A case-based, small-group cooperative learning course in preclinical veterinary science aimed at bridging basic science and clinical literacy

J P Schoeman[a*], M van Schoor[a], L L van der Merwe[a] and R A Meintjes[b]

ABSTRACT

In 1999 a dedicated problem-based learning course was introduced into the lecture-based preclinical veterinary curriculum of the University of Pretoria. The Introduction to Clinical Studies Course combines traditional lectures, practical sessions, student self-learning and guided tutorials. The self-directed component of the course utilises case-based, small-group cooperative learning as an educational vehicle to link basic science with clinical medicine. The aim of this article is to describe the objectives and structure of the course and to report the results of the assessment of the students' perceptions on some aspects of the course. Students reacted very positively to the ability of the course to equip them with problem-solving skills. Students indicated positive perceptions about the workload of the course. There were, however, significantly lower scores for the clarity of the course objectives. Although the study guide for the course is very comprehensive, the practice regarding the objectives is still uncertain. It is imperative to set clear objectives in non-traditional, student-centred courses. The objectives have to be explained at the outset and reiterated throughout the course. Tutors should also communicate the rationale behind problem-based learning as a pedagogical method to the students. Further research is needed to verify the effectiveness of this course in bridging the gap between basic science and clinical literacy in veterinary science. Ongoing feedback and assessment of the management and content are important to refine this model for integrating basic science with clinical literacy.

Key words: case-based teaching, cooperative learning, clinical reasoning skills, problem-based learning, structured tutorials.

Schoeman, J P, van Schoor M, van der Merwe L L, Meintjes R A **A case-based, small-group cooperative learning course in preclinical veterinary science aimed at bridging basic science and clinical literacy**. *Journal of the South African Veterinary Association* (2009) 80(1): 31–36 (En.). Department of Companion Animal Studies, Faculty of Veterinary Science, University of Pretoria, South Africa.

INTRODUCTION AND BACKGROUND

The Foresight study report[32] of the Association of Veterinary Medical Colleges of the United States of America concluded that it is imperative to change the way we educate tomorrow's veterinary students. Veterinary school curricula have to become more flexible and adaptive to the rapidly changing demands on veterinarians or otherwise the veterinary profession may become irrelevant to the society it serves[26]. The focus is for curricula to be able to respond to changing demands for professional veterinary services within a relatively short period of time. This objective places renewed emphasis on an effective educational vehicle or pedagogical base to deliver these innovative curricula. The way in which knowledge and learning are introduced and the role of the student in such a process should be considered and conceptualised in the curriculum.

Traditionally, pre-clinical veterinary curricula have been heavily biased towards didactic lectures. There is a move towards supplementing lecture-based courses with student-centred courses that focus on integrated problem-based, self-directed and cooperative learning. An example of such a course that was introduced in 1999 at the Faculty of Veterinary Science of the University of Pretoria in South Africa is the case-based learning course: Introduction to Clinical Studies 400 (ICS400).

Problem-based learning (PBL) has many and varied interpretations, ranging from a narrow definition describing pure PBL to an all-inclusive definition encompassing many alternatives[16,19]. For the purpose of this discussion PBL in medical education is defined as a student-centred method of learning that uses clinical cases as problems to serve as challenges for self-directed, independent and cooperative study in a small-group setting. This approach is also in line with recently formulated key features of PBL as described by Newman[21] and Shanley[29]. Pure PBL is a process of learning where students take responsibility for their own learning under the guidance of a tutor, whose role is to facilitate learning in a non-directive way[17]. The course described in this article is an adaptation of the pure PBL defined above. Rather than facilitating learning non-directively, the tutors intervene to set and maintain the quality of both the process of learning and the learning resulting from the process. They act as facilitators guiding the group learning process and also provide expert knowledge related to the case.

Recent studies have highlighted concerns about pure PBL as a method of learning. Of paramount concern is the perceived lack of effectiveness of PBL to contribute to the knowledge base and clinical skills of medical students[5,7,23]. Some of the other difficulties reported are the lack of in-depth learning and the unevenness of preparation among students[10] as well as the high cost and difficult logistics[29]. Another disadvantage of case-based, small-group PBL includes the considerable demands placed on teaching staff, because it is a time-consuming method of teaching and requires a full range of specific skills from the tutors in constructing and presenting an appropriate case-based challenge[27]. Discomfort and anxiety about[4] and resistance to self-directed learning[27] on the part of the students, as well as the interpersonal difficulties that may arise from small-group learning (as summarised by Miflin[19]) and the difficulties with assessment of individual performance in a team environment[27], are some of the other problems with PBL as a method of teaching.

The aim of this article is to describe the structure and objectives of the Introduction to Clinical Studies Course and to report the results of the assessment of the students' perceptions on some aspects of the PBL component of the course. This is the 1st report describing the application of PBL to facilitate the integration of different disciplines and to assist in bridg-

[a]Department of Companion Animal Studies, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa.

[b]Department of Veterinary Anatomy and Physiology, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa.

*Author for correspondence.
E-mail: johan.schoeman@up.ac.za

Received: December 2008. Accepted: January 2009.

Table 1: **The core learning objectives of the Introduction to Clinical Studies Course.**

1. Students should be able to identify abnormalities in a patient and develop an appreciation for the degree of abnormality.
2. Students should become familiar with the correct terminology applied to these abnormalities.
3. Students should be able to relate these abnormalities to the underlying disturbed function (i.e. disease or pathophysiological processes).
4. Students should develop the vocabulary and logic to group these underlying alterations in function, disease or pathophysiological processes into ranked problem statements, stated at the correct level and based on the available evidence.

Table 2: **The ancillary learning objectives of the Introduction to Clinical Studies Course.**

1. To enable students to develop clinical reasoning skills in a low-risk environment[4];
2. to enable students to identify what they already know that is pertinent[13,21] and to challenge students to recognise the need for additional facts, skills and conceptual understanding[27];
3. to enable students to integrate basic and applied knowledge from previously taught courses, facilitating interdisciplinary integration[13];
4. to set a context for the acquisition of knowledge applicable to future requirements for case management and problem solving[21,30];
5. to enable students to structure knowledge in a clinical context by developing an integrated, progressive and consistent approach to cases[6,20,25];
6. to enhance students' ability to work in a cooperative manner and to introduce students to the positive aspects of cooperative small-group learning[20,21];
7. to motivate students in their preclinical years and to increase their enthusiasm for learning[13,21,30];
8. to encourage students to assume more responsibility for their education and to develop their self-learning skills[4].

ing the gap between basic science and clinical literacy in the field of veterinary medicine.

Objectives of the Introduction to Clinical Studies Course

The veterinary curriculum at the University of Pretoria currently consists of 6 years of predominantly lecture-based courses and a 7th year comprising clinical rotations. The ICS 400 course is part of the 4th year of study, by which time the students have completed anatomy, physiology, genetics, immunology and virology amongst other basic science courses.

The ICS 400 course affords the students the opportunity to integrate the ever-growing information data-base in a case-based manner. They are presented with the information pertaining to 4 cases throughout the year and the tutor (lecturer) guides them through the process of structuring old and new information into a logical and useful conclusion. The intention is to facilitate the transition from obtaining and memorising information (a skill honed by traditional lecture-based teaching and assessing) to seeking information to solve clinical problems.

The core learning objectives of the ICS400 course are listed in Table 1 and the ancillary learning objectives in Table 2.

Structure of the Introduction to Clinical Studies Course

The course spans 1 academic year. It commences with traditional lectures on aspects of the clinical examination of canine, bovine and equine patients. The class is then divided into 5 groups of approximately 20 students each. Over the next 3 weeks these groups attend 3 practical sessions on the clinical examination of canine, bovine and equine patients respectively. Table 3 provides a summary of the practical component of the course.

Thereafter an experienced tutor gives an introductory lecture to the whole class explaining the objectives and structure of

Table 3: **The practical component of the Introduction to Clinical Studies Course with approximately 20 students per group.**

Timing	Time frame	Traditional lecture or practical	Objective
Prior to practical session	Approximately 80 minutes	Lectures on the aspects of the clinical examination of a bovine patient	To enable the student to approach the practical session with enough theoretical knowledge to examine a bovine patient
Prior to practical session	Approximately 80 minutes	Lectures on the aspects of the clinical examination of an equine patient	To enable the student to approach the practical session with enough theoretical knowledge to examine an equine patient
Prior to practical session	Approximately 80 minutes	Lectures on the aspects of the clinical examination of a small animal patient	To enable the student to approach the practical session with enough theoretical knowledge to examine a small animal patient
Practical session – bovine	60–90 minutes per student group – *c.* 20 students per group	Practical session with a demonstration of the examination of a bovine patient followed by all students examining bovine patients in turn	To enable the student to examine a bovine patient
Practical session – equine	60–90 minutes per student group – *c.* 20 students per group	Practical session with a demonstration of the examination of an equine patient followed by all students examining equine patients in turn	To enable the student to examine an equine patient
Practical session – small animal	60–90 minutes per student group – *c.* 20 students per group	Practical session with a demonstration of the examination of a small animal patient followed by all students examining small animal patients in turn	To enable the student to examine a small animal patient

Table 4: **Examples of how related abnormalities can be grouped into master problems.**

Abnormalities	Master problem
Small liver, low serum urea and albumin, prolonged bleeding times	Liver failure
Halitosis, weight loss, non-regenerative anaemia, elevated serum urea and creatinine, isosthenuric urine	Renal failure
Weight loss, heart murmur, hepatomegaly, modified transudate ascites	Heart failure
Chronic diarrhoea and vomition, panhypoproteinaemia, weight loss	Protein-losing enteropathy
Weight loss, anasarca, proteinuria, hypercholesterolaemia	Protein-losing nephropathy
Panhypoproteinaemia, regenerative anaemia, malaena	Gastrointestinal blood loss

the student-centred, case-based component of the course. The 1st of 4 real-life cases with a wide range of abnormalities is then handed out to the students. The case typically consists of transcripts of the history, the signalment and the clinical examination of the patient, as well as the applicable laboratory findings including haematological, biochemical, urinalysis and faecal examination data. For the purpose of discussing the cases, the students are divided into groups of approximately 7 students each. Three tutorial sessions are allocated to the 1st case and 2 tutorial sessions to each subsequent case. Each group discusses the case that has been presented to them in the group, establishing a check list of *learning issues.*

Learning issues are particulars of the case at hand where the students are unsure about the 'what', 'why' or 'how' of (1) the terminology used and/or (2) the manner in which the presence of clinical signs and other pertinent information is usually established and recorded and/or (3) the degree of severity of the abnormality.

Students then have to seek resources cooperatively and independently (without tutor guidance) to provide answers to the learning issues raised – i.e. identifying and grading the abnormalities. A list of core resources is provided in the library. The students will schedule a meeting with the designated tutor. At this session, which lasts approximately 1 to 1.5 hours, these abnormalities are discussed in the group and the tutor will determine whether the students have correctly identified and graded the relevant abnormalities using the appropriate scientific terminology.

Following the 1st tutorial meeting, the students will cooperatively attempt to group and rank the abnormalities and establish the common pathophysiological mechanisms or disease processes underlying these abnormalities. The group will schedule a 2nd tutorial meeting with the tutor. At the 2nd session, which lasts another 1 to 1.5 hours, the pathophysiological processes underlying the abnormalities identified during the 1st tutorial meeting are discussed in the group under the guidance of the tutor. A report-back session is subsequently scheduled.

The students will then collaborate, with the aid of resources, to produce the Master Problem List. A Master Problem List (MPL) comprises the grouping of related abnormalities into major problems. See Table 4 for an example of how related abnormalities are synthesised into master problems.

The report-back session lasts approximately 30 minutes. The tutor will determine whether the students have correctly established a MPL based on the pathophysiology discussed at the 2nd tutorial meeting. The preparation and participation of the group is subjectively assessed by the tutor and expressed as a percentage. As a rule the group is allocated an overall mark assigned to each individual student, but poor or outstanding contributions by individual students can be reflected in lower or higher marks for the particular student.

In total, these groups are presented with 4 cases throughout the year: 2 small animal cases, 1 bovine and 1 equine case. As students gain experience and confidence in what is expected of them, the 2nd tutorial and the so-called report-back session can be combined into 1 session lasting approximately 2 hours. After the completion of the 4 cases, a 5th and final case is handed out to the students 4 weeks prior to a written examination at the end of the year. The students are expected to prepare this case cooperatively and in the same fashion as the previous 4 cases. The preparation, however, takes place without the guidance of the tutor. A written examination ensues, comprising an open-book format and multiple-choice questions. See Table 5 for a summary of the case-based component of the course.

METHODS

A questionnaire was devised as an instrument to evaluate this course. The questionnaire was provided to the students in person just after their final examination. The questionnaire was developed to research the students' perception of the teaching and their academic self-perception. The students' perception of the lecturers/tutors, their perceptions of atmosphere and their social self-perception were not evaluated as they were not relevant to the objectives of the project. The study was approved by the Research Committee of the Faculty of Veterinary Science, University of Pretoria.

Three specific areas were addressed with 4 questions pertaining to each area:

1. the ability of the course to enhance the students' problem-solving skills;
2. the volume and scope of the work;
3. the clarity of the learning objectives.

See Table 6 for a list of the questions grouped into the above categories *post hoc.*

A 5-point Likert scale was used, where '1' meant that the student *strongly disagreed* with the statement and '5' meant that the student *strongly agreed.* This translated into '1' indicating a very negative response through to '5' indicating a very positive response. The data were adjusted to account for negative statements. Quantitative questionnaire data were imported into a statistical package for the social sciences (SPSS 14, SPSS Inc., Chicago, Illinois). Mean scores for each of the 3 specific question areas were calculated. These mean scores of the 3 specific question areas were compared within the whole group with the 1 sample *t*-test for related samples. Gender was dichotomised into male and female and age into 4 ordinal groups: 20–22 years old; 23–24 years old; 25–26 years old; older than 26 years. Mean scores were compared between groups with the ANOVA for multiple age groups and the independent samples *t*-test for the 2 gender groups. Significance was set at $P < 0.05$.

RESULTS

The questionnaire was distributed to 130 undergraduate veterinary students in October 2007 – all of whom were at the end of their 4th year of study. The response rate (aided by a lottery of 2 good stethoscopes!) was 95% (124/130). 115/130 (88.5%) questionnaires were complete in all respects and used in the analysis.

Thirty-one respondents were male and 84 were female. Seventy-one students were between 20 and 22 years of age; 25

Table 5: **The case-based component of the Introduction to Clinical Studies Course with approximately 7 students per group.**

Timing	Time frame	Case-based component	Objective
Prior to 1st tutorial	Approximately 40 minutes	Traditional style lecture explaining the objectives and structure of the case-based component and handing out the 1st case	To equip the students with knowledge of what outcomes are expected during the case-based component of the course (entailing the self-directed learning and tutorials).
Prior to 1st tutorial	Approximately 1 week	Student research or self-learning	To allow the students time to prepare for the 1st tutorial by studying the case, defining and grading the abnormalities and stating abnormalities using scientific terminology.
First tutorial meeting	Approximately 90 minutes per group	Student discussion with tutor facilitation and intervention	To allow students to discuss the abnormalities identified under tutor guidance to enable structured quality learning.
Prior to 2nd tutorial	Approximately 1 week	Student research or self-learning	To allow students time to prepare for the 2nd tutorial by studying the underlying pathophysiological processes leading to each of the abnormalities identified at the 1st tutorial.
Second tutorial meeting	Approximately 90 minutes per group	Student discussion with tutor facilitation and intervention	To allow students to discuss the underlying pathophysiology of each abnormality identified under tutor guidance to enable structured quality learning.
Prior to report back session	Approximately 1 week	Student research or self-learning	To allow students time to prepare for the final report back session by grouping related abnormalities into master problems.
Report-back session and assessment of group	Approximately 30 minutes per group	The tutor assesses the group; handing out of the 2nd case.	Students are evaluated based on their preparation for and participation in the tutor guided sessions and their ability to draw up a ranked master problem list.
Preparation prior to final assessment	Approximately 4 weeks	After completion of self-learning and discussion of 4 cases as set out above, a final case is handed to the students and time allowed for cooperative preparation without tutor assistance	To allow the students time to study the case, define and state the abnormality using scientific terminology, study the pathophysiological processes leading to each abnormality and grouping problems together as a few master problems based on the underlying pathophysiology of each abnormality.
Final assessment	Approximately 120 minutes	In an open book session the students answer 3 multiple-choice type questions based on the list of abnormalities, underlying pathophysiology and master problem list	To allow the lecturer to evaluate the students' knowledge of scientific clinical terminology, interpretation of abnormalities and pathophysiology and ability to group problems together as master problems.

were between 23 and 24 years; 8 between 25 and 26 years of age and 11 were older than 26 years.

The answers to the questions pertaining to the sample's perceptions of the problem-solving skills acquired by the students in this course attained a mean score of 4.04/5. The answers to the questions pertaining to the sample's perceptions of the workload in this course attained a mean score of 3.54/5. The answers to the questions pertaining to the sample's perceptions of the clarity of the learning objectives of this course attained a mean score of 2.80/5. The mean score related to the problem-solving skills was significantly higher than the mean scores related to the workload and the course objectives, respectively ($P < 0.001$ for both). The mean score related to the workload also had a significantly higher score than the

Table 6: **The statements contained in the questionnaire grouped into 3 categories.**

Statements pertaining to problem-solving skills:
• This course has enabled me to understand things which initially seem difficult.
• As a result of studying this course, I feel more confident about tackling unfamiliar problems.
• This course helped me to relate ideas in this subject to those in other subjects, wherever possible.
• This course has sharpened my analytic skills.
Statements pertaining to the workload:
• The work-load was too heavy.
• There was a lot of pressure on me as a student in this course.
• I have generally been given enough time to understand the things I have to learn in this course.
• The volume of work in this course meant that it couldn't all be thoroughly comprehended.
Statements pertaining to the learning objectives:
• It was always easy to know the standard of work expected of me in this course.
• I usually had a clear idea of where I was going and what was expected of me in this course.
• It was clear right from the start what was expected from students.
• I am clear about the learning objectives of the course.

mean score related to the clarity of the course objectives ($P < 0.001$).

There was no statistically significant difference between the perceptions reported by female and male students for course objectives ($P = 0.07$), workload ($P = 0.115$) or problem-solving skills attained ($P = 0.711$). There was also no statistically significant difference between the perceptions across the student age groups for course objectives ($P = 0.692$), workload ($P = 0.948$) or problem solving skills attained ($P = 0.287$).

DISCUSSION

The students' feedback on the acquisition of problem-solving skills was very favourable. They were very positive that the course enabled them to understand concepts which initially seemed difficult. They felt confident about tackling unfamiliar problems in future and relating ideas and skills learnt in this course to other subjects. This concurs with other studies reporting on students' positive perceptions on the acquisition of problem solving skills[8,13,24].

The students' feedback on the workload of this problem-based course was also positive. They felt that the workload was manageable and they had generally been given enough time to understand the material they had to assimilate in the course. From the results it can thus be inferred that the ISC400 course as it is structured, complements the current predominantly lecture-based curriculum, without consuming too much of the students' time.

The last aspect addressed in our study was the students' perceptions on the clarity of the course objectives. The mean score of this group of questions was significantly lower than the other 2 groups of questions. The responses reflected uncertainty as to the standard of work expected of them in this course and that they did not always have a clear idea of the expected end results. One has to bear in mind that it is the students' 1st attempt at a non-traditionally taught course and although the study guide for this course is very comprehensive, the practice is still uncertain. Students need to be informed at the outset and guided throughout regarding the objectives of the problem-based learning course and on how it will be assessed. This is in accordance with other studies evaluating undergraduate veterinary medicine students' attitude towards a non-traditional course[6,13,18,20].

Students need to be comfortable with learning different skill sets from those they acquire from traditionally taught courses[6]. They need to be aware that their self-confidence in clinical reasoning skills will increase with practice[24]. Clinical reasoning expertise and the ability to integrate new knowledge into existing knowledge structures is only gained through multiple representations or examples of knowledge[8,11,22]. It was reported that veterinary students displayed a rapid grasp of the process and that their ability to discover and apply scientific concepts at a preclinical level impressed facilitators[13]. In the ICS400 course, the case-based component is preceded by a 40 minute lecture explaining the objectives and structure of the course. However, it would be prudent to also emphasise the rationale behind student-centred, case-based learning and its role in the attainment of the skill sets highlighted in ancillary learning objectives in Table 2[33].

RECOMMENDATIONS

To ensure that students are clearer about the objectives of the course, the following is suggested: a) the 1st lecture should be expanded to include the rationale behind PBL as a pedagogical method; b) the tutors should be encouraged to emphasise the core and ancillary objectives throughout the course and; c) the group of tutors should meet to discuss each case and share insights with the course coordinator and the case author(s) before meeting with the individual student groups to ensure consistency in the interpretation of the key problems of the case.

The role of the tutor is thus of pivotal importance. A standardised approach to training lecturers for this role is not sufficient, because every problem-based learning programme is unique to each institution, as are the expectations of the students and tutors. Accordingly the type and degree of support given by the tutor differs with every PBL course. The various roles the tutor fulfills will depend on the objectives for the specific course presented by the individual institution[16]. However, a growing body of research suggests that students learn more and more deeply from guided learning than from self-directed discovery[14,28,29]. Furthermore, students need multiple examples and feedback in order to attain effective transfer of basic concepts such as an integrated, progressive and consistent approach to solving clinical cases[22]. It is believed that 1 of the major strengths of our course is the fact that the tutors are subject experts guiding the learning process during the tutorials. Nevertheless, regardless of whether tutors are subject experts or not, they should have expertise in group facilitation and self-directed learning[2]. Formal training should be provided to tutors to facilitate the necessary expertise. In-service training by an expert on PBL from the faculty of education should be considered.

LIMITATIONS AND FURTHER RESEARCH

The purpose of this research was not so much to gain new knowledge, but rather an effort to bring about change with a view to improving the course. This study did not address the effectiveness of the course to contribute to the knowledge base and/or reasoning skills. The assessment of the effectiveness of PBL is fraught with difficulty because of the complex multi-factorial context in which the learning takes place[12,19,23]. A major problem is teasing out the effect size among disparate outcome variables[1]. Traditional quantitative research methodologies have thus far been unable to attribute success or failure to specific educational interventions[23]. Despite these reservations there is compelling practical evidence that PBL results in consistent gains in satisfaction on the part of both the lecturers and the students[3,23]. Educational theories, cognitive science and empirical research favour inductive learning above traditional lecture-based teaching methods in attaining applicable learning objectives[9,27].

In addition, several factors limit the generalisability of this study. First, the data used are limited to the experience of 1 class only. Second, students' responses might be expected to vary with different tutors. Third, this group of students might have responded similarly to another teaching method.

Future studies should explore students' responses to different tutors and teaching methods and employ direct measures to assess students' understanding and ability to integrate knowledge.

CONCLUSIONS

The ICS400 course combines traditional lectures with practical sessions, student self-learning and guided tutorials and acts as an example of curricular innovation aimed at bridging the gap between basic and clinical sciences. The ICS400 course is essentially a method of teaching where self-directed learning and clinical reasoning skills are developed under the guidance of subject experts in a small-group cooperative setting.

In concurrence with previous studies[3,31], this study concludes that students are essentially positive about their experiences with this unique model of PBL. The results of this study indicate that tutors require adequate guidance on their communication of the rationale of PBL as a method of teaching and of the course objectives. Problem solving skills are part

of the professional competencies of practising veterinarians, but it is a skill that has to be developed with the ultimate goal of allowing students to become reflective professionals[15]. Further research is needed to verify the usefulness of this course in bridging the gap between basic science and clinical literacy in veterinary science and to refine the model.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Professor Fred Reyers for the pioneering work he did in establishing this problem-based learning course in the BVSc curriculum at the Faculty of Veterinary Science, University of Pretoria.

REFERENCES

1. Albanese M A 2000 Problem-based learning: why curricula are likely to show little effect on knowledge and clinical skills. *Medical Education 729–738*
2. Albanese M A 2004 Treading tactfully on tutor turf: does PBL tutor content expertise make a difference? *Medical Education* 38: 918–920
3. Albanese M A, Mitchell S 1993 Problem-based learning: a review of literature on its outcomes and implementation issues. *Academic Medicine* 68: 52–81
4. Blumberg P 2005 Why self-directed learning is not learned and practiced in veterinary education. *Journal of Veterinary Medical Education* 32: 290–295
5. Colliver J A 2000 Effectiveness of problem-based learning curricula: research and theory. *Academic Medicine* 75: 259-266
6. Dale V H M, Nasir L, Sullivan M 2005 Evaluation of student attitudes to cooperative learning in undergraduate veterinary medicine. *Journal of Veterinary Medical Education* 32: 511–516
7. Dochy F, Segers M, Van den Bossche P, Gijbels D 2003 Effects of problem-based learning: a meta-analysis. *Learning and Instruction* 13: 533–568
8. Ertmer P A, Newby T J, MacDougall M 1996 Students' responses and approaches to case-based instruction: the role of reflective self-regulation. *American Educational Research Journal* 33: 719–752
9. Eshach H, Bitterman H 2003 From case-based reasoning to problem-based learning. *Academic Medicine* 78: 491–496
10. Espey E, Ogburn T, Kalishman S, Zsemlye M, Cosgrove E 2007 Revitalizing problem based learning: student and tutor attitudes towards a structured tutorial. *Medical Teacher* 29: 143–149
11. Eva K W 2005 What every teacher needs to know about clinical reasoning. *Medical Education* 39: 98–106
12. Greveson G C, Spencer J A 2005 Self-directed learning–the importance of concepts and contexts. *Medical Education* 39: 348–349
13. Howell N E, Lane I F, Brace J J, Shull R M 2002 Integration of problem-based learning in a veterinary medical curriculum: first-year experiences with Application-Based Learning Exercises at the University of Tennessee College of Veterinary Medicine. *Journal of Veterinary Medical Education* 29: 169–175
14. Kirschner P A, Sweller J, Clark R E 2006 Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discover, problem-based, experiential & inquiry-based learning. *Educational Psychologist* 41: 75–86
15. Mamede S, Schmidt H G 2004 The structure of reflective practice in medicine. *Medical Education* 38: 1302–1308
16. Maudsley G 1999 Do we all mean the same thing by 'problem-based learning'? A review of the concepts and a formulation of the ground rules. *Academic Medicine* 74: 178–185
17. Maudsley G 1999 Roles and responsibilities of the problem based learning tutor in the undergraduate medical curriculum. *British Medical Journal* 318: 657–661
18. McLean M 2003 What can we learn from facilitator and student perceptions of facilitation skills and roles in the first year of a problem-based learning curriculum? *BMC Medical Education* 3: 9–19.
19. Miflin B 2004 Small groups and problem-based learning: are we singing from the same hymn sheet? *Medical Teacher* 26: 444–450
20. Monahan C M, Yew A C 2002 Adapting a case-based, cooperative learning strategy to a veterinary parasitology laboratory. *Journal of Veterinary Medical Education* 29: 186–192
21. Newman M J 2005 Problem based learning: an introduction and overview of the key features of the approach. *Journal of Veterinary Medical Education* 32: 12–20
22. Norman G R 2005 Research in clinical reasoning: past history and current trends. *Medical Education* 39: 418–427
23. Norman G R, Schmidt H G 2000 Effectiveness of problem-based learning curricula: theory, practice and paper darts. *Medical Education* 34: 721–728
24. Patterson J S 2006 Increased student self-confidence in clinical reasoning skills associated with case-based learning (CBL). *Journal of Veterinary Medical Education* 33: 426–431
25. Pickrell J A, Boyer J, Oehme F W, Clegg V L, Sells N 2002 Group learning improves case analysis in veterinary medicine. *Journal of Veterinary Medical Education* 29: 43–49
26. Prasse K W, Heider L E, Maccabe A T 2007 Envisioning the future of veterinary medicine: the imperative for change in veterinary medical education. *Journal of the American Veterinary Medical Association* 231: 1340–1342
27. Prince M, Felder R 2007 The many faces of inductive teaching and learning. *Journal of College Science Teaching* 36: 14–20
28. Schmidt H G 2000 Assumptions underlying self-directed learning may be false. *Medical Education* 34: 243–245
29. Shanley P F 2007 Viewpoint: leaving the 'empty glass' of problem-based learning behind: new assumptions and a revised model for case study in preclinical medical education. *Academic Medicine* 82: 479–485
30. Thomas R E 1997 Problem-based learning: measurable outcomes. *Medical Education* 31: 320–329
31. Vernon D T, Blake R L 1993 Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine* 68: 550–563
32. Willis N G, Monroe F A, Potworowski J A, Halbert G, Evans B R, Smith J E, Andrews K J, Spring L, Bradbrook A 2007 Envisioning the future of veterinary medical education: The Association of American Veterinary Medical Colleges Foresight Project, final report. *Journal of Veterinary Medical Education* 34: 1–41
33. Yoshioka T, Suganuma T, Tang A C, Matsushita S, Manno S, Kozu T 2005 Facilitation of problem finding among first year medical school students undergoing problem-based learning. *Teaching and Learning in Medicine* 17: 136–141