely to be the best facilitators (Davis *et al.*, 1992). Schmidt (1994) found "that students need a minimum level of structure to profit from PBL instruction. This structure can be internally provided through prior knowledge available for understanding the new subjects, or offered by the environment in the form of cues of what is relevant and what should be the focus of activities. If prior knowledge falls short, or if the environment lacks structure, students will turn to their tutors for help and direction. Under those conditions, students who are guided by a subject-matter, expert tutor may benefit more than those students guided by a non-expert staff tutor or by a student tutor."

In conclusion, it could be argued that the best tutor is the subject-matter expert who understands the course and the curriculum and who has the appropriate group facilitation skills. The second choice would be a medically qualified member of staff who is not an expert in the area but who understands the course and the curriculum and has the appropriate group facilitation skills. The third choice would be someone who has an understanding of the curriculum and the appropriate group facilitation skills but who does not have medical understanding or knowledge. There are, however, many examples of where non-experts and non-medically qualified facilitators function effectively. What are essential, however, is group facilitation skills and appropriate personal qualities.

Staff development

Newer approaches to health professions education make many demands on the medical teacher and the different roles of the teacher have been described (Harden, 1997). Many teachers are more comfortable with the role of information provider as in lectures or clinical teaching. Few

have experience of the role of facilitator and feel comfortable in this role. Many find difficulties in implementing a PBL approach and an extensive staff development programme is mandatory prior to the introduction of a PBL course. Models for faculty development for PBL have been described (Irby, 1996).

A staff development programme should address the competences expected of the tutor as described in the previous section. The staff development programme may be provided as:

- a formal course which includes active involvement of staff and a study of examples of PBL;
- guided on-the-job experience with a new facilitator initially sitting in with an experienced facilitator during PBL sessions;
- self-study through the use of books and other resource material, for example, reading this booklet.

Role of study guides

Much attention has been paid to the role of the tutor in PBL facilitation. Less attention has been paid to the use of study guides as a form of support. Student study guides have been described by Rowntree (1986). They can help students to manage their own learning (Laidlaw & Harden, 1990) and can support PBL as used in the undergraduate medical curriculum at the University of Dundee Medical School. The guides provide:

- a description of the problem scenarios or tasks;
- assistance with identification of learning issues;
- information about how the problem or task contributes to the overall learning outcomes for the medical course;
- a description of other learning opportunities available such as lectures, sessions in the integrated learning area and clinical skills centre.

The study guides have been rated by students as one of the most helpful and popular features of the course and have been identified by external evaluators as an example of good practice. The guides can also be made available to students in electronic format (Harden & Smyth, 1994).

Student assessment and PBL

The approach to student assessment should be reviewed at the same time as PBL is introduced as a learning strategy. Student behaviour and approach to learning is influenced by the assessment tools used (Harden, 1992). If the assessment process emphasizes factual recall and rote memorization, PBL may appear less attractive to students and students may be less enthusiastic to participate in the PBL process. If, on the other hand, the assessment process tests a deeper learning, understanding and/or problem solving, then the relevance of the PBL will be apparent.

Student assessment in PBL is governed by principles similar to those applied to the assessment of students more generally. The assessment should be designed to test the individual student's ability to fulfil the curriculum outcomes or objectives. Student assessment benefits from a mixed menu approach which is designed to test a range of curriculum outcomes.

If the curriculum outcome to be assessed is knowledge, this may be effectively and efficiently tested using multiple-choice questions (MCQs).

If the curriculum outcome to be assessed is problem solving, then modified essay questions (Knox, 1975) provide a method capable of testing higher order thinking and application of knowledge. The extended matching item format (Case & Swanson, 1993) is an extension of the multiple-choice format that may be used to test clinical decision making, data interpretation and other intellectual activities that require recall and recognition of knowledge and problem solving.

The objective structured clinical examination (OSCE) (Harden & Gleeson, 1979) provides a robust framework for testing a range of curriculum outcomes such as clinical methods, data interpretation, health promotion and disease prevention and can be designed to assess ethics, attitudes and problem solving.

Some PBL schools have adopted the progress test. This provides students and staff with feedback about student progress (Blake *et al.*, 1994, 1996). The progress test is usually MCQ based and covers the whole curriculum making revision for the test impractical. It is claimed, therefore, that it does not disrupt the learning process or drive learning styles and is unlikely to prejudice the educational philosophy of the curriculum the students are following.

The triple-jump method has been designed to assess student ability in the PBL process (Painvin *et al.*, 1979) but it is not widely used.

An innovative approach which offers potential is the use of portfolios for assessment (Snadden & Thomas, 1998). Students can include in their portfolio evidence of work undertaken in relation to the problem and their reflections on how this work has helped them meet the curriculum outcomes. The portfolio may include material such as case histories, log books, checklists of clinical skills mastered and other personal achievements such as publications in their records of achievement or portfolios. Assessment of the portfolio can test curriculum outcomes such as independent learning, record keeping and other areas difficult to assess by traditional approaches. Portfolio assessment can also measure group work and individual contributions to groups.

One issue for consideration is whether the student's performance in the PBL group should be assessed by their tutor and/or other members of the group. While the objectives of so doing are worthwhile, practical considerations include the reliability of the procedure and the effects the process may have on tutor/student relations.

Relationship of PBL to other educational strategies and curriculum developments

Skilful curriculum design involves employing a sophisticated blend of educational strategies to obtain the desired educational outcomes. The SPICES model (Harden *et al.*, 1984) identifies a range of educational strategies and provides educators with an instrument for analysis of the curriculum and for future planning.

Student centred	teacher centred
Problem-based	information gathering
Integrated	discipline based
Community oriented	hospital based
Electives with a core curriculum	standard course
Systematic	apprenticeship

PBL contributes to a more student-centred curriculum. It requires students to work out for themselves what they need

to learn and to undertake the necessary studies to meet these needs. However, faculty usually identify the learning objectives and develop the problem scenarios; in other words, the curriculum outcomes remain firmly in faculty control. Moreover, students are required to adopt a problem-based approach to learning as determined by faculty and attendance at PBL group sessions is often made compulsory.

PBL is a useful approach to delivering an integrated teaching and learning programme. Other approaches to integration are available and many systems-based, multidisciplinary programmes are not problem based. PBL is also a useful approach for multiprofessional education (Harden, 1998) with students from the different professions contributing from their disciplines' perspective to the problem as presented (Mires *et al.*, 1999).

A PBL curriculum can be community based or hospital based. Problems can be designed to have a community orientation. In a community-based curriculum a task-based approach is perhaps of most value.

An important development in medical education is the move to a core curriculum with options or special study modules. Such curricula may or may not be problem based. The core curriculum may be problem based but the options need not be so and vice versa. The problem scenarios help to define the core.

It is difficult to provide systematic, thorough coverage of core content with PBL and one of the criticisms voiced about PBL is that students may have gaps in their knowledge and skills. The counter-argument is that the gaps are not important because with the problem-based approach students learn how to identify their own learning needs, learn how to make use of educational resources and, with time, they can remedy the learning deficits for themselves.

Conclusions

PBL is an important development in health professions education with the advantages and the disadvantages well documented.

It contributes to the sophisticated blend of educational strategies consistent with current trends in curriculum planning.

Thought is needed as to which of the many approaches to PBL should be adopted, how it can be implemented in practice in your situation and what resources and staff are needed to support the PBL process.

References

ALBANESE, M.A. & MITCHELL, S. (1993) Problem-based learning: a review of literature on its outcomes and implementation issues, *Academic Medicine,* 68, pp. 52–81.

ALLEN, M.G. (1992) *An Annotated Bibliography: Transferable Personal Skills and the Higher Education Curriculum* (Sheffield, Employment Department, University of Sheffield).

ASPEGREN, K., BLOMQVIST, P. & BORGSTROM, A. (1998) Live patients and problem-based learning, *Medical Teacher,* 20, pp. 417–420.

BARROWS, H.S. (1985) *How to Design a Problem-based Curriculum for the Pre-clinical Years* (New York, Springer).

BARROWS, H.S. (1986) A taxonomy of problem-based learning methods, *Medical Education,* 20, pp. 482–486.

BARROWS, H.S. & TAMBLYN, R.M. (1976) An evaluation of problem-based learning in small groups utilising a simulated patient. *Journal of Medical Education,* 51, pp. 52–54.

BARROWS, H.S. & TAMBLYN, R.M. (1980) *Problem-based Learning: an Approach to Medical Education* (New York, Springer).

BLAKE, J., JOHNSON, A., MUELLER, C.B., NORMAN, G., KEANE, D., CUNNINGHAM, J., COATES, G. & ROSENFELD, J. (1994) Progress report on the personal progress index, *Pedagogue, Perspectives on Health Sciences Education,* 5, pp. 1–6.

BLAKE, J.M., NORMAN, G.R., KEANE, D.R., MUELLER, C.B., CUNNINGHAM, J. & DIDYK, N. (1996) Introducing progress testing in McMaster University's problem-based medical curriculum: psychometric properties and effect on learning, *Academic Medicine,* 71, pp. 1002–1007.

BLIGH, J. & WILKINSON, P. (1997) Report of a workshop on problem-based learning and its implications for medical education in the UK, *Postgraduate Medical Journal,* 73, pp. 449–459.

BORDAGE, G. & LEMIEUX, M. (1991) Semantic structures and diagnostic thinking of experts and novices. In Research in Medical Education. *Academic Medicine* 66, (suppl.), pp. S70–S72.

BOUD, D. (1985) Problem-based learning in perspective, in D. BOUD (Ed.), *Problem-based Learning in Education for the Professions* (Sydney, Higher Education Research and Development of Australia).

BOUD, D. & FELETTI, G.I. (1991) *The Challenge of Problem-based Learning* (London, Kogan Page).

CASE, S.M. & SWANSON, D.B. (1993) Extended matching items: a practical alternative to free response questions, *Teaching and Learning in Medicine* 5, pp. 107–115.

CENTRE FOR MEDICAL EDUCATION (1989) *Dental Vocational Training Guide* (Dundee, Centre for Medical Education).

CENTRE FOR MEDICAL EDUCATION (1996) *Learning Paediatrics: a Training Guide for Senior House Officers* (Dundee, Centre for Medical Education).

CENTRE FOR MEDICAL EDUCATION & CANCER RELIEF MACMILLAN FUND (1995) *Helpful Essential Links to Palliative Care* (Dundee, Centre for Medical Education, and Perspective).

CHARLIN, B., MANN, K. & HANSEN, P. (1998) The many faces of problem-based learning: a framework for understanding and comparison, *Medical Teacher,* 20, pp. 323–330.

DAVIS, M.H., HARDEN, R.M., LILLEY, P.M., MCMANUS, N.K., ROGERSON, E. & SMYTH, J.J. (1998) The relative merits of the CD and the OHP in small group sessions: the SACARA experience. Association for Medical Education in Europe. Abstracts of the AMEE Conference, Vienna, Austria, *Medical Teacher,* 20, p. 55.

DAVIS, W.K., NAIRN, R., PAINE, M.E., ANDERSON, R.M. & OH, M.S. (1992) Effects of expert and non-expert facilitators on the small group process and on student performance, *Academic Medicine,* 67, pp. 407–474.

DEWEY, J. (1929) *The Quest for Certainty* (New York, Minton).

DOLMANS, D. (1994) *How Students Learn in a Problem-based Curriculum* (Maastricht, Universitaire pers Maastricht).

DOLMANS, D.H.J.M., SNELLEN-BALENDONG, H., WOLFHAGEN, I.H.A.P., & VAN DER VLEUTEN, C.P.M. (1997) Seven principles of effective case design for a problem-based curriculum, *Medical Teacher,* 19: pp. 185–189.

DUEK, J.E., WILKERSON, L. & ADINOLFI, T. (1996) Learning issues identified by students in tutorless problem-based tutorials, *Advances in Health Sciences Education,* 1, pp. 29–40.

EVANS, GLASSER & HOMME (1960) The RULEG system for the construction of programme learning sequences, in: S.M. MARKLE (1964) *Good Frames and Bad: A Grammar of Frame Writing* (New York, Wiley).

FOORD, M. (1964) Inductive versus deductive methods of teaching area by programmed instruction, *Educational Review,* 16, pp. 130–136.

GENERAL MEDICAL COUNCIL (1993) *Tomorrow's Doctors* (London, GMC).

GAGNE, R.M. & BROWN, L.T. (1962) Some factors in the programming of conceptual learning, *Journal of Experimental Psychology,* 53, pp. 66–71.

GODDEN, D.R. & BADDELEY, A.D. (1975) Context dependent memory in two natural environments: on land and underwater, *British Journal of Psychology,* 66, pp. 325–331.

HARDEN, R.M. (1983) Preparation and presentation of patient-management problems, *Medical Education,* 17, pp. 256–276.

HARDEN, R.M. (1986) Ten questions to ask when planning a course or curriculum, *Medical Education,* 20, pp. 356–365.

HARDEN, R.M. (1992) Assessment feedback and learning, in: R.M. HARDEN, I.R. HART & H. MULHOLLAND (Eds) Approaches to the assessment of clinical competence. *International Proceedings of the Fifth Ottawa Conference,* pp. 9–16 (Dundee, Centre for Medical Education).

HARDEN, R.M. (1997) The good teacher is more than a lecturer: twelve roles for the teacher. Association for Medical Education in Europe. Abstracts of the AMEE Conference, Copenhagen, Denmark, *Medical Teacher,* 19, p. 150.

HARDEN, R.M. (1998) AMEE Guide No 12: Multi-professional education: Part 1—Effective multi-professional education: a three-dimensional perspective, *Medical Teacher,* 20, pp. 402–408.

HARDEN, R.M., CROSBY, J.R. & DAVIS, M.H. (1999) An introduction to outcome-based education, *Medical Teacher,* 21, pp. 7–14.

HARDEN, R.M. & DAVIS, M.H. (1998) The continuum of problem-based learning, *Medical Teacher,* 20, pp. 317–322.

HARDEN, R.M. & GLEESON, F.A. (1979) Assessment of clinical competence using an Objective Structured Clinical Examination, *Medical Education,* 13, pp. 39–54.

HARDEN, R.M., LAIDLAW, J.M., KER, J.S. & MITCHELL, H.E. (1996) Task-based learning: an educational strategy for undergraduate, postgraduate and continuing medical education: Parts 1 and 2, *Medical Teacher,* 18, pp. 7–13 and 91–98.

HARDEN, R.M. & SMYTH, J.J. (1994) Computer-based study guides, *Medical Teacher,* 16, pp. 309–321.

HARDEN, R.M., SOWDEN, S. & DUNN, W. R. (1984) Some educational strategies in curriculum development: the SPICES model, *Medical Education,* 18, pp. 284–297.

HEMKER, H.C. (1998) Critical perceptions of problem-based learning, *Advances in Health Sciences Education,* 3, pp. 71–76.

IRBY, D.M. (1996) Models of faculty development for problem-based learning, *Advances in Health Sciences Education,* 1, pp. 69–81.

KNOX, J.D.E. (1975) *The Modified Essay Question,* Booklet No 5, Association for the Study of Medical Education (Edinburgh, ASME).

KRIEL, J.R. & A'BECKETT HEWSON, M.G. (1986) Conceptual frameworks in clinical and pre-clinical textbooks, *Medical Education,* 20, pp. 94–101.

LAIDLAW, J.M. & HARDEN, R.M. (1990) What is . . . a study guide?, *Medical Teacher,* 12, pp. 7–11.

MARGETSON, D. (1998) What counts as problem-based learning?, *Education for Health,* 11(2), pp. 193–201.

MARKLE, S.M. (1964) *Good Frames and Bad: a Grammar of Frame Writing* (New York, Wiley).

MIRES, G.J., HARDEN, R.M., WILLIAMS, F.L.R., MCCAREY, M. & HOWIE, P.W. (1999) Multi-professional teaching of medical and midwifery students on labour and delivery. Association for Medical Education in Europe, Annual Conference Abstracts, Prague, Czech Republic, *Medical Teacher,* 21, pp. 99–100.

NIEUWENHUIJZEN KRUSEMAN, A.C., KOLLE, L.F.J.TH.M. & SCHERPBIER, A.J.J.A. (1997) Problem-based learning at Maastricht—an assessment of cost and outcome, *Education for Health,* 10(2), pp. 179–187.

NORMAN, G. (1998) PBL—the least worst curriculum design?, *Advances in Health Sciences Education,* 3, pp. 1–2.

PAINVIN, C., NEUFELD, V.R., NORMAN, G. & WALKER, I. (1979) The triple jump exercise: a structured measure of problem-solving and self-directed learning, in: *Proceedings of the 15th Conference on Research in Medical Education, Washington DC.*

PETRUSA, E.R. & ALLENSWORTH, C. (1985) Problem-based attending rounds, *Medical Teacher,* 7, pp. 191–202.

ROGERSON, E. & HORTON, P. (1998) Problem-directed learning and course assessment in a Bachelor of Nursing degree programme. Association for Medical Education in Europe. Abstracts of Annual Conference, Vienna, Austria, *Medical Teacher,* 20, p. 51.

ROSS, N. (1991) *Problem-based learning in undergraduate medical education: a discussion paper* (Birmingham, University of Birmingham).

ROWNTREE, D. (1996) *Teaching through Self Instruction* (London, Kogan Page).

SCHMIDT, H.G. (1994) Resolving inconsistencies in tutor expertise research: does lack of structure cause students to seek tutor guidance?, *Academic Medicine,* 69, pp. 656–662.

SCHMIDT, H.G. & MOUST, J.H.C. (1995) What makes a tutor effective? A structural-equations modelling approach to learning in problem-based curricula, *Academic Medicine,* 70, pp. 708–714.

SCHMIDT, H.G., MACHIELS-BONGAERTS, M., HERMANS, H., TENCATE, T.J., VENEKAMP, R. & BOSHUIZEN, H.P.A. (1996) The development of diagnostic competence: comparison of a problem-based, an integrated and a conventional medical curriculum, *Academic Medicine,* 71, pp. 658–664.

SEFTON, A.J. (1997) From a traditional to a problem-based curriculum—estimating staff time and resources, *Education for Health,* 10(2), pp. 165–178.

SHIN, J.H., HAYNES, R.N. & JOHNSTON, M.E. (1993) Effect of problem-based, self-directed undergraduate education on life-long learning, *Canadian Medical Education Journal,* 148, pp. 969–976.

SHOEMAKER, H.A. (1960) The functional context method of instruction, *IRE Transactions of Medical Education,* 3, pp. 52–67.

SNADDEN, D. & THOMAS, M. (1998) The use of portfolio learning in medical education, *Medical Teacher,* 20, pp. 192–199.

VERNON, D.T.A. & BLAKE, R.L. (1993) Does problem-based learning work? A meta-analysis of evaluative research, *Academic Medicine,* 68, pp. 550–563.

WALTON, H.J. & MATTHEWS, M.B. (1989) Essentials of problem-based learning, *Medical Education,* 23, pp. 539–558.

WESTBERG, J. & JASON, H. (1993) *Collaborative Clinical Education: the Foundation of Effective Health Care* (New York, Springer).

WHITEHEAD, A.N. (1932) *The Aims of Education* (London, Williams & Norgate).