Medical Education 1994, **28**, 372–380

What drives the student in problem-based learning?

DIANA H. J. M. DOLMANS & H. G. SCHMIDT

Department of Educational Research and Development, University of Limburg, Maastricht, The Netherlands

Summary. In problem-based learning, the development of self-directed learning skills is encouraged through confronting students with (professional) problems. However, several other elements of a problem-based curriculum, such as general teaching objectives, lectures and tutors, may have an impact on students' actual learning activities. The present study focuses on the extent to which various elements of a problem-based curriculum influence students' decisions on what to study. First, interviews were conducted to obtain qualitative data about what actually takes place when students initiate learning activities during self-study. Based on the findings of these interviews, a questionnaire was developed, consisting of statements describing elements of the learning process and their influence on student learning. Elements included in the questionnaire were: the discussion in the tutorial group, content tested, course objectives, lectures, the tutor and reference literature. The students reported that all these elements may have an impact on decisions on what to study. Moreover, first-year students tend to rely more on the literature cited in the references list and content covered in lectures and tests than students in the other three curriculum years. In general, the influence of these elements showed a decrease over the four curriculum years. The influence of the discussion in the tutorial group, on the contrary, tended to increase over the four curriculum years. These findings suggest that students in a problem-based curriculum become more accomplished self-directed learners over the four curriculum years, even although they are provided with many clues which may play a role in their decisions on what to study.

Correspondence: Dr Diana Dolmans, Department of Educational Development and Educational Research, University of Limburg, PO Box 616, 6200 MD Maastricht, The Netherlands.

Key words: students, medical/*psychol; motivation; problem solving; teaching/*methods; *educ med undergrad; decision making; learning; professional competence; Netherlands

Introduction

In the Department of Educational Development and Research at the University of Limburg, Maastricht, the development of self-directed learning skills in problem-based learning (PBL) is encouraged by confronting students with (professional) problems. Tutorial groups, comprising eight to 10 participants, meet twice a week during a 2-hour session in which they discuss these problems. A problem usually consists of a description of a set of phenomena in need of some kind of explanation. The task of the group is to explain these phenomena in terms of underlying (biomedical or psychosocial) processes, principles or mechanisms (Schmidt 1983). During the analysis of the problem, students make use of pre-existing ideas, opinions and prior knowledge. While discussing the possible explanations, students seek out what they do not yet know and what they need to learn to better understand the phenomena described in the problem. This provides them with both the direction and extent of study that needs to be undertaken to acquire a deep understanding of the problem (Barrows 1985). To that end, students generate learning issues and search for corresponding relevant literature.

Basic to PBL is that student learning is organized around problems. Barrows (1985) claims that the problem serves as a challenge to students' reasoning or problem-solving skills and as an organizer for their learning. The only way to discover what you already know, what you have really stored in your memory, is to work with a problem. Through problem analysis students realize what they already know and do not have to

study. More importantly, however, they discover what they really do not know and must concentrate on in their study. When students discuss a problem they ask themselves whether or not their knowledge and skills are adequate to deal with this problem. This provides them with both a sense of direction and the depth of study that needs to be undertaken. Through problem discussion, students identify their own learning needs and formulate these needs as learning issues for further perusal. These issues are listed and serve as guides for what they should learn during self-study. The generation of learning issues by students is assumed to stimulate the development of self-directed learning skills (Walton & Matthews 1989; Blumberg *et al.* 1990). The main advantage of encouraging self-directed learning skills is that students learn how to deal with problems in the future, preparing themselves to become independent, lifelong learners (Barrows & Tamblyn 1980). The creation of a pattern of lifelong learning is required to keep in step with current knowledge and good practice in medicine (Walton & Matthews 1989).

Since problems are a major factor influencing the nature of students' self-study, a direct relationship is expected between the learning issues generated and the students' learning activities during self-study. In a previous study, Dolmans *et al.* (in press) investigated the relationship between student-generated learning issues and students' actual learning activities. They compared the learning issues generated by each tutorial group with the teacher-generated objectives. In addition, they measured students' learning activities through a list of topics on which students were asked to indicate how much time they had spent on studying each topic and to what degree they had mastered that topic on a 5-point Likert scale. A correlation between learning issues produced and learning activities carried out was expected. The results, however, revealed a moderate negative correlation between the two variables. These results suggest that the learning issues generated may only to some extent define what students actually will study during a course.

Several explanations for the apparent lack of the match between student-generated learning issues and students' learning activities during self-study may be possible. For instance, a particular issue, although not raised during the initial discussion, may become relevant as students scan the literature. It is also possible that students do not generate a particular issue because they covered this issue during a lecture. This implies that, although the students did not identify this issue, students' mastery of the topics related to that issue may be high. The tutor's point of view may also play a role in decisions on what to study.

From this description, it becomes apparent that not only student-generated learning issues, but several other elements of a problem-based curriculum, such as general teaching objectives, lectures and tutors, may also have an impact on students' actual learning activities. Teaching objectives may provide the students with a framework about what is expected from them during a course. The tutor may ask questions such as: 'What does that mean?', 'Are there any other explanations?' in order to probe the students' knowledge deeply (Barrows 1988). It is obvious that these questions will influence the issues on which students concentrate and, hence, which issues may become a focus of self-study. In other words, it is unlikely that student-generated learning issues are the sole factor influencing the nature of students' self-study.

The aim of the present study is to identify to what extent various elements of a problem-based curriculum influence students' decisions on what to study. Interviews were conducted with students and a questionnaire was administered to students in four different curriculum years. This was done to find out to what extent experience-related differences among students may occur.

Methods

Materials

The study was conducted at the Medical School of the University of Limburg, Maastricht, The Netherlands, in the academic year 1992–1993. The first 4 years of the curriculum are structured as a series of 6-week courses. About 150 students participate in each curriculum year. These students are randomly assigned to 18 tutorial groups, each comprising eight to 10 students. Each tutorial group is guided by a tutor.

Previous to the construction of the questionnaire, six first-year students were interviewed by the first author of this article to explore what actually happens when students initiate learning

activities during self-study and what kinds of considerations might play a role in choosing the literature and deciding what to study. The following questions were addressed to them: 'Try to describe what kind of activities you will conduct for the next tutorial group meeting'; 'What kind of resources are you going to consult?'; 'How do you select these resources?'; and 'What factors influence which subject-matter will be covered during self-study?'. Students were told to keep in mind the course in which they were currently working, while answering these questions.

Based on their responses, a questionnaire was developed. The questionnaire was divided into themes reflecting aspects that might influence students' learning activities during self-study. The questionnaire contained 20 statements: four about the influence of the discussion in the tutorial group; six about the influence of content tested; three about the influence of course objectives; two about the role of lectures; three about the influence of the tutor; and two about the selection of reading materials. Table 1 contains the 20 items. Students were asked to indicate on a 5-point Likert-type scale whether they (1) totally disagree, (2) disagree, (3) are neutral, (4) agree, or (5) totally agree with each statement. While judging these statements they were requested to keep in mind their learning activities for self-study during the last academic year.

Table 1. The items of the questionnaire and the corresponding themes

	Theme 1: Influence of the discussion in the tutorial group
(1)	The discussion in the tutorial group determines to a large extent what I will study
(2)	The tutorial group discussion is an important stimulus for my learning activities during self-study
(3)	The learning issues generated are the most important starting point for my learning activities during self-study
(4)	I study to a large extent independently from the learning issues generated
	Theme 2: Influence of content tested
(5)	I take a look at the questions included in the tests to get an idea of how deeply I should study particular subject-matter
(6)	The questions that are included in the tests to a large extent determine what I will study
(7)	The closer the date the test will be administered to us, the more time I spend on test preparation
(8)	The closer the date the test will be administered to us, the less time I spend on studying the learning issues generated in the tutorial group
(9)	I do not spend any time on studying particular issues, if I am convinced that these issues will not be tested
(10)	The learning issues generated in the tutorial group are tuned to the subject matter expected to be tested
	Theme 3: Influence of the course objectives
(11)	At the start of a course, I consult the course objectives stated in the course book
(12)	At the end of the course, I consult the course objectives to check whether I covered all the subject matter I was expected to cover
(13)	During the course, the course objectives influence what kind of learning activities I will conduct
	Theme 4: Influence of lectures
(14)	Topics covered during lectures influence which topics I select for self-study
(15)	Lectures are an important source of information to decide which topics I will study more extensively
	Theme 5: Influence of the tutor
(16)	In general, tutors stimulate my learning activities
(17)	In general, tutors stimulate students to make use of different sources of information
(18)	In general, tutors have an important influence on the selection of learning issues
	Theme 6: Influence of reference literature
(19)	I usually confine myself to the reference literature cited in the course book when searching for relevant literature
(20)	I hardly review literature beyond the sources that are included in the course book

Procedure

The questionnaire was administered to all students of the first four curriculum years, at the end of the academic year 1992–1993. A total of 407 students (68%) filled out the questionnaire. The response rate was 77% (n = 115) in the first year, 77% (n = 115) in the second year, 49% (n = 73) in the third year and 69% (n = 104) in the fourth year. The response rate in the third year was rather low. Many third-year students had left for elective studies abroad shortly after the questionnaire was distributed among the students.

A confirmatory factor analysis model was carried out to assess the adequacy of the six elements influencing students' decisions on what to study outlined above. A correlation matrix was used as input for the confirmatory factor analysis. In the confirmatory factor analysis model, as specified in this study, all common factors are correlated, observed variables 1–4 were affected by the first common factor (the discussion in the tutorial group), observed variables 5 to 10 were affected by the second common factor (the influence of content tested), observed variables 11, 12 and 13 were affected by the third common factor (the influence of course objectives), observed variables 14 and 15 were affected by the fourth common factor (lectures), observed variables 16 to 18 were affected by the fifth common factor (tutor) and observed variables 19 and 20 were affected by the sixth common factor (the selection of reading materials). Furthermore, all observed variables were assumed to be affected by a unique factor (error in each variable), and no pairs of unique factors were correlated. The LISREL VII program was used to determine whether the data confirmed this model (Jöreskog & Sörbom 1990). Coefficients alpha were computed to estimate the reliability of each factor. Analysis of variance was used to compare the average scores for each factor within different curriculum years.

Students' comments collected from the interviews will be presented to demonstrate further what kinds of considerations may play a part in students' decisions on what to study regarding the learning issues generated in the tutorial group session. The students interviewed are identified as A, B, C, and so forth.

Results and discussion

The correlation coefficients between the common factors varied between –0·03 and 0·28 (n = 407). A model is assumed to fit the data if three conditions are met: (1) the χ^2 divided by the degrees of freedom should be lower than 2, a P-value that differs from zero; (2) the root mean square residual should be lower than 0·07; and (3) the goodness-of-fit-index and the adjusted goodness-of-fit-index, which takes into account the number of degrees of freedom, should be higher than 0·80 (Saris & Stronkhorst 1984).

The results of a 6-factor model as outlined above showed that the second and third condition specified by Saris & Stronkhorst were satisfied (χ^2 [149 d.f.] = 308·17, P = 0·000, a root mean square residual of 0·056, a goodness-of-fit index of 0·93, and adjusted goodness-of-fit index of 0·90). The first condition is not met although it does not differ much. Since two out of three conditions are met it may be concluded that the 6-factor model shows a reasonable fit with the data.

Table 2 provides an overview of the mean scores and standard deviations for each factor.

Table 2. Number of items per factor (n items), mean scores (M) on a scale from 1 'totally disagree' to 5 'totally agree' and standard deviations (SD), number of students (n students), alpha coefficient

Factor	n items	M	SD	n students	Alpha coefficient
(1) Discussion in tutorial group	4	3·36	0·69	404	0·61
(2) Content tested	6	2·86	0·71	403	0·67
(3) Course objectives	3	3·48	0·99	406	0·78
(4) Lectures	2	2·99	1·04	406	0·82
(5) Tutor	3	3·12	0·73	406	0·60
(6) Reference literature	2	3·15	0·92	406	0·51

This table also shows that the coefficient alpha for each factor varies between 0·51 and 0·82. The mean scores in Table 2 indicate that all factors have an impact on students' decisions on what to study. Factor 3, the influence of course objectives, received the highest average score on a scale from 1 to 5, in which 1 is 'totally disagree' and 5 'totally agree'. Factor 1, the influence of the discussion in the tutorial group, also scored relatively high. Factor 2, the influence of content tested, and factor 4, lectures, received the lowest average scores.

For each factor, analysis of variance was used to estimate whether the average scores differed across the four curriculum years. Table 3 contains the results of these analyses. In this table the mean scores for curriculum years 1–4 are presented for each factor, as well as the corresponding standard deviations, the *F*-values and the *P*-values. A *P*-value lower than 0·05 is assumed to be significant. As can be seen in Table 3, significant differences between the curriculum years 1–4 were found for factor 2, the influence of content tested, factor 4, the influence of lectures, and factor 6, the impact of reference literature on students' decisions on what to study. In the following, each factor will be discussed separately.

Influence of the discussion in the tutorial group

During the discussion in the tutorial group, students analyse a problem new to them and try to find out what information is required to explain the mechanisms underlying the phenomena described in the problem. In this analysis, students acquire insight into the subject matter that is dealt with in the problem. The learning issues that are eventually listed can be seen as a result of this analysis. It may be obvious that the discussion preceding the generation of learning issues and the learning issues that are eventually listed contain important information about the direction of students' self-study. This assumption is corroborated by the data presented in Table 3. As can be seen in Table 3, the influence of the tutorial group on what students will study is higher in curriculum years 3 and 4 than in curriculum years 1 and 2 (albeit not significantly). This finding might be explained by an increased experience of students in generating learning issues that provide clear guidelines regarding what content should be studied. Students' comments during the interviews highlighted that the discussion preceding the generation of learning issues plays a different role for students in decisions on what they study. One student (first year) said that the initial problem discussion provides him with clues which he uses when searching for relevant information:

> F: 'The discussion of a problem is an important guide in deciding what should be studied. Learning issues directly specify what should be studied, but they are often formulated in such a manner that it is not possible to search for these issues in an index or something like that. Words that are used during the brainstorm can often be used to search in an index and provide clear guidelines what content should be

Table 3. Mean scores (scale 1 'totally disagree' to 5 'totally agree'), with standard deviations within brackets, for curriculum years 1 to 4. The *F* values and the *P* values are also included

Factors	1	2	3	4	*F*	*P*
(1) Discussion in tutorial group	3·28	3·30	3·39	3·50	2·232	0·084
	(0·69)	(0·74)	(0·67)	(0·64)		
(2) Content tested	3·08	2·89	2·62	2·74	7·874	0·000
	(0·68)	(0·62)	(0·68)	(0·78)		
(3) Course objectives	3·56	3·55	3·43	3·35	1·068	0·363
	(0·96)	(0·99)	(0·98)	(1·05)		
(4) Lectures	3·32	2·79	2·90	2·89	6·006	0·001
	(0·91)	(1·03)	(1·18)	(1·01)		
(5) Tutor	3·22	3·12	3·10	3·04	1·169	0·321
	(0·67)	(0·71)	(0·79)	(0·78)		
(6) Reference literature	3·60	3·21	3·22	2·55	28·922	0·000
	(0·83)	(0·80)	(0·88)	(0·87)		

studied. If I do not possess much knowledge about a particular subject, I usually write down some words that are mentioned during the brainstorm.'

Another student (first year) said that the initial problem discussion intrinsically motivated him:

A: 'If we explore a particular topic during the initial discussion of a problem, it really influences my self-study. In this circumstance, I am more actively involved in the subject matter. One looks at a problem from various angles and this encourages me to spend more time on self-study.'

The increased influence of the discussion in the tutorial group on students' decisions on what to study can be explained by an increased experience of students in generating clear learning issues. When students were asked in the interviews to describe how they make use of these issues during self-study, it became apparent that student-generated learning issues indeed aid the direction of what students are going to study and in particular influence the selection of reading materials. One student (first year) said:

D: 'In general, I first take a look at the learning issues generated and the problem. Next, I start searching for difficult words in a medical dictionary to obtain some global information about these difficult terms. Subsequently, I search in the reference list for relevant literature. Sometimes a particular chapter of a book is recommended. If no particular chapter is recommended, I search in the index of the recommended books for key words and its corresponding pages. Next, I start reading these pages. Mostly I use several books. After reading I summarize and write down the relevant information.'

The findings in Table 3 seem to provide evidence for the assumption that students become better self-directed learners as a result of being in the curriculum for a longer time.

Influence of content tested

In each course book, a self-assessment test is included to provide students with formative feedback about their performances. At the end of each course an achievement test is administered to the students, which is also aimed at providing students with formative feedback. The results in Table 3 demonstrate that the influence of content tested on students' self-study is highest in curriculum year 1, decreases in curriculum years 2 and 3 and shows an increase in curriculum year 4. The interviews revealed that, particularly at the end of the course, students fill out the self-assessment test in order to decide whether or not they have mastered certain subjects. If students notice that they do not possess enough knowledge about a particular domain, they will pursue certain learning activities regarding the items tested. One first-year student said during the interviews:

E: 'Usually, I fill out the self-assessment test at the end of the course, before the end-of-the-course examination. When filling out this test, I notice that I do not master certain topics. Subsequently, I search for information regarding these issues and sometimes several other topics, closely related to this issue, will also be studied.'

A disadvantage of including a self-assessment test in the course book is that students may tune their learning activities to the content that is tested. This would imply that students' learning activities are not guided by the learning issues generated in the tutorial group, which would hence be detrimental to the development of self-directed learning skills. In general, the results indicate that students in the first and second curriculum years are more test-driven than students in the third and fourth curriculum years.

Course objectives

In each course book, global course objectives are listed. These objectives provide students with information about the subject matter dealt with in the course and as such are assumed to influence students' self-study. Three questions were included in the questionnaire about this aspect of a problem-based curriculum. The results in Table 3 indicate that the influence of the course objectives on students' learning activities does not differ significantly across the four curriculum years. The interviews revealed that most students use the course objectives at the end of the course as a check whether they covered the subject matter intended to be studied during the course. One first-year student said:

A: 'The day before the achievement test takes place, I usually read the course objectives to obtain information about what we were expected to study during this course.'

Lectures

In each course, a limited number of lectures is included. The questionnaire contained two items

about the influence of these lectures on students' self-study. The results in Table 3 indicate that the influence of topics covered during lectures on students' self-study is strongest in curriculum year 1. In general, first-year students tend to rely more on content covered in lectures than students in the other three curriculum years. A possible explanation for this finding is that first-year students are less experienced self-directed learners. The interviews revealed that students deal with content covered during lectures in a different manner. One first-year student said that lectures give him an overview of what he is expected to study during a course.

> D: 'During a lecture if often becomes clear what topics should be known. Afterwards, when studying the learning issues, a lot of things attract attention, ... oh ..., that is what I have heard this morning.'

Another student said that a lecture gives him information about what he is expected to study during a course:

> A: 'A lecture gives me some information about what is important to be studied. Although they are brief, they provide guidelines about what subject matter should be studied. This more or less confirms that I am studying the right issues during self-study.'

One student said that he used the lecture as a guide for studying the literature relevant for the course at hand:

> E: 'During some lectures I write down some key words that are often mentioned. Afterwards, I search in the literature for these words and spend some time on it during self-study.'

Influence of the tutor

The tutor also influences what students will study, since he or she guides the tutorial group process and uses his or her expert knowledge — if any — when discussing the problem. As can be seen in Table 3 no significant difference is found among the four curriculum years. According to students' comments during the interviews, some tutors play a major role whereas other tutors play a minor role. In such cases, students collect information regarding the learning issues generated in other tutorial groups. One student (first year) said:

> B: 'The tutor influences what I will study I think. He guides us fairly well. Particular topics are being repeated, since we did not master that topic. This is only one example of his influence. The tutor is an expert in anatomy, which is a basic discipline, and as a consequence he has a lot of knowledge. However, this differs across tutors. One tutor plays only a minor role, whereas another tutor plays a major role.'

Selection of reading materials

Students in a problem-based curriculum are encouraged to consult different resources. In each course book, suggestions for learning resources are listed at a rather global level. Two items were included in the questionnaire about the use of different resources and the influence of the list of resources on students' self-study. The results in Table 2 demonstrate that students, in particularly during the first year, confine themselves to the reference literature cited in the course book when searching for relevant literature. During the fourth curriculum year, students make less use of the reference literature cited in the course book. This finding again provides evidence for the assumption that students in a problem-based curriculum become better self-directed learners.

When students were asked during the interviews what kind of action they would take regarding the learning issues generated for the next meeting, most gave an overview of the resources they were going to use during their self-study. Obviously, during the process leading to the generation of learning issues, students get an idea of the literature that will be useful. This seems to demonstrate that students take a broader perspective and do not confine themselves to the learning issues as formulated. This particularly holds for studying the mechanisms of action of the heart, the kidneys and the lungs. (Six first-year students were interviewed during a course dealing with issues such as mechanisms of action of heart, kidneys and lungs.) Students know that they should learn something about the anatomy and physiology of these organs, and as a consequence make use of a few handbooks. One student (first year) said during the interviews:

> F: 'When studying heart, kidneys and lungs, I make use of a physiology book, since I am sure that I can find something in it about this subject. Subsequently, I make use of a pathology book and read the chapter about the respiratory system. I read as long as I think will be necessary to have read everything that is of importance.'

Several students said during the interviews that they prefer particular books based on previous experiences with their usefulness and readability. Another reason often mentioned was that students prefer to use books which are also often used by other students in the tutorial group. One student (first year) said:

> D: 'The books that I used to study the learning issues generated were chosen on previous experiences in other courses. I am used to these books, I know what is in them, I know that these books are good, and I know that this book is the one that is generally used by all students when studying physiology. The book is also included in the reference literature in the course book.'

Conclusion

Basic to problem-based learning is that student learning is organized around problems. During initial problem analysis, students identify their learning needs and generate learning issues which serve as guides during self-study. As a consequence, these student-generated learning issues are supposed to play a central role in students' decisions on what to study. A detailed analysis of a problem-based curriculum, however, reveals that it is unlikely that student-generated learning issues are the only factor influencing students' self-study, since students are not only confronted with problems, but also with tests, course objectives, lectures, tutors' ideas and reference literature. The present study was aimed at identifying to what extent several elements of a problem-based curriculum influence the nature of students' self-study. The results demonstrate that the availability of a reference list, course objectives, lectures, tests and the tutor all have an impact on students' learning activities during self-study. Moreover, first-year students tend to rely more on the literature cited in the reference list and content covered in tests and lectures than students in the other three curriculum years. In general, the influence of these elements diminishes over the four curriculum years. The influence of the discussion in the tutorial group, on the contrary, seems to increase over the four curriculum years (this increase, however, is not significant). These findings suggest that students in a problem-based curriculum indeed become better self-directed learners as a result of being in the curriculum for a longer time and, hence, becoming more experienced. In conclusion, students in a problem-based curriculum are provided with many clues and directions that directly or indirectly play a role in their decisions on what to study, such as reference literature, course objectives, lectures and tests. In addition, students become better self-directed learners over the four curriculum years.

This finding is in agreement with the results of a study by Blumberg & Michael (1992). They addressed the question whether student-generated learning issues are a major force driving students' self-directed learning skills. They compared the use of library resources among students in a traditional curriculum and students in a problem-based learning curriculum in which they are required to determine their own learning issues, but can also compare their learning issues with teacher-generated objectives. The data showed that students in the problem-based learning curriculum acquire behaviours that reflect continued and self-directed learning skills. Blumberg & Michael (1992) concluded that the availability of teacher-generated learning objectives does not subvert the development of self-directed learning skills. They argue that the key to encouraging self-directed learning skills lies in consistency among all aspects of the curriculum, such as (1) the student-generated learning issues, (2) teaching objectives, (3) the material covered in resource sessions, and (4) the material that is tested.

References

Barrows H.S. (1985) *How to Design a Problem-based Curriculum for Preclinical Years*. Springer Publishing Company, New York.

Barrows H.S. (1988) *The Tutorial Process*. Southern Illinois University School of Medicine, Springfield, Illinois.

Barrows H.S. & Tamblyn R.M. (1980) *Problem-based Learning. An Approach to Medical Education*. Springer Publishing Company, New York.

Blumberg P. & Michael J.A. (1992) Development of self-directed learning behaviors in a partially teacher-directed problem-based learning curriculum. *Teaching and Learning in Medicine* **4**, 3–8.

Blumberg P., Michael J.A. & Zeitz H. (1990) Roles of student-generated learning issues in a problem-based curriculum. *Teaching and Learning in Medicine* **2**, 149–54.

Dolmans D.H.J.M., Schmidt H.G. & Gijselaers H.G. (1994) The relationship between student-generated learning issues and self-study in problem-based learning. *Instructional Science* (in press).

Jöreskog K.G. & Sörbom D. (1990) LISREL VII. *User's Guide*. National Educational Resources, Chicago, Illinois.

Saris W. & Stronkhorst H. (1984) *Causal Modelling in Nonexperimental Research*. Sociometric Research Foundation, Amsterdam.

Schmidt H.G. (1983) Problem-based learning: rationale and description. *Medical Education* **17**, 11–16.

Walton H.J. & Matthews M.B. (1989) Essentials of problem-based learning. *Medical Education* **23**, 542–58.

Received 13 *October* 1993; *editorial comments to author* 10 *February* 1994; *accepted for publication* 19 *July* 1994