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The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23

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Abstract

Background: Case-based learning (CBL) is a long established pedagogical method, which is defined in a number of ways depending on the discipline and type of 'case' employed. In health professional education, learning activities are commonly based on patient cases. Basic, social and clinical sciences are studied in relation to the case, are integrated with clinical presentations and conditions (including health and ill-health) and student learning is, therefore, associated with real-life situations. Although many claims are made for CBL as an effective learning and teaching method, very little evidence is quoted or generated to support these claims. We frame this review from the perspective of CBL as a type of inquiry-based learning.

Aim: To explore, analyse and synthesise the evidence relating to the effectiveness of CBL as a means of achieving defined learning outcomes in health professional prequalification training programmes.

Method: *Selection criteria*: We focused the review on CBL for prequalification health professional programmes including medicine, dentistry, veterinary science, nursing and midwifery, social care and the allied health professions (physiotherapy, occupational therapy, etc.). Papers were required to have outcome data on effectiveness. *Search strategies*: The search covered the period from 1965 to week 4 September 2010 and the following databases: ASSIA, CINAHL, EMBASE, Education Research, Medline and Web of Knowledge (WoK). Two members of the topic review group (TRG) independently reviewed the 173 abstracts retrieved from Medline and compared findings. As there was good agreement on inclusion, one went onto review the WoK and ASSIA EndNote databases and the other the Embase, CINAHL and Education Research databases to decide on papers to submit for coding. *Coding and data analysis*: The TRG modified the standard best evidence medical education coding sheet to fit our research questions and assessed each paper for quality. After a preliminary reliability exercise, each full paper was read and graded by one reviewer with the papers scoring 3–5 (of 5) for strength of findings being read by a second reviewer. A summary of each completed coding form was entered into an Excel spread sheet. The type of data in the papers was not amenable to traditional meta-analysis because of the variability in interventions, information given, student numbers (and lack of) and timings. We, therefore, adopted a narrative synthesis method to compare, contrast, synthesise and interpret the data, working within a framework of inquiry-based learning.

Results: The final number of coded papers for inclusion was 104. The TRG agreed that 23 papers would be classified as of higher quality and significance (22%). There was a wide diversity in the type, timing, number and length of exposure to cases and how cases were defined. Medicine was the most commonly included profession. Numbers of students taking part in CBL varied from below 50 to over 1000. The shortest interventions were two hours, and one case, whereas the longest was CBL through a whole year. Group sizes ranged from students working alone to over 30, with the majority between 2 and 15 students per group. The majority of studies involved single cohorts of students (61%), with 29% comparing multiple groups, 8% involving different year groups and 2% with historical controls. The outcomes evaluation was either carried out postintervention only (78 papers; 75%), preintervention and postintervention (23 papers; 22%) or during and postintervention (3 papers; <3%). Our analysis provided the basis for discussion of definitions of CBL, methods used and advocated, topics and learning outcomes and whether CBL is effective based on the evaluation data.

Conclusion: Overwhelmingly, students enjoy CBL and think that it enhances their learning. The empirical data taken as a whole are inconclusive as to the effects on learning compared with other types of activity. Teachers enjoy CBL, partly because it engages, and is perceived to motivate, students. CBL seems to foster learning in small groups though whether this is the case delivery or the group learning effect is unclear.

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Practice points

- There is no international consensus as to the definition of case-based learning (CBL) though it is contrasted to problem-based learning (PBL) in terms of structure. We conclude that CBL is a form of inquiry-based learning and fits on the continuum between structured and guided learning. We therefore propose the definition: The goal of CBL is to prepare students for clinical practice, through the use of authentic clinical cases. It links theory to practice, through the application of knowledge to the cases, using inquiry-based learning methods.
- The evidence overwhelmingly suggests that health professional students enjoy CBL and think that it helps them learn better. Whether this is reflected in assessment results is far from clear. However, enjoyment can lead to increased engagement and motivation for learning, which in itself is a desirable and positive effect.
- Teachers enjoy CBL. As well as potentially making better use of teaching time available, more engaged and motivated students make for a more enjoyable teaching experience.
- CBL appears to foster effective learning in small groups, possibly through the effect of having more engaged learners, but perhaps also through having more structured learning activities closely linked to authentic clinical practice scenarios.
- Online CBL can work well providing attention is paid to the online learning environment.

Introduction

Case-based learning (CBL), also referred to as case study teaching and case method learning, is a long established pedagogical method, which is defined in a number of ways depending on the discipline and type of 'case' employed. The first full-time pathology professor at the University of Edinburgh, James Lorrain Smith, introduced what he called the 'case method of teaching pathology' in 1912 (Sturdy 2007). Smith advocated students' correlating the clinical history of patients, including their symptoms and signs, with the findings at postmortem by researching the patients' cases from their clinical records. Moreover, this case method aimed to help students link science and clinical practice.

The Harvard Business School (HBS) is often credited as one of the first, if not the first, major institutions to adopt the case method across its curriculum. Founded in 1908, the case method was adopted in 1920 and is still used today. Its website states:

> 'when students are presented with a case, they place themselves in the role of the decision maker as they read through the situation and identify the problem they are faced with. The next step is to perform the necessary analysis – examining the causes and considering alternative courses of actions to come to a set of recommendations. To get the most out of cases, students read and reflect on the case, and then meet in learning teams before class to 'warm up' and discuss their findings with other classmates. In class – under the questioning and guidance of the professor – students probe underlying issues, compare different alternatives, and finally, suggest courses of action in light of the organization's objectives' (Harvard Business School 2011).

The linkage of theory and practice is a common aim of CBL courses, as is the development of clinical reasoning in medical programmes. Queen's University Centre for Teaching and Learning (Ontario, Canada) has a useful description of generic CBL:

> 'Using a case-based approach engages students in discussion of specific situations, typically real-world examples. This method is learner-centred and involves intense interaction between the participants. CBL focuses on the building of knowledge, and the group works together to examine the case. The instructor's role is that of a facilitator, and the students collaboratively address problems from a perspective that requires analysis. Much of CBL involves learners striving to resolve questions that have no single right answer' (Queen's University 2011).

According to the National Centre for Case Study Teaching in Science, cases should:

- Be authentic (based on real patient stories)
- Involve common scenarios
- Tell a story
- Be aligned with defined learning outcomes
- Have educational value
- Stimulate interest
- Create empathy with the characters
- Include quotations in the patient voice to add drama and realism
- Promote decision making
- Have general applicability

(Herreid 1997/98).

In health professional education, learning activities are obviously often based on patient cases – patients' being real (on the wards, in clinics and in the community), simulated (people acting as patients with specific problems), virtual (online patients of varying degrees of authenticity and sophistication) or text-based. Such cases are believed to enhance the relevance of subject matter by focusing on real life and the actual performance of health professionals. Basic, social and clinical sciences are studied in relation to the case, are integrated with clinical presentations and conditions (including health and ill-health) and student learning is, therefore, associated with real-life situations.

CBL in the context of this review of health and social care professional education does not include 'real' patient cases in clinical settings, where interaction is often not planned, is opportunistic and relies on patient goodwill, but rather on formal learning activities where cases are developed and delivered in addition to clinical encounters. However, there are very broad definitions of the term 'case' and sometimes it is not always clear what a case actually is when it is referred to in

the literature. This ambiguity is a problem as there is no succinct and widely accepted definition of CBL, and therefore in the review we looked at the varying definitions with a view to proposing a definition.

CBL is often contrasted with problem-based learning (PBL) though the differences are not always clear. Barrows and Tamblyn's definition of PBL is 'learning that results from the process of working towards the understanding of a resolution of a problem. The problem is encountered **first** in the learning process' (Barrows & Tamblyn 1980, p. 1). According to Srinivasan et al. (2007), in a paper included in this review, CBL uses a guided inquiry method, with defined learning outcomes, and is more structured than PBL.

Although many claims are made for CBL as an effective learning and teaching method, very little evidence is quoted or generated to support these claims. Hence, the need to look more systematically at the evidence; we have been unable to find a published review related to CBL within health professional education that focuses on effectiveness. On the basis of the descriptions of CBL mentioned earlier in the text, which resonate with the concepts behind inquiry-based learning, we use inquiry-based learning as a conceptual framework against which to compare and contrast 'cases' as the basis of inquiry. Inquiry-based learning emphasizes constructivist approaches to learning, with knowledge being acquired in a series of steps and through group processes. Of the four levels of inquiry-based learning (confirmation, structured, guided and open), defined by Banchi and Bell (2008) we would expect CBL to fit between structured and guided. This learning process fosters a deep approach to learning, where students move from acquiring and reproducing knowledge, to seeking meaning through the application of knowledge so they see things in a different way (Marton & Säljö 1997; Entwistle 2009).

Review aim

The aim of this review is to explore, analyse and synthesise the evidence relating to the effectiveness of CBL as a means of achieving defined learning outcomes in health professional prequalification training programmes.

Objectives

(1) To identify the published empirical evidence on the effectiveness of CBL in health professional prequalification training programmes, analyse this evidence and synthesise conclusions and recommendations from it.
(2) To evaluate the strengths and limitations of published data.
(3) To propose a definition for CBL.

Subsidiary questions

In the course of our analysis, we aim to answer the following questions:

(1) How is CBL defined?
(2) What methods of CBL are used and advocated?
(3) What are students' and educators' views on CBL?
(4) Is CBL effective in health professional education?
(5) In what ways is CBL effective?
(6) How does CBL promote learning?

Review methodology

The topic review group (TRG) was based at Warwick Medical School during the early stages of this graduate entry medical school's curriculum review. Following a decision by the curriculum review team to develop the new curriculum in a CBL format, the group wished to explore the evidence for the effectiveness of such an approach. The team members came from diverse backgrounds and had a range of expertise in learning, teaching and curriculum development. Their professions and disciplines included general practice (GP), paediatrics, pathology, psychology, physiology and midwifery, as well as further specialization in health professional education, e-learning, communication skills and research methodology. The group also included a medical student.

We registered our topic and protocol with best evidence medical education (BEME) in August 2010 and, following feedback, made minor alterations to the protocol in October the same year.

Selection criteria

Inclusions. In order to review a wide cross section of papers, we decided to include studies involving medicine, dentistry, veterinary science, nursing and midwifery, social care and the allied health professions (physiotherapy, occupational therapy, etc.), plus combinations of these. To answer the primary review aim, studies had to include outcome data relating to the effectiveness of CBL and not merely be descriptions of educational activities, even though such papers might include definitions of CBL. We limited the search to papers published from 1965 onwards and included papers not in English.

Exclusions. We did not exclude papers on the basis of what we defined as poor methodology (see subsequent sections), or which had small numbers of students, in order to capture as many outcome data as possible. We excluded papers that focused solely on PBL as categorized as such by the authors, whose students were not from one of the health professions (e.g., they were from law, business, etc.) and which did not include evaluation data, plus papers from pre-1965.

Search strategies. Diane Clay, an information scientist based in the Health Sciences Research Institute and Warwick Medical School, planned and carried out the searches in October 2010. The search covered the period from 1965 to week 4 September 2010 and the following databases: ASSIA, CINAHL, EMBASE, Education Research, Medline and Web of Knowledge (WoK; see Appendix 1 for search syntax).

The initial search was run over Medline and EMBASE concurrently. Figures in brackets in Appendix 1 refer to total number of hits from both databases combined at the various stages of the search, and the final bold number is the end total. When duplicate papers were removed on the Ovid System (Medline as primary), the figures were Medline: 173 and Embase: 71. The citations and abstracts were imported into

Table 1. Results from databases.

Database	Total abstracts	Excluded	Duplicates	Full papers	Excluded full	Coded
Medline	173	94		79	30	49
CINAHL	53	37	2	14	4	10
EMBASE	71	47	7	17	6	11
Education research	115	92	4	19	6	13
ASSIA	13	6	6	1	0	1
WoK	374	291	35	48	26	22

EndNote X4, and the project lead did a quick review of the 173 titles and abstracts in the Medline database for relevance (with a more detailed review later – see subsequent sections). The search strategy seemed to be fairly sensitive as evidenced by this scan and the number of titles, and was therefore, only modified in order to meet the search terms needs of the other databases. The remaining databases were searched one to two weeks later.

The number of citations from all the databases is listed in Table 1 and a flow chart in Appendix 2. The search results were entered into EndNote X4. Two of the TRG reviewed each of the 173 titles/abstracts in the Medline database independently to decide which full papers were required and which could be eliminated straight away. Reviewer 1 elected to keep 74 and discard 99 titles; reviewer 2 elected to keep 77, discard 92 and was unsure about 4. After discussion and reaching a consensus, the reviewers agreed to keep 79 (for full retrieval) and to discard 94.

Reviewer 1 then reviewed the WoK and ASSIA EndNote databases and reviewer 2 the Embase, CINAHL and Education Research databases. With Medline as the primary database, we identified duplicates in the other databases; these were filed under *trash*. All remaining abstracts were read and dealt with in relation to the inclusion/exclusion criteria. The main reason for exclusion at the abstract stage was that the papers were opinion or minor reviews without empirical data; a small number focused on CBL postqualification (e.g., resident or specialist training) and, mainly within the WoK search, because they did not include any health professional students (i.e., focused on business, law, etc.). Conference proceedings for which no full paper could be identified were also rejected.

One TRG member hand searched the table of contents of *Medical Education, Academic Medicine and Medical Teacher* but found only two papers not already identified and these had been published since the original search. Because of this poor yield, we decided not to search other journals.

The number of papers we identified through these searches are listed in Table 1, which includes the number of duplicates, papers excluded at the abstract stage and at the full paper stage, plus the final figure for coded papers. We had one paper translated by a bilingual colleague, and this was included in the data analysis.

Coding the papers

If the paper was not rejected after reading the abstract, the full paper was retrieved. If there was no abstract available, the full paper was retrieved. All full papers were then entered into the coding stage. A number of papers were rejected at this stage when read in full. The main reason for exclusion at this point was that no evaluation data were given in the paper because either the paper was merely a description of a CBL intervention without evaluation or a review of the topic, though we did not identify any systematic reviews within the health professional literature. A small number of papers were rejected because they focused on CBL post qualification (e.g., resident or specialist training), which had not been apparent from the abstract and, mainly within the WoK search, because they did not include any health professional students (i.e., focused on business, law, etc.), again not identified from the abstract. Coded papers were then filed under *coded* in the relevant EndNote library.

We modified the standard BEME coding sheet to fit our research questions – this was discussed and further amended after the first group coding. The standard fields included: title, date and authors of paper, who coded and when, whether the paper fitted the inclusion criteria of focusing on CBL for health and social care prequalification students with evaluation data, the location of the study, the number and type of students involved, research design and the impact level for evaluation according to Kirkpatrick's hierarchy (Kirkpatrick 1967). The coding parameters we added included: the focus or topic of the CBL, the learning outcomes (if stated), the intervention and length of intervention, the number of students learning together in a group, the number of years the CBL had been taking place, plus a space to add text relating to whether the paper answered any of the subsidiary questions. Each paper was also assessed on its evaluation methods, strength of findings (1–5) and overall impression (poor to excellent) as is standard on the BEME coding sheet.

Criteria for judging the papers were more global than specific but included: number of participants, number of cohorts, whether there was any comparison of cohorts including historical, level 2 or above outcome data, preintervention and postintervention data, some attempt at exploring how CBL is effective, clear description of analytical method.

As a preliminary inter-rater agreement exercise, all seven members of the review team independently coded three papers from three different databases. Paper 1: all reviewers except one rated this as 1/poor, with the exception rating it as reject; paper 2: four reviewers rated this as poor but either 1 or 2 and three as acceptable (1, 2 and 3), after discussion, the rating was poor, 2; paper 3: all reviewers rejected this as having no evaluation data.

Table 2. Coding based on first review.

Kirkpatrick level	1 student reaction	86
	2a change in attitude	9
	2b change in knowledge	41
	3 change in behaviour	0
	4 organisational change	0
Strength of findings	1	29
	2	40
	3	22
	4	13
	5	0
Overall impression	Poor	53
	Acceptable	38
	Good	13
	Excellent	0

Table 3. Double coding ($n = 34$).

Coding	Reviewer 1	Reviewer 2
Excellent + 4		1
Good + 4	13	8
Acceptable + 4		2
Poor + 4		1
Good + 3		3
Acceptable + 3	19	9
Poor + 3	2	1
Good + 2		1
Acceptable + 2		5
Poor + 2		0
Acceptable + 1		1
Poor + 1		2
Total significant papers	34	23

Pragmatically, we felt that the level of agreement meant that papers could be initially be coded by one reviewer, with all papers categorized as 3–5 being coded independently by a second reviewer. The final number of coded papers for inclusion was 106, but on closer examination of the papers, we found that Horsch et al. (1999) and Horsch et al. (2000) included different data but on the same cohort and number of students, as did Peplow et al. (1990) and Peplow et al. (1992). We have, therefore, amalgamated these two duos of papers using the earlier year (i.e., 1999 and 1990) giving a final total of 104 papers. Of these, 65 were coded by a single reviewer (62.5%) and 39 papers by two reviewers (37.5%).

Data analysis

A summary of each completed coding form was entered into an Excel spread sheet. Table 2 shows the number of papers by categorization: Kirkpatrick level (some papers included evaluation data at more than one level), strength of findings and overall impression as coded by the first reviewer. We agreed that we would rate papers as high quality if they scored 3–5, based on the strength of the findings, plus excellent, good or acceptable, based on the overall impression. All the 'good' papers were rated 4 (13) but only 19 (47%) of the acceptable papers were rated 3, giving 32 papers that we classified as having significant and important findings for our study at that stage. These 32 papers were then coded by the second reviewer (Table 3). After this coding, we agreed that 23 papers would be classified as of higher quality and significance (22%), as excellent/good/acceptable plus 3 or 4. In the results and findings section below, we give synthesis results from the full 104 papers and then the 23 significant papers.

Findings: Classifications of papers

We include the following in tables, with one column for all the papers and one column for the significant papers: geographical location of the study (Table 4); year of publication (Table 5); types/professions of students (Table 6); number of students in the studies (Table 7) and number of students learning together in a group (Table 8).

Table 4. Geographical location.

Location	Number in full sample ($n = 104$)	Number in significant sample ($n = 23$)
UK	5	0
Other Europe	19	6
Asia	9	0
North America	54	14
South America	1	0
Africa	2	0
Australasia	14	3

Table 5. Year of publication.

Year	Number in full sample ($n = 104$)	Number in significant sample ($n = 23$)
2010	6	2
2009	9	1
2008	12	2
2007	15	5
2006	14	4
2005	9	5
2004	6	1
2003	1	0
2002	10	1
2001	2	1
2000	3	0
1990–1999	14	1
Pre-1990	3	0

Table 6. Professions of students.

Student profession	Number in full sample ($n = 104$)	Number in significant sample ($n = 23$)
Chiropractic	1	0
Dentistry	5	1
Medicine	68	15
Nursing	9	2
Paramedic	2	0
Pharmacy	2	0
Psychology	3	1
Social science	1	1
Speech pathology	1	0
Veterinary	5	3
Mixed	7	0

Table 7. Number of students in studies.

Total number	Number in full sample ($n = 104$)	Number in significant sample ($n = 23$)
Fewer than 50	22	2
51–100	13	4
101–200	32	9
Over than 200	21	7
Not given	16	1 (but 4 years data)

Note: The smallest study had six students and the largest over a 1000 (exact number not given).

Table 8. Number of students learning together on cases per group.

Number in group	Number in full sample ($n = 104$)	Number in significant sample ($n = 23$)
Working alone	13	4
2–15	41	7
16–30	5	2
More than 30	9 (usually whole year group)	2
Not given	36	8

Interventions

There was a wide diversity in the type, timing, number and length of exposure to cases and how cases were defined (see Appendix 3); so diverse that it is difficult to tabulate these. The shortest interventions were two hours, and one case; whereas the longest was CBL through a whole year. There were 20 papers, which used some form of online or e-learning, and two with simulation. In only 35 of the papers, were specific learning outcomes defined for the students; these could be topic specific, more generic or a mix of both.

Design

Papers were classified as either evaluating a single cohort: students all undergoing the same intervention in the same academic year (designated S in Appendix 3); or multiple cohorts: students undergoing different interventions for comparison or an intervention with a control group (designated M in table) or similar interventions over different year groups and no comparison (MY in Appendix 3). Students in the same year with the same intervention compared with historical controls using national examinations are also classified as multiple groups (MH). There were 63 papers with single cohorts (61%), 30 with multiple and comparison (29%), nine with different year groups (8%) and two with historical controls (2%).

The outcomes evaluation was either carried out postintervention only (78 papers; 75%), preintervention and postintervention (23 papers; 22%) or during and postintervention (three papers; $< 3\%$).

Analysis

The type of data presented in this study was not amenable to traditional quantitative meta-analysis because of the variability in interventions, information given, student numbers (and lack of) and timings. We have, therefore, adopted a narrative synthesis approach to compare, contrast, synthesise and interpret the data (Popjay et al. 2007). Narrative synthesis involves the development of a theory of how an intervention (i.e., CBL) works, why and for whom, through a preliminary synthesis of findings of included studies, an exploration of the relationships in the data and an assessment of the robustness of the synthesis. In this review, we are guided by the theory relating to inquiry-based learning and further develop this during the analysis and synthesis of the papers.

Results: Synthesis of findings

A summary of the papers is given in Appendix 3. The results and analysis are presented under the headings of the subsidiary research questions, based on all 104 papers: definitions, methods/learning activities, student and faculty views/feedback, effectiveness based on level 2 outcome data for single cohorts. We then summarise the significant papers involving single cohorts (10). This is followed by a section of analysis of the effectiveness in relation to papers that compare two or more groups, finishing with the significant papers involving a comparison (13). Our conclusions about the ways in which CBL works and how it promotes learning are then discussed taking into account the evidence from the results.

Definitions of CBL

There were a number of definitions given for CBL in the introduction to papers, some referenced to earlier literature and some stated without citation or evidence. The definitions can be categorized into underlying themes:

Goal: The purpose of the learning, other than specific learning outcomes.

In this theme authors write about students being exposed to real, or authentic, cases before clinical attachments or during rotations for added breadth of patient presentations, to prepare them for clinical practice (Hudson & Buckley 2004), to provide opportunities for formulating diagnoses and management plans (Anderson & Helberg 2007) and to understand how underlying mechanisms relate to identifying and treating illness (Ferguson 2006). Students can address an integral picture of the whole patient instead of separate views of diseased organs (Chan et al. 2008). CBL is predicated on the aim that the learning context should closely match the situations in which the information will be utilized (Sutyak et al. 1996). It requires changing the traditional roles and responsibilities of students and faculty and revising instructional goals and design (Sutyak et al. 1996).

Content: What is included in the case, the learning activities?

There is an emphasis on real-life practice and cases (Stewart & Gonzalez 2006; Bowe et al. 2009; Schoeman et al. 2009), but this reality can focus on a community as well as individual patients (Bair 1980).

Process: What takes place in CBL, what is helping students learn?

The linking of theory (classroom-based) to practice (clinical) is strongly emphasized (Koh et al. 1995; DeMarco et al. 2002; Stewart &Gonzalez 2006), with integration of basic science and clinical management (Beech & Domer 2002; DeMarco et al. 2002; Chan et al. 2008; Chan et al. 2008; Blewett & Kisamore 2009; Bowe et al. 2009) and across diverse courses (Garvey et al. 2000; Ferguson 2006; Chan et al. 2008). CBL is stated to be both patient-centred (Sutyak et al. 1996; Chan et al. 2008) and student-centred (Sutyak et al. 1996; DeMarco et al. 2002; Patterson 2006). CBL functions as a bridge between learning/knowledge and working life (Hong et al. 1998; Hansen et al. 2005; Hakkarainen et al. 2007), while strengthening the link between theory and practice (Hudson & Buckley 2004; Stewart & Gonzalez 2006), and mirroring the decision-making process of the workplace (Stewart & Gonzalez 2006). It promotes active discussion and participation (Hansen & Krackov 1994). Students engage in problem solving with support and feedback from colleagues and experts (Sutyak et al. 1996). Although not all CBL is delivered through group activities, it can be used to encourage group work (Rybarczyk et al 2007) and cooperative learning (Stewart & Gonzalez 2006), with small groups working towards a common goal.

These themes of goal, content and process with the emphasis on linking theory to practice are hallmarks of inquiry-based learning. Instead of 'research questions' or problems, the raw material for the inquiry is the case, usually with defined learning outcomes (structured inquiry).

Methods of CBL used and advocated

Methods in this study refer to the methods used in the interventions described in the papers, and thus those that were evaluated. As shown in Table 8 earlier in the text, the most common method of case delivery was by small group or large group discussion, usually with a facilitator; other methods included online and computer-based cases, video presentations (Kumagai et al. 2010), whole class, whole class discussion after online cases (Canham Van Dijken et al. 2008), students reviewing cases prior to sessions in order to be able to discuss them in groups (Bowe et al. 2009), facilitated discussion with trigger questions (Leonard et al. 2002). Less common methods included fourth year students writing cases and discussing them with first year students (Hansen & Krackov 1994); case studies being adapted to integrate nutrition and physical therapy issues – the nutrition students worked collaboratively with the physical therapy students to address the nutrition issues affecting the case scenarios (Smith Jr. & Christie 2004); cases as a vehicle for discussion of interprofessional roles and responsibilities (Lindqvist et al. 2005). In respect of the last of these CBL was described as being feasible for interprofessional groups (Lindqvist et al. 2005).

Of interest in terms of definitions and methods of CBL is the paper by Irby (1994). Expert practitioners articulated their own knowledge to medical students and residents to facilitate development of 'knowing-in-action' and this included 'teaching rounds', i.e., case orientated instructional sessions held predominantly in a hospital conference room with the ward team. Three different methods are described: bedside teaching, lecture teaching and iterative teaching. Although this is called cased-based, it raises the question of the nature of cases in terms of being based on real patients but also being taught with real patients present. Many authors state that their cases are based on authentic cases, though how they are actually written and developed is not always described, but the patient is not physically present in the classroom or online. Irby's method of bedside teaching is obviously different to this, as the patient is physically present, though the patient is not present in the lecture, only information about their case.

Topics for the CBL: Specific and generic learning outcomes

The topics for the CBL in the papers are listed in Appendix 3. As previously mentioned, only a proportion included learning outcomes, either specific outcomes relating to topic/subject goals or to more generic learning outcomes/goals. Examples of the former topics or outcomes are: formulating a custom oral rehabilitation plan for their own patient and to justify it with confidence (Lechner et al. 2001); understanding of human anatomy and physiology (Cliff 2006); implicit and explicit learning outcomes with relation to radiology – the stated goal was to learn about diffuse airways disease but implicit to learn of difficulty of interpreting X-rays without clinical history (Chew et al. 2005); there was also an example of an objective that might be difficult to assess: increasing motivation for anatomy (Scott 1994).

Examples of generic outcomes are: creating a culturally competent approach to meeting the emotional and physical needs of the families described in the case studies (Hilgenberg & Schlickau 2002); interprofessional learning outcomes (Lindqvist et al. 2005); interdisciplinary working (Smith & Christie 2004); critical thinking (Anderson & Helberg 2007; DeSanto-Madeya 2007), diagnostics in clinical practice (Anderson & Helberg 2007; Blewett & Kisamore 2009); establishing priorities in cases (Bair 1980), group working (Bair 1980), critical decision points (Choi et al. 2009); clinical decision making (DeSanto-Madeya 2007; Critchley et al. 2009), clinical problem-solving (Dupuis & Persky 2008), diagnostic reasoning (Kopp et al. 2008); solving complex problems (DeMarco et al. 2002; DeSanto-Madeya 2007); applying the course concepts of stereotypes, prejudice and attribution to case material, examining the interrelation between attitudes and behaviours, and examining a societal implication of prejudiced attitudes (Leonard et al. 2002) and the initial skills required for the practice of evidence-based medicine (Ferguson 2006).

We cannot infer that there were no defined learning outcomes for interventions if they were not listed in the papers, and we also cannot know if any defined outcomes were only known by the educators. If defined by educators, but not known to students, this fits with guided inquiry and resembles PBL.

Evaluation: Is CBL effective in health professional education?

The majority of papers restricted their outcome evaluation to level 1; some included faculty as well as student reaction and feedback.

Level 1 – Student reaction

The majority of student feedback in relation to their CBL experiences was very positive. Common words used to describe their opinion were: liked/highly satisfied/stimulated/motivated/challenged/helpful/of value/appreciated (Novak 1971; Bernheimer et al. 1982; Engel & Hendricson 1994; Hansen & Krackov 1994; Scott 1994; Schwartz et al. 1994; Koh et al. 1995; Peplow 1996; Hong et al. 1998; Horsch et al. 1999; Garvey et al. 2000; Richardson & Birge 2000; Lechner et al. 2001; Maleck et al. 2001; DeMarco et al. 2002; Mayo 2002; Quattrochi et al. 2002; Steinberg et al. 2002; Tarnvik 2002; Trevena & Clarke 2002; Sutphen et al. 2003; Massonetto et al. 2004; Simonsohn & Fischer 2004; Smith & Christie 2004; Damjanov et al. 2005; Hansen et al. 2005; Hoag et al. 2005; Lindqvist et al. 2005; Bezuidenhout et al. 2006; Jamkar et al. 2006; Williams 2006; Wilson et al. 2006; Anderson & Helberg 2007; Drakeford et al. 2007; Hakkarainen et al. 2007; Kolbt et al. 2007; Krockenberger et al. 2007; Owen et al. 2007; Stjernquist & Crang-Svalenius 2007; Canham Van Dijken et al. 2008; Dupuis & Persky 2008; Blewett & Kisamore 2009; Bowe et al. 2009; Braeckman et al. 2009; Critchley et al. 2009), fun (Horsch et al. 2000), real-life relevance (Anderson & Helberg 2007), gained in confidence (DeMarco et al. 2002), felt achieved objectives (Koh et al. 1995), increased confidence in planning management (Lechner et al. 2001), liked progression within a case (Lechner et al. 2001), helped apply knowledge (Loving & Siow 2005), involved deeper learning approach (Schwartz et al. 1994), helped in learning factual material (Schwartz et al. 1994), enhanced learning (Street et al. 2007) and an effective means to learn concepts (Struck & Teasdale 2008). It was a valuable learning experience and they wanted more (Anderson & Helberg 2007).

Students commented on the degree of creativity, challenge, interest and enjoyment afforded through the case-study method (Mayo 2002), and they stated it improved their understanding (Rabe et al. 2007). In Mayo's (2004) study, the majority of students indicated that CBL stimulated academic challenge, bolstered personal interest and involvement in the subject matter and offered a sharply realistic perspective from which to apply course content (Mayo 2004). CBL led to an improvement in personal confidence (Peplow 1990). Students commented that they thought there was a good link between cases and real-life practice (Simonsohn & Fischer 2004) and that they preferred CBL to more traditional presentations (Struck & Teasdale 2008). Students gave a high score to CBL for learning, understanding and clinical problem solving (Stjernquist & Crang-Svalenius 2007) while it made anatomy more relevant (Hansen and Krackov 1994; Scott 1994; Peplow 1996), improved self-learning skills (Jamkar et al. 2006), was valued as a first introduction to clinical skills (Hudson & Buckley 2004), improved clinical skills (Jamkar et al. 2006) and better prepared them for clinical teaching (Waydhas et al. 2004). CBL helped students comprehend abstract course material by providing concrete illustrations and opportunities to verify their understanding of core concepts, and case studies were both a welcome contrast and complement to lecture and discussion methods (Leonard et al. 2002). Students enjoyed applying and integrating course material using real-life situations (Leonard et al. 2002). CBL also improved students' attitude to medical education (Jamkar et al. 2006).

Students' self reports of learning were cited, often without more objective evidence of change: for example, claims that critical skills were enhanced (DeSanto-Madeya 2007). Patterson (2006) studied students over four consecutive year groups of students; three of those four years reported increased confidence in making problem lists and two of those three years also reported increased confidence in choosing appropriate diagnostic tests. Over six years of CBL, 80% of students stated that CBL promoted independent learning and critical thinking (Krockenberger et al. 2007). Garvey et al (2000) found that the majority of students agreed that CBL was a worthwhile progression from PBL.

When CBL was delivered in small groups, the group learning process itself was highly rated, but there is a problem disentangling cause and effect due to confounders. For example, Curran et al. (2008) found that students were satisfied with CBL but this seemed to be related more to the group learning process rather than the CBL specifically. Students became more positive towards several aspects of the group activity and more generally towards group work (Thurman et al. 2009). They felt that CBL improves communication through group discussion (Chan et al. 2008). In Williams' (2009) study, the majority of students (74%) *agreed* or *strongly agreed* that the discussion sessions facilitated interaction between teaching staff and students, and 80% of students *agreed* or *strongly agreed* that case-based learning fostered more beneficial interaction between classmates. Female students were more positive than males in initial case discussions (Peplow 1998).

Online cases were popular, with the majority of students preferring web-based cases to lectures (Krockenberger et al. 2007; Morrow 2010). For e-learning formats, the ease of use was important in ensuring student satisfaction (Drakeford et al 2007); they liked computer-based cases (Boeker et al. 2005) though navigation could be poor (Boeker et al. 2005), and satisfaction was reduced if there were problems with the learning platform (Hakkarainen et al. 2007).

In a few studies, there was a mixed reaction, both positive and negative (Kaufert et al. 2010). Although some students liked CBL, they were not sure it helped prepare them for summative assessment (Blewett & Kisamore 2009) or to work collaboratively (Stewart & Gonzalez 2006). A major source of student dissatisfaction was work load (Schoeman et al. 2009) and the adverse amount of time that was required for activities (deSanto-Madeya 2007; Hakkarainen et al. 2007; Rodríguez-Barbero & López-Novoa 2008; Struck & Teasdale 2008), while not having enough time frustrated students (Lechner et al. 2001). Students preferred small groups to large groups or working on their own (Dupuis & Persky 2008) but also liked larger collaborative groups in which they worked in pairs

(Hilgenberg & Schlickau 2002). Some preferred more structure (Dupuis & Persky 2008; Hilgenberg & Schlickau 2002), clearer instructions (Hilgenberg & Schlickau 2002) and did not like the ambiguity of learning tasks (Hakkarainen et al. 2007). Some students struggled with self-directed learning, as this was the first time they had had to do this (Rodríguez-Barbero & López-Novoa 2008). However, in one study, students in the unstructured group found their work to be more enjoyable than students in the structured group (Sutyak et al. 1996). Radon et al. (2006) found that students enjoyed CBL, but they did not think it a replacement for more traditional teaching in the classroom.

Process evaluation: Proxies of student reaction are attendance and involvement, which are also examples of process evaluation, i.e., the implementation of the intervention rather than its impact (Pawson & Tilley 1997). Hoag et al. (2005) found CBL resulted in better student attendance. Although there were also results showing that most students completed more than the required number of cases (Radon et al. 2006), in some studies students did more cases only if they were mandatory compared with voluntary (Hege et al. 2007) and when cases were voluntary, not all students used them, in fact less than 60% (Critchley et al. 2009). Henning et al. (2006) used a simple approach to discourse analysis following introduction of a case-based approach, videoing three of the small groups of students involved in the learning. One conclusion was that the transition from lectures grew easier with each cycle of instruction. Unsurprisingly, students participated in small group discussion more if they were asked open ended questions about the cases; questions about case content tended to elicit shorter responses, whereas questions about values resulted in longer, less technical answers. The results said more about the group learning process and facilitation than about the efficacy or learning potential of the cases themselves.

Level 2 – Changes in attitudes or knowledge

As shown in Table 2, a smaller proportion of studies attempted to assess students' knowledge and/or attitudes through the use of tests and surveys, and only a small number looked at change in knowledge/attitudes through the use of preintervention and postintervention testing. In relation to attitudinal assessment, some instruments were validated and others derived specifically for the intervention. The papers that included a control or comparison group will be described later.

Beech and Domer (2002) showed that knowledge of physiology increased as demonstrated by a postintervention test compared with a preintervention test, whereas Drakeford et al. (2007) showed that students improved their knowledge of asthma and inhaler management. Students' competence in performing three clinical reasoning skills also seemed to improve over the course of the 15-week semester devoted to CBL (Patterson 2006). Both Jamkar et al. (2006) and Dietrich et al. (2010) showed increased knowledge scores. However, it is hard to conclude that the CBL method itself alone was responsible for the increased learning, as we would expect knowledge to be enhanced by other teaching and learning methods.

Faculty evaluation

As well as from students, some authors sought feedback from faculty/teaching staff. Educators were positive (Hansen 1994; Kaufert et al. 2010) and enjoyed CBL while feeling that it achieved its objectives (Koh et al. 1995); it was welcomed as an addition to conventional teaching methods (Reimer et al. 2006). There were differences of opinion in terms of resources. Faculty could find the CBL programme time intensive (Jamkar at al. 2006), particularly in terms of preparation (Hansen 1994). In contrast the case-based approach was also said to require only one faculty facilitator, and could be applied to a large group, thus being less susceptible to intra-group problems (Blewett & Kisamore 2009). Similarly, the overall impression of Peplow's (1996) study was that the programme had promoted some of the favourable aspects of small-group learning, yet was not demanding on staff-time.

Staff noted that students appeared to have more active involvement in patient management (Jamkar et al. 2006) and showed increased interest in the topic (Koh et al. 1995). Hudson & Buckley (2004) commented that tutors believed that cases provided a relaxed, nonthreatening environment, which fostered confidence and allowed for the gradual emergence of clinical skills, and believed that CBT was a learning environment that introduced students to clinical skills in a way that built their confidence for future patient encounters. Faculty considered CBL an effective learning tool for interprofessional learning (Smith & Christie 2004).

Sutyak et al. (1998) found that faculty preferred unstructured cases, with room for students to go wrong; students could make diagnostic and treatment mistakes without risk, while also receiving immediate specific feedback on the 'patient's' condition.

The efficacy of CBL: How it might work?

A number of statements were made about the efficacy of CBL and how it achieved its effectiveness, without empirical or objective evidence being given, other than student feedback. For example, Braeckman et al. (2009) stated that CBL is as good as workplace visits with real patients as evaluated by student self reports but gave no objective evidence of this. Cliff (2006) based his conclusion on what were referred to as unpublished oral reports from selected students obtained from structured group interviews and stated that cases improved students' understanding of difficult physiology concepts. These students indicated that the discussion of the case during the study review was particularly valuable in helping them overcome misconceptions about the subject material (Cliff 2006).

Efficacy may not be related to sophistication of case delivery as results of Rabe et al. (2007) indicated that, even in a resource-constrained environment, the use of simple software like PowerPoint could promote the identification and pursuit of individual learning issues and help to better develop self-directed learning skills.

Active participation in learning was a key theme. Students thought that learning was enhanced by the group work

(Dupuis & Persky 2008), whereas educators felt it encouraged learner engagement (Engel & Hendricson 1994). Basic science information could be learned and applied most effectively when students participated actively in the process of acquiring knowledge (Hansen 1994). CBL was said to aid the development of applied reasoning skills (Mayo 2002) and higher order thinking skills (Rybarczyk et al. 2007), while enhancing students' development of conceptual knowledge at a deeper level of understanding, benefiting the application of that knowledge across diverse cases and contexts. Thurman et al. (2009) and Choi et al. (2009) found that students' learning styles did not influence their perceived learning experience with case-based e-learning. However, there might be a maturity effect as in one study graduate entry students performed better in early CBL than did school leavers (Peplow 1992).

The effectiveness of CBL seems to relate to the active learning undertaken by students (as with inquiry-based learning) and the application of knowledge acquired to different cases, thus enhancing its relevance.

Quality papers involving single cohorts

CBL intervention in radiology by Chew et al. (2005) involved five online cases per week: the cases included the same X-ray films but the brief history and examination given for each case differed. The authors stated the method was based on that of the HBS with an emphasis on experiential learning, with students' needing to make a diagnosis while coming to an understanding that the history and examination of a patient are fundamental for the correct interpretation of an X-ray and formulation of a management plan.

Cliff (2006) used a CBL approach with the aim of overcoming four common misconceptions relating to respiratory physiology. They concluded that in spite of the tenacity of these ideas, the case-based approach led to some decrease in their prevalence as determined by a pretest–posttest design. The students indicated that the discussions about the cases helped their understanding; however, there was a need for further activities to dispel the myths completely.

A paper by Hakkarainen et al. (2007) describes an action research project and is interesting because it includes data on students creating video cases: simulations of possible social situations related to open-ended real-life cases acted as the starting point and context for learning. Data were collected in relation to characteristics of meaningful learning, derived from previously published models and in terms of the emotional responses of the students, both positive and negative. Creating cases meant the students were active and collaborative learners, and the cases functioned as a bridge between their learning and their working lives. Overall, they indicated positive emotions while creating and learning from cases. Students rated the online learning environment less well for opportunities to collaborate, which may be a reflection of the learning platform more than the case-based approach, as they noted technical problems. They did not like the strict timetable and the ambiguity of the learning tasks. However, the authors did not correlate 'what' the students learnt with how they felt when they were learning it. So, while the students felt motivated and positively engaged, there were no data as to whether the product they produced was academically good or poor.

Hansen et al (2005) results supported their previous findings (1994) that CBL in general is more enjoyable and that students are better able to see the connection between knowledge and clinical practice. In this study, CBL was defined as a variant of PBL and a small group activity for which students were given six weeks to prepare a case presentation.

Hoag et al. (2005) set out to measure the effect of introducing cases on critical thinking and other variables such as student attendance at case-based sessions, as well as student opinion. There was no measurable effect on critical thinking as measured by a five-item multiple-choice question (MCQ). The authors acknowledged methodological limitations in the way they measured critical thinking, and suggested that there might indeed be an increase but their methods could not detect it. Although student attendance was significantly higher for the case session as compared with lectures, the authors did admit that attendance was mandatory at some of the case sessions, which would obviously skew results. Students rated the student/instructor interaction as being greater in the case versus the lecture sessions. But this is not surprising, as lectures have limited scope for interaction. Overall, students and instructors liked the case sessions so the authors stated that these were to be continued.

The value of these data from Krockenberger et al. (2007) is that it is from four years of student and staff experience. For the level 1 outcome survey, the response rate was 72%. Students felt that web-based cases promoted understanding, independent learning and critical thinking (80% of respondents) and they liked these with only 8% preferring the time to be given to lectures rather than cases.

The Simonsohn and Fischer (2004) paper was translated from the German. Data were from experience of CBL over two years. Feedback was collected from students first on paper and then online. Students stated that the CBL increased their motivation and that there was a good link between the cases and real-life practice. Students preferred cases to lectures and used the cases more when they were assessed on them, which is not surprising.

An objective of the paper by Thurman at al. (2009) was to explore how veterinary students learn from one another – the nature of collaborative learning. Students were required to work on a case in self-selected groups of six; small and large animal cases were randomly assigned. Each group was required to set their own learning objectives and to attend two formal meetings with their teachers, three to four weeks apart. In their evaluation, only one-third of the students made spontaneous comments about collaborative or interactive activities being effective for their overall learning. The students became more positive towards several aspects of the group activity and more generally towards group work as time progressed. The students completed both preintervention and postintervention questionnaires, but were not assessed individually but rather on their group presentations.

Evaluation involving comparison or controls

Of these 32 papers, only 13 have been coded as good or excellent. The latter will be discussed in more detail after a brief description of the weaker papers under sub headings referring to the Kirkpatrick levels.

Level 1

A study by Kolb et al. (2007) only compared Spanish and German students' views about occupational health as a topic after they had studied online cases; Spanish students were found to be more interested. Waydhas et al. (2004) had students prior to surgical clinical bedside teaching either receiving cases beforehand (intervention group) or not receiving them in order to prepare for the teaching. Not surprisingly, students in the intervention group stated that they were on the whole better prepared for teaching and also said their teachers were better prepared. Hege et al. (2007), using a computer-based system, compared five different ways of presenting cases: voluntary cases without added 'motivation' (i.e., students were not told the relevance of the cases to the subsequent examinations); voluntary cases where the relevance to the examination was made clear; mandatory cases; learning by teaching (i.e., the students created the cases themselves); a combined strategy (which seemed to be integration with other teaching including PBL). This was a weak study only looking at student acceptance of the method: students liked some methods of case delivery but not others. They did more of the cases in the mandatory group than in the voluntary groups.

Level 2

The majority of papers found no differences between CBL cohorts and either controls or students' having other interventions. Carrero et al. (2009) split their 68 students into two groups for basic life support training and compared CBL with a multimedia presentation. The intervention consisted of only three cases: one case per hour for three hours. Both groups increased their knowledge after the intervention. Gemmell (2007) compared one year group having a new CBL curriculum with the previous year group and found no difference in examination scores between the two years. Peplow (1996) also found no difference in marks in assessment between traditional and case teaching. Lyon et al. (1991) found no difference in knowledge attained between CBL via computer cases and the 'control' group who had access to the same cases on paper but concluded that computer-based cases took less time to complete than paper ones. Baumberger-Henry (2005) split the students into three groups: co-operative learning and cases; lecture and cases; lectures only; and found no difference between the groups on examination scores or the students' self-perception of problem-solving and decision making via appropriate instruments. However, this project focused more on describing the co-operative learning rather than the case approach so results are inconclusive on the merits of the CBL.

Schwartz et al. (2007) compared the efficacy of HPS-based (human patient simulator) training and CBL in medical students and found no significant difference in outcomes as measured by student performance on a chest pain objective structured clinical examination (OSCE) evaluating chest pain diagnosis and therapy. This was in contrast to Howard et al. (2010) who compared interactive case studies (ICS) with HPS work in acute care syndrome: the HPS group scored significantly higher after the intervention than before but the ICS group actually scored lower afterwards compared with their preintervention scores. One reason given was fatigue but this does not really explain the results. Moreover the HPS students agreed more strongly that their intervention stimulated critical thinking and that the knowledge gained could be transferred to the clinical setting.

In contrast, McBride & Prayson (2008) compared 32 students in one year group in the step 1 national United States medical licensing examination with previous years and found above-average performance in cell biology, histology and pathology. Jamkar et al. (2006) found that students who had additional CBL compared with controls scored better on a postintervention written assessment. However, this was a short report paper with little detail on numbers of students or the evaluation. Mayo (2002, 2004) compared a standard lecture format course with standard lecture plus case (psychology). In the assessment, the CBL students did significantly better. Dupuis and Persky (2008) compared student performance in examinations after they had done one mandatory case and up to five additional voluntary cases with scores from previous years (historical controls) and found that marks for questions relating to areas of the course covered by the cases were significantly higher than the controls. However, scores for questions that covered information presented using the standard class format used in previous years were significantly lower than the historical controls.

Maleck et al. (2001) compared 10 computer-based cases with paper-based equivalents. Students were randomly allocated to one of four study groups (three intervention and one control) but for only one week's duration. Group A had computer-based cases with interactive elements, group B computer-based cases with no interactivity, group C paper-based cases and group D (control) no access to cases. Although no difference in knowledge attainment was shown, group C reported the highest level of concentration. A Chinese study (Tian et al. 2008) with unclear data interpretation, also compared four methods: pure explanation; explanation and multimedia delivery; explanation and case-based teaching; explanation, multimedia and case-based teaching. The case-based delivery improved examination scores more than multimedia alone but, perhaps not surprisingly, the last method was best.

Sheehan et al. (2000) compared two groups of medical students: one at the end of an academic year and one at the beginning of the next year and found that the CBL was not effective for emphasizing key concepts in surgery. However, there is no explanation given for why this comparison was undertaken nor of the nature of the case method used.

Sutyak et al. (1996; 1998) used CBL during surgical clinical attachments and compared structured and unstructured cases.

Students in the first and fifth rotations of third year were randomly assigned to either. In the structured cases, students analyzed a sequence of specific cases that presented preorganized data requiring analysis with only one plausible diagnosis. The unstructured cases were designed to encourage concurrent consideration of multiple diagnoses while the students elucidated the pertinent medical data. The structured cases were said to teach pattern recognition of the preorganized history, examination and laboratory data, whereas the unstructured cases were said to attempt to teach the thought pattern that recognizes pertinent history and examination findings, relate them to other subject areas (not just the 'topic for the day'), and lead to a more limited number of medical tests to formulate the proper diagnosis (Sutyak et al. 1996). Students found the unstructured cases more enjoyable. The results in terms of assessment are mixed and confusing in that the authors recommended unstructured cases as the method of preference although higher scores were obtained in the examinations from those who underwent teaching via structured cases. An exception was for clinical reasoning where the unstructured cases appeared more beneficial for nonsurgically orientated students.

Richardson and Birge (2000) compared two groups, one of which had an extra case-based hour and one which did not, with a standard physiology assessment. Scores of the CBL group were significantly higher compared with other students. CBL did not cause any difference in attitudes pre and post an interprofessional case-based intervention for groups versus controls (Lindqvist et al. 2005).

Irby's (1994) paper is a difficult one to classify. As mentioned earlier in the text, it describes three methods of case-based teaching and includes interviews with teachers who used one of the methods plus observation of a teaching session. So, there is a process evaluation plus a comparison of sorts. However, the paper is very descriptive and the definition of case-based teaching refers more to real patients as 'cases' rather than cases developed for learning purposes. Irby (1994) discusses the teaching in terms of experiential learning but does not compare in any qualitative judgmental way. The data were empirical, however, in that it is based on staff interviews and observation of process.

Significant papers involving comparison or controls

Grauer et al. (2008) described an interesting randomised study of student performance and evaluation comparing CBL/PBL and lecture-based (LB) learning with students in large groups. The authors called their approach a blended case-based/problem-based approach to overcome the time concerns associated with small-group PBL. The delivery described is certainly more CBL than traditional PBL with a short introduction to each problem being provided by the instructor, followed by case discussion. Students were given the history, physical examination findings, blood and urinalysis results and were asked to sequentially develop (1) a problem list, (2) a list of differential diagnoses for each problem, (3) a hypothesis diagnosis based on intersecting differential diagnoses and (4) a list of additional diagnostic tests or treatments to prove or disprove the hypothesis. After this stepwise discussion, the case was summarized and additional questions were posed by the instructor as necessary to ensure complete coverage of the problem as well as of the pathophysiology and other learning objectives underlying the case presentation. Performance was measured by a MCQ test immediately and four months after the intervention. There was no significant difference between scores across the two groups. A separate evaluation of student perceptions showed some differences: although fewer CB/PB students described their instruction as effective and they were worried that they missed out on information that was shared with the LB group, many reported having a better understanding of the material through this type of teaching and they also declared an increased ability to solve real-world problems because of the material they worked with. Both CB/PB and LB students faced positive and challenging experiences in their respective groups. Students were more familiar with the LB format and felt more comfortable with this method of pedagogy, classroom organization and expectations. CB/PB students were more likely to access the lecture material online than LB students, but there was no difference in the amount of time they spent studying. Students from both groups indicated that the most ideal learning environment would include both LB and CB/PB applications. There were some methodological limitations resulting in contamination across groups.

Katsikitis et al. (2002) compared PBL and CBL groups of students' learning about eating disorders by means of a process evaluation as they observed student behaviour in the groups. In terms of outcomes, there was no difference in knowledge measured via examinations between the two methods or learning. Srinivasan et al's. (2000) comparison, students preferred CBL to PBL because CBL made better use of time, led to fewer unfocused tangents and decreased outside work and 'busy' work (defined as required work without benefit). Half of the students thought CBL provided more opportunity for clinical problem solving; more than half of the faculty staff felt that CBL offered the opportunity to apply the skills learned in the CBL sessions in different practice settings, while more than half the faculty felt PBL offered more opportunities for application of problem solving skills within the session. Fewer than 5% of students and faculty felt that there were no advantages to the CBL format. There were no data reported in terms of level 2.

Rybarcyk et al. (2007) found that students in the case-based group working with specific cases around physiology (cellular respiration) did better in the final assessment than the comparison group; however, they also found that the popular misconception that some students have in this area of cellular respiration was not corrected by the addition of the case compared with the controls.

Damjanov et al. (2005) compared the scores on part 1 NBME (National Board Medical Examinations in the United States) of three different year groups: there was no difference with the overall scores but the CBL students did better with the pathology questions, which was the focus of the CBL. However, Morrow et al. (2010) compared students' NBME examination scores in the academic year 2008–2009, who had participated in CBL using web-based cases, with each of the five previous years (no web-based cases). The one-way ANOVA

analysis revealed no statistically significant differences. Students scored equally well following either web-based cases or traditional lectures.

Friedl et al. (2006) compared interactive, case-based teaching (ICBT) with multimedia modules presenting content systematically (SMM) and with print medium (PM), with SMM and PM being historical controls. The ICBT group measured at pretest was significantly less motivated and was feeling more challenged. MCQ knowledge pretest was better with ICBT, but post-test was equal. ICBT and SSM were found to be significantly better than PM for learning related to operating theatre standardized tasks and procedural understanding of the operation.

Koles et al. (2005) carried out a comparison of established case-based group discussion (CBGD) with team-based learning (TBL) using a crossover design so that all the students had experience of both methods. The aims of this study were to compare the effectiveness of TBL with CBGD as an active learning strategy and to determine if either TBL or CBGD improved learning for any subgroups of students. Prior to the introduction of TBL, pathology instruction in year 2 consisted of 81 hours of lecture time and 19 hours of CBGD distributed across all courses. The CBGD consisted of a pathologist and 15–20 students discussing a clinical case that included history and physical examination, imaging studies, laboratory test data, gross and microscopic morphology of disease, with open-ended questions embedded throughout the exercise. The TBL exercises that were introduced consisted of similar clinical case content and morphology of pathologic processes, but were organised around several MCQs, inserted at critical points in the development of the case, requiring groups of 5–6 students to make consensus judgments about the interpretation of data. A single pathologist facilitated the discussion among all eight teams of students. The outcome data to measure efficacy was the comparison of how students assigned to either strategy performed on pathology questions administered in end-of-course examinations. The results showed no difference in examination scores across the student groups. Analysis of examination performance of students in the lowest and highest academic quartiles, however, showed that students in the lowest academic quartile demonstrated less deterioration of knowledge after active learning with TBL than with CBGD as evidence by assessment results at mid-point and end of the course. There was no difference in student satisfaction with either method but students felt that TBL enhanced the contributions of their peers to the learning process. This study shows the difficulty of teasing out the effects of educational interventions across different studies as each institution defines CBL in different ways. In this study, the results relating to satisfaction could be affected by group size: the CBGD groups had three times as many students as the TBL, allowing we can presume more interaction between the students, but yet no increase in knowledge overall. However, as the authors point out, it is not surprising that students in the highest academic quartile showed no differences in knowledge retention related to the method of learning, indicating that the method of delivery is less important for high achieving students than for those who struggle.

In a study to show what might help make CBL effective, Richards and Inglehart (2006) compared CBL for dental students with and without the presence of a behavioural science instructor, hypothesizing that the students' ratings of the importance of patient-centred and culturally relevant information would increase when they were drawing up a problem list as well as planning a treatment with the instructor present. This hypothesis was indeed supported by the results. The students who were taught in what was described as an interdisciplinary fashion (i.e., with behavioural science instructor) wrote more comments about patient-centred and culturally sensitive issues than the students who were taught without the presence of a behavioural science instructor in the classroom. This is of interest as it indicates that structured rather than guided or open inquiry achieves better learning in this context.

Kopp et al. (2008) looked at the effects of computer-based cases involving errors on diagnostic reasoning by randomizing students into four groups. Each case featured a fictional student exploring the case with a fictional GP supervisor who gives feedback: group 1 – student correctly diagnoses; group 2 – student makes errors in diagnosis corrected by GP; group 3 GP – tutor gives elaborated feedback on correct/incorrect decisions and group 4 – minimal feedback given. In the postintervention knowledge test, greater improvement in diagnostic reasoning was demonstrated by the groups where errors were made and corrected by elaborated feedback. The group where errors were made but minimal feedback was given scored the worst on the posttest.

Longer term evaluation

Although a number of papers had student feedback and results from more than one year of CBL, only one included a longer term follow-up of the same student cohort. Dayal et al. (2008) showed that knowledge gained about nutrition and history taking continued from the intervention in year 3 to year 4 but as there was no comparison group it is difficult to conclude that this retention was due to the case-based method or would not have been similar with other learning activities.

In what ways is CBL effective? How does CBL promote learning?

We will consider these two questions together: first from the perspective of the evidence in the papers and then in the discussion, reflecting on this evidence to draw conclusions.

Authors used the following adjectives to describe the nature of the students' learning generated by the selected methods: self-directed (Bair 1980), cooperative (Baumberger-Henry 2005), interactive (Hong et al. 1998; Blewett 2009), active (Chan 2008; Dupuis & Persky 2008), experiential (Chew et al. 2005) and team (Blewett and Kisamore 2009). CBL was said to make use of limited educational time (Bair 1980) and not to require direct involvement by content experts (Drakeford et al. 2007). Moreover, cases could be chosen to expand knowledge of a condition or to discuss cases not exposed to in clinical

settings (Morrow et al. 2010). Overall, the importance of active and interactive learning was stressed as contributing to efficacy, while CBL was considered a vehicle for the transfer of learning from theory into clinical application.

Educators advocated for CBL as it provided opportunity for reflection, an important part of the process (Irby 1994; DeMarco et al. 2002) and allowed students to apply knowledge from literature to patients (Garvey et al. 2000; Richards & Inglehart 2006). It also required creativity, a reduced focus on traditional lecture presentations and a dedication to encouraging students to use reasoning and decision-making skills (Garvey et al. 2000). Hofsten et al. (2010) declared the problem-solving process and free discussion with no obvious correct or incorrect answers to be important.

A good summary for this question is that: 'the [learning] group focuses on creative problem solving with some advance preparation, discovery is encouraged in a format in which both students and facilitators share responsibility for coming to closure on cardinal learning points (i.e., on the continuum between structured and guided). Learners are presented with a clinical problem and have time to struggle, define and resolve the problem. However, when learners begin to explore tangents, the facilitators use guiding questions to bring them back to the main learning objective. Students may ask questions of local experts during the session' (Srinivasan et al. 2007, p. 74).

Summary of answers to research questions

(1) How is CBL defined?

CBL is learning and teaching approach that aims to prepare students for clinical practice, through the use of authentic clinical cases. These cases link theory to practice, through the application of knowledge to the cases, and encourage the use of inquiry-based learning methods.

(2) What methods of CBL are used and advocated?

Typically, CBL takes place in small face-to-face groups but may also take place online and, less commonly by individuals and in large groups.

(3) What are students' and educators' views on CBL?

Both students and educators are very positive about CBL.

(4) Is CBL effective in health professional education?

Yes – but there is patchy and inconclusive evidence that it is more effective than other methods.

(5) In what ways is CBL effective?
(6) How does CBL promote learning?

CBL promotes learning through the application of knowledge to clinical cases by students, enhancing the relevance of their learning and promoting their understanding of concepts. Students prefer an inquiry-based approach on the continuum between structured and guided learning rather than open (Figure 1).

Limitations of the papers

Overall, there were a lot of gaps in the primary studies eligible for review relating to student numbers, outcomes, hard evidence (empirical data rather than description), longer term evaluation and sustained delivery. Conclusions were often drawn without adequate findings to back these up. There was very little detail about the nature of the cases and how they were developed. Some of these limitations may be due to word count restrictions. Often it was difficult to ascertain what differences authors perceived between CBL and PBL when comparing these methods; there was often an assumption that readers would know what PBL entailed.

Discussion and conclusions

A good description of the goal of a CBL approach is:

> 'The advantages of the case-based method are the promotion of self-directed learning, clinical reasoning, clinical problem-solving, and decision making by providing repeated experiences in class with a collegial infrastructure and by focusing the student on the complexity of clinical care' (Richards & Inglehart 2006, p. 284).

How well CBL actually does promote these outcomes is not clear. However, the evidence we have summarised in the results does show that CBL encourages students to integrate their learning in the context of authentic clinical scenarios involving individual or groups of patients (Bair 1980). However, these benefits come with the cost of changing traditional roles and responsibilities of student and teacher to make the most of CBL (Sutyak et al. 1996).

How do students learn via CBL?

The learning theories applied to CBL derive mainly from adult-learning and inquiry-based learning approaches. Thus, CBL promotes a deep learning approach (Hofsten et al. 2007), with active (Stewart & Gonzalez 2006; Chan et al. 2008) and meaningful (Hakkarainen et al. 2007) learning. By emphasizing the active and interactive components of the learning process, CBL blends aspects of the cognitive and social constructivist models of teaching and learning (Mayo 2004). It enables students to see the direct relevance (Koh et al. 1995) and logical direction (Krockenberger et al. 2007)of the information to be learnt for their goal of clinical practice, so that they are more highly motivated and are more likely to remember such information (Hong et al. 1998). CBL facilitates the development of reflective thinking and deeper conceptual understanding (Schwartz et al 1994).

What is the evidence that CBL allows students to learn in a more effective way than via other more traditional methods? The short answer is there is little good and reliable evidence. Those studies that have compared the effect of CBL with other methods on knowledge and behaviour of learners have generally shown no significant difference between approaches. Even when a difference has been shown, there are often methodological problems with the study, casting

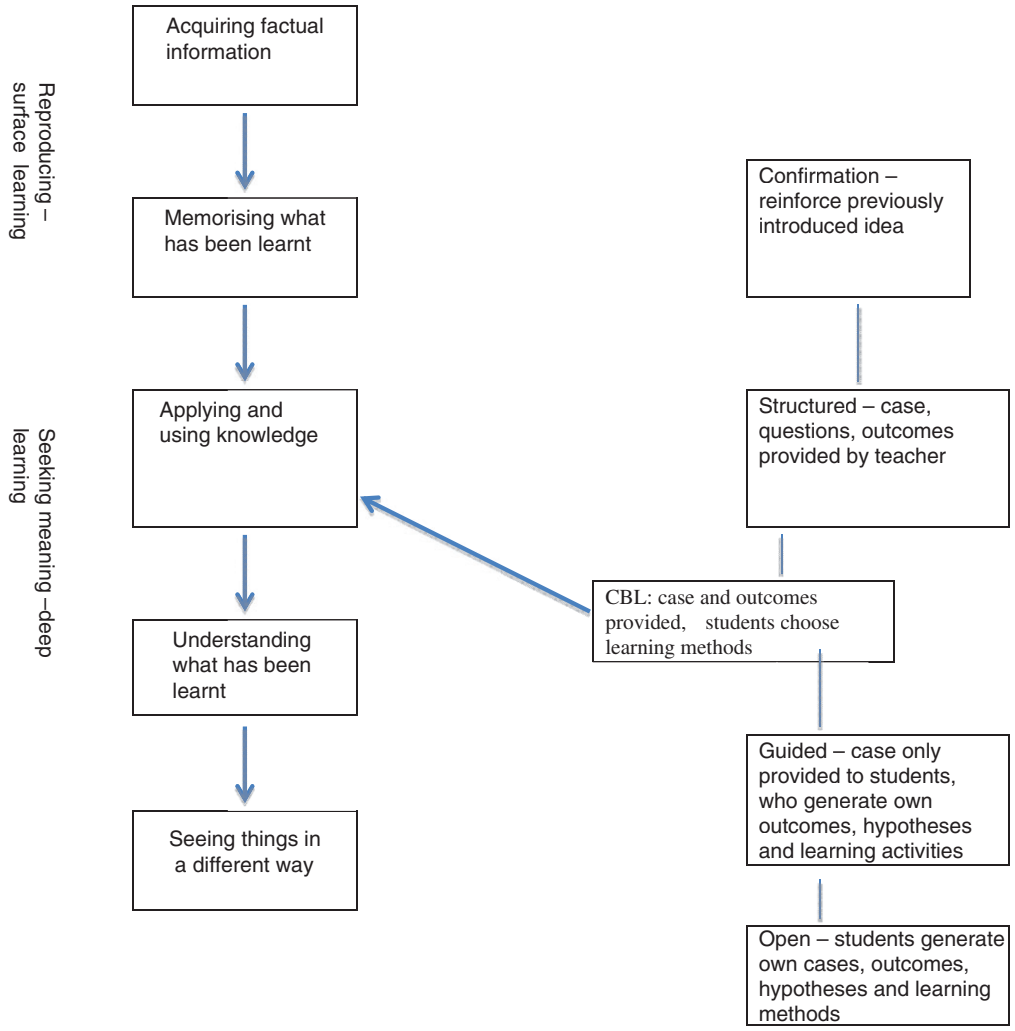

Figure 1. Student learning in CBL on an inquiry-based continuum (adapted from Entwistle 2009 and Banchi & Bell 2008).

some doubt on the reliability of findings. This is a consistent problem in medical education research, where lack of methodological rigour, poorly controlled confounders, incomplete reporting of variables and imprecisely defined outcomes make comparison between studies very difficult or impossible.

More reliable, however, are the studies that have shown that students enjoy CBL and are better able to connect theory to clinical practice (Hansen 2005) as well as improvements in the engagement of students, with CBL fostering more active and collaborative learners (e.g., Hakkarainen et al. 2007).

These factors are clearly important, but what are the advantages of CBL in comparison with other learning methods? Some of the evidence we have gathered includes that CBL can be:

> '. . .used in the classroom to expose nursing students to a variety of clinical situations where decisions can be creatively controlled and designed without causing potential harm to the patient' (Baumberger-Henry 2005, p. 239).

Moreover, the development of cross-disciplinary cases minimises duplication in teaching materials (Chan et al. 2008), and enhances communication between and engagement of faculty members in various disciplines (Chan et al. 2008).

When compared with PBL

'(CBL) helps focus the learners on the key points of a clinical case and encourages a structured approach to clinical problem-solving while allowing facilitators to correct any incorrect assumptions of the learner, which does not always happen in PBL' (Dupuis & Persky 2008, p. 1) and there is more advanced preparation required for CBL (Srinivasan et al. 2007).

CBL methods were also thought to require less time and be more efficient in disseminating large amounts of material within relatively short time frames than PBL (Grauer et al. 2008).

Taken together, these findings allow us to draw some conclusions about CBL:

- Students enjoy CBL and think that it helps them learn better. Whether this is reflected in assessment results is far from clear; however, enjoyment can lead to increased

engagement and motivation for learning, which in itself is a desirable and positive effect.
- Teachers enjoy CBL. As well as potentially making better use of teaching time available, more engaged and motivated students make for a more enjoyable teaching experience.
- CBL provides an opportunity to introduce interprofessional learning.
- CBL appears to foster effective learning in small groups, possibly through the effect of having more engaged learners, but perhaps also through having more structured learning activities closely linked to authentic clinical practice scenarios.
- Online CBL can work well providing attention is paid to the online learning environment.

Limitations of the review

Knowing from our experience of the health education literature and our reading of published BEME reviews that there is often a paucity of rigorous empirical data relating to effectiveness of educational interventions, we decided to have wide inclusion criteria and not limit this review to medical education. This resulted in a diverse range of papers focusing on CBL, giving richer data but making synthesis of findings more difficult. Our grading of papers in relation to their 'quality' and significance was to some extent subjective, though we had good agreement and included only those papers in the final 23 on which two of the TRG agreed. As noted in previous BEME reviews, there is always a possibility of publication bias affecting pooling of data but we did find that most of the papers including comparison data did not show any positive affects of CBL over other methods.

The variation in the naming and definition of CBL, particularly in comparison to PBL, is likely to have led to our missing relevant papers and highlights the need for consensus on terminology in this area.

Recommendations for further research

We have provided a definitions of CBL based on an analysis of definition in the literature and a theoretical framework for its effectiveness in terms of inquiry-based learning. Further exploration into the effectiveness and impact of CBL requires agreement on the definition, and methodologies that allow a better qualitative understanding of how students learn from cases rather than focusing on whether CBL is better than other educational interventions. Example lines of inquiry could be: how much structure is required? Does this vary as students mature? Are there are differences in the ways in which cases are prepared and presented? How authentic do cases need to be? How well do cases prepare students for clinical experience? How do they facilitate the translation of theory and knowledge into practice? Do cases extend or limit students' clinical reasoning by suggesting a single diagnosis per presentation?

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Appendix 1: Search Syntax

Medline and EMBASE search syntax:

(1) Case-based.ti. (919)
(2) case stud*.ti. (38110)
(3) case method*.ti. (149)
(4) 1 or 2 or 3 (39176)
(5) (learning or teaching or instruction*).ab,ti. (436868)
(6) 4 and 5 (1978)
(7) collaborative learning.ab,ti. (440)
(8) self directed learning.ab,ti. (1715)
(9) active learning.ab,ti. (1208)
(10) 7 or 8 or 9 (3321)
(11) case-based.ab. (2876)
(12) 10 and 11 (71)
(13) (case study or case studies).ab. (51063)
(14) 10 and 13 (101)
(15) case method*.ab. (738)
(16) 10 and 15 (4)
(17) 12 or 14 or 16 (174)
(18) 6 or 17 (2103)
(19) limit 18 to (english language and humans and yr = '1965 to Current') (1539)
(20) exp Education, Medical/(311305)
(21) 19 and 20 (359)
(22) remove duplicates from 21 **(244)**

For ASSIA the search syntax was:

Query: ((((TI = (Case-based)) or(TI = (Case stud*)) or(TI = (Case method*)))

and((TI = (learning or teaching or instruction*)) or(AB = (learning or

teaching or instruction*)))) or((TI = ((Collaborative learning) or (self

directed learning) or (active learning)) or AB = ((Collaborative learning)

or (self directed learning) or (active learning))) and(AB = ((case-based)

or (case stud*) or (case method*))))) and((DE = 'medical education')

or(TI = (Law or legal) and TI = education) or(AB = (Law or legal) and

AB = education) or(TI = business and AB = education) or(TI = business and

TI = education) or(AB = business and AB = education)) **(13)**

(NB Queries entered as separate lines but exported as above.)

For CINAHL the search was carried out via NHS Evidence Databases, as the university system was too slow:

CINAHL 1981- to 121010

No.	Database	Search term	Hits
1	CINAHL	((case-based)).ti [Limit to: (Age Groups All Adult) and (Language English)]	460
2	CINAHL	((case stud*)).ti [Limit to: (Age Groups All Adult) and (Language English)]	5229
3	CINAHL	((case method*)).ti [Limit to: (Age Groups All Adult) and (Language English)]	68
4	CINAHL	1 OR 2 OR 3 [Limit to: (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English)]	5473
5	CINAHL	((Learning OR teaching OR instruction*)).ti,ab	61,223
6	CINAHL	4 AND 5 [Limit to: (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English)]	169
7	CINAHL	((Collaborative learning)).ti,ab	896
8	CINAHL	((self directed learning)).ti,ab	742
9	CINAHL	((active learning)).ti,ab	1011
10	CINAHL	7 OR 8 OR 9	2558
11	CINAHL	((case-based)).ab	10618
12	CINAHL	10 AND 11	99
13	CINAHL	(((case study) OR (case studies))).ab	31453
14	CINAHL	10 AND 13	163
15	CINAHL	((case method*)).ab	18006
16	CINAHL	10 AND 15	100
17	CINAHL	12 OR 14 OR 16	209
18	CINAHL	6 OR 17 [Limit to: (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English)]	206
19	CINAHL	exp EDUCATION, HEALTH SCIENCES/	139577
20	CINAHL	18 AND 19 [Limit to: (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English) and (Age Groups All Adult) and (Language English)]	**53**

For Education Research:
Search ID#
Search Terms Search Options
S23 S18 and S22 = **115 hits**
Search modes – Boolean/Phrase
S22 S19 or S20 or S21
Search modes – Boolean/Phrase
S21 TX nurs*
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S20 TX medical student*
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S19 TX medicine OR doctor*
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S18 S8 AND S17
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S17 S12 and S16
Search modes – Boolean/Phrase
S16 S13 or S14 or S15
Search modes – Boolean/Phrase
S15 AB case method*
Search modes – Boolean/Phrase
S14 AB case stud*
Search modes – Boolean/Phrase
S13 AB case-based
Search modes – Boolean/Phrase
S12 S9 or S10 or S11
Search modes – Boolean/Phrase
S11 TX active learning
Search modes – Boolean/Phrase
S10 TX self directed learning
Search modes – Boolean/Phrase
S9 TX collaborative learning
Search modes – Boolean/Phrase
S8 S4 and S7
Search modes – Boolean/Phrase
S7 S5 or S6
Search modes – Boolean/Phrase
S6 AB (learning OR teaching OR instruction*) Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S5 TI (learning OR teaching OR instruction*) Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S4 S1 or S2 or S3
Search modes – Boolean/Phrase
S3 TI case method*
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S2 TI case stud*
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase
S1 TI case-based
Limiters – Published Date from: 19650101-20101031; Language: English
Search modes – Boolean/Phrase

Web of Knowledge including:
Science Citation Index Expanded (SCI-EXPANDED) – 1970 to present
Social Sciences Citation Index (SSCI) – 1898 to present
Arts & Humanities Citation Index (A&HCI) – 1975 to present
Conference Proceedings Citation Index- Science (CPCI-S) – 1990 to present
No time/language limits.
13 **512**
#12 OR #6
Timespan = All Years
# 12 57
#11 AND #10
Timespan = All Years
# 11 > 100,000
Title = (case)
Timespan = All Years
# 10 2,418
#9 OR #8 OR #7
Timespan = All Years
# 9 979
Title = (active ADJ learning)
Timespan = All Years
# 8 360
Title = (self ADJ directed ADJ learning)
Timespan = All Years
# 7 1,080
Title = (collaborative ADJ learning)
Timespan = All Years
# 6 458
#5 AND #4
Timespan = All Years
# 5 > 100,000
Title = (learning OR teaching OR instruction)
Timespan = All Years
# 4 3,418
#3 OR #2 OR #1
Timespan = All Years
# 3 325
Title = (case ADJ method*)
Timespan = All Years
# 2 179
Title = (case ADJ stud*)
Timespan = All Years
# 1 2,916
Title = (case ADJ-based)
Timespan = All Years

NB. There were **512 results** but only **374 references** as results appeared in more than one subject field.

Appendix 2: Flow diagram of literature search and paper selection

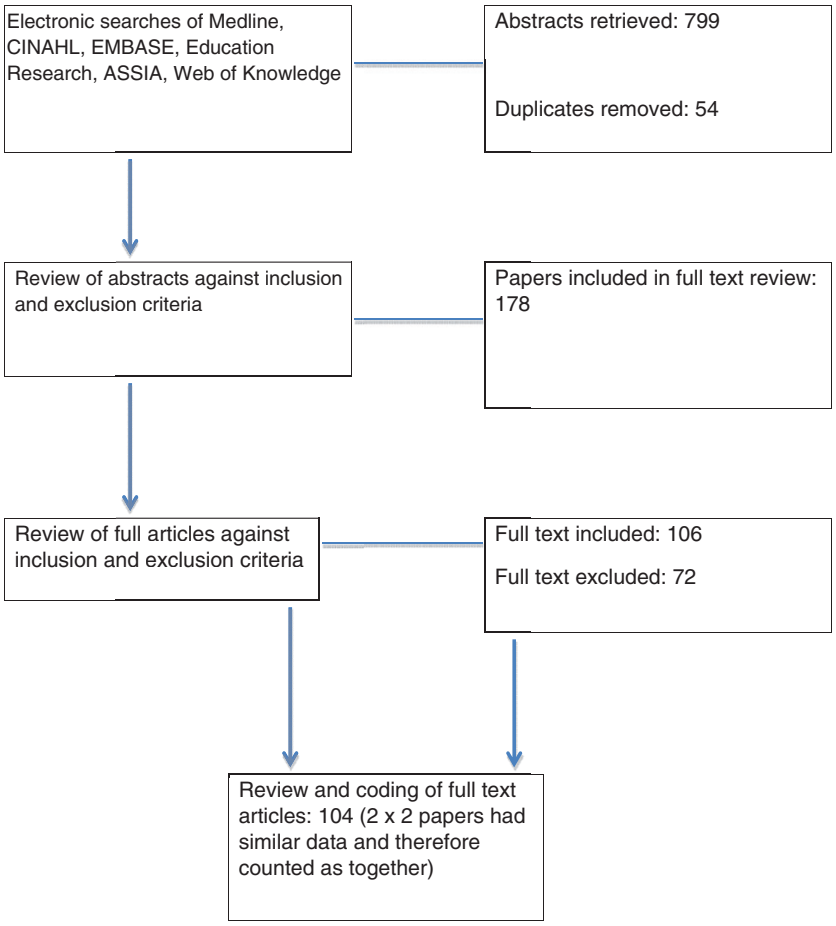

Figure 2. Flow diagram of literature search and paper selection.

Appendix 3: Included Papers

Authors	Year	Journal	Location	Students	No	CBL type	Topic	Group size	LO's	Design	Groups	Outcomes	Level 1	Level 2a	Level 2b	Qualitysignif
Anderson & Helberg	2009	S Dakota J	N Am	Medical	45	2 × 1.5 hours	SOAP notes	3–4	Y	Pre/post	S	Valuable	x	x		
Bair	1980	J Community Health	N Am	Medical	159	1/12 + 4 meetings	Comm med	4–10	Y	Post	S	Fostered confidence			x	
Baumberger-Henry	2005	Nurs Educ Today	N Am	Nurse		1 case	Nursing	3–4		Pre/post	M	No difference		x		
Beech & Domer	2002	J Cancer Educ	N Am	Medical	28	90 mins case	Physiol	8–10		Pre/post	S	Inc knowledge			x	
Bernheimer et al.	1982	J Med Educ	N Am	Medical		20 problems	Fam med			Post	S	Enjoyed	x			
Bezuidenhout et al.	2006	J Clin Pathol	Africa	Medical	142	1 week	Clin path	5	Y	Post	S	Enjoyed	x			
Blewett & Kisamore	2009	BMC Med Educ	N Am	Medical/osteopath	390	2 hours	Microbiol	8	Y	Pre/post	S	Better interactive	x		x	
Boeker et al.		AMIA Annu Symp Proc	Eur	Medical	31	Computer-based	Neuro-oncology			Post	S	No difference	x		x	
Bowe et al.	2009	Med Teach	N Am	Medical	135	1 case	Organ systems		Y	Post	S	Interaction contributed	x			
Braeckman et al.	2009	J Occup Environ Med	Eur	Medical	338		Occ health		Y	Post	S	As good as workplace visits	x		x	
Canham et al.	2008	Med Teach	Eur	Medical	242	2-hour workshop	Pathophysiol	120		Post	MY	Satisfied, stimulating	x			
Carrero et al.	2009	Med Teach	Eur	Medical	68	1-hour workshop	BLS	34		Pre/post	M	No difference			x	
Chan et al.	2008	Ann Acad Med Singapore	Asia	Medical	137	5 months	Cross curric			Post	MY	Aids integration	x			
Chew et al.	2005	Acad Radiol	N Am	Medical	141	5 cases in 1/52	Radiology	3–4	Y	Post	S	Worthwhile	x			*
Choi et al.	2009	Br J Educ Technol	Asia	Dental	70	9 modules	Anaesth	1 (e)		Inter/post	S	Not affected by learning styles	x		x	
Cliff	2006	Adv Physiol Educ	N Am	Nurse	42	1 case	Resp physiol	3–5	Y	Pre/post	S	Reduced misconceptions			x	*
Critchley et al.	2009	Anaesth Intensive Care	Asia	Medical	149	6 cases	Anaesth	8–10	Y	Post	S	Well received	x			
Curran et al.	2008	Med Teach	N Am	N/P/SW		6 modules	IPL care plans			Post	S	Satisfied	x			
Damjanov et al.	2005	Croat Med J	N Am	Medical	846	2nd yr pathology	Pathology	20		Post	M	Change in pathology score	x		x	*
Dayal et al.	2008	J Nutr Educ Behav	N Am	Medical	268	2 hour workshop	Ob/Gyn	25	Y	Pre/post	S	Self report increased knowledge	x			
DeMarco et al.	2002	J Nurs Educ	N Am	Nurse	7	10 × 1 hours	Nursing	1		Post	S	Motivated, gained confidence	x			
DeSanto-Madeya	2007	Nurs Sci Q	N Am	Nurse		Weekly case	Med/surg			Post	S	Benefited	x			
Dietrich et al.	2010	J Padiat Adolesc Gynecol	N Am	Medical	6	20 cases	Paed adol gynae	1 (e)		Pre/post	S	Improved test score			x	
Drakeford et al.	2007	J Paediatr Child Health	Aust	Medical	40	2 × 1.5 hrs	Asthma		Y	Pre/post	S	Enhances skills	x		x	
Dupuis	2008	Am J Pharm Educ	N Am	Pharmacy	252	1 semester	Clin pharm	4–5		Post	MH	Increased knowledge	x		x	
Engel & Hendricson	1994	J Dent Educ	N Am	Dental	93	6 × 1 hr	Orthodontics	10–11	Y	Post	S	Positive	x		x	
Ferguson	2006	Med Educ	N Am	Medical		3 cases	Clin practice			Post	S	Assessed by essay	x			
Friedl et al.	2006	Ann Thorac Surg	Eur	Medical	69	1 module	Cardiac surgery	1	Y	Pre/post	M	Variable			x	*
Garvey et al.	2000	Eur J Dent Educ	UK	Dental	76	3 hours weekly	Dentistry	7–8	Y	Post	S	Positive	x			
Gemmell	2007	Clin Chiropr	UK	Chiro	100		Major pain			Post	M	No difference			x	
Grauer et al.	2008	J Vet Med Educ	N Am	Vet	110	14 hours	Small animal urology	Large		Post	S	No difference in exams	x		x	*
Hakkarainen et al.	2007	Australas J Educ Technol	Eur	Soc	33	videos	Networks	3–5 online		Post	S	Variable	x			*
Hansen & Krackov	1994	Clin Anat	N Am	Medical	295	12 × 1.5 hrs	Anatomy	12–13	Y	Post	MY	Positive	x			
Hansen et al.	2005	Am J Obstet Gynecol	N Am	Medical	183		Obs gynae	3–5		Post	S	Enjoyed more, links theory	x			*
Hege et al.	2007	Med Teach	Eur	Medical/law		Online	Internal med			Post	M	Students accepted	x			
Henning et al.	2006	Nurse Educ	N Am	Nurse	13	6 × 2 hrs	Complex needs	3		Inter/post	M	Used discourse analysis				
Hilgenberg & Schlickau	2002	J Transcult Nurs	N Am	Nurse		online	Cultural comp	2	Y	Post	S	Learn from content	x			
Hoag et al.	2005	Clin Lab Sci	N Am	Med	123	9 × 50 minutes	Clin immunol			Post	S	No change in critical thinking	x		x	*
Hofsten et al.	2010	Nurse Educ Today	Eur	Nurse	69	5 weeks	Disease			Post	S	Learnt through discussion				*
Hong et al.	1998	Med Teach	Asia	Pharm	55	4 cases	Pharm			Post	S	Positive	x			
Horsch et al.	1999	Med Inf Eur	Eur	Medical	32	2 × 4 hrs	Med imaging			Post	S	Liked	x			
Horsch et al.	2000	Int J Med Inform	Eur	Medical	75	Online	Radiology			Post	S	Mixed	x			
Howard et al.	2010	Comput Inform Nurs	N Am	Nurse	49	2 hours	Acute coronary syn			Pre/post	M	HPS better	x		x	
Hudson & Buckley	2004	Adv Physiol Educ	Aust	Medical	254	Whole year	Physiol	Large	Y	Post	MY	Valued as non-threatening	x			

Irby	1994	Acad Med	N Am	Medical	6	3 teaching rounds	Internal med	2 + 2 interns		Post	M	Interactivity good	x			
Jamkar et al.	2006	Med Educ	Asia	Medical		8 sessions	Surgery	8–10		Post	M	Scored better		x	x	
Katsikitis et al.	2002	Educ Psychol	Aust	Medical	64	1.5 hrs	Psych	3–4 10–12		Post	M	No difference with PBL			x	*
Kaufert et al.	2010	Med Health Care Philos	N Am	Medical			Ethics			Post	S	Adds important perspective	x	x		
Koh et al.	1995	Occ Med	Asia	Medical	105	2 hrs	Occup med	20	Y	Post	S	Enjoyed	x			
Kolb et al.	2007	Int Arch Occup Environ Health	Eur	Medical	212		Occup med			Post	M	Variable	x			
Koles et al.	2005	Med Educ	N Am	Medical	80	19 hrs	Pathology	15–20 5–6		Inter/post	M	No difference CBL and TBL	x		x	*
Kopp et al.	2008	Med Educ	Eur	Medical	153	1 session	Clin reasoning			Pre/post	M	Working through errors helps			x	*
Krockenberger et al.	2007	J Vet Med Educ	Aust	Vet		online	Pathology			Post	MY	Satisfied	x			*
Kumagai et al.	2010	Med Educ	N Am	Medical	170	1 online case	Multicultural	1?		Post	S	Helpful	x			
Lechner et al.	2001	Br Dent J	Aust	Dental	32	1 session CDROM	Orthodontics		Y	Post	S	Positive	x			
Leonard et al.	2002	Teach Psychol	N Am	Psychol			Intro psychol		Y	Post	S	Helpful	x			
Lindqvist et al.	2005	J Interprof Care	UK	Mixed	46	× 1/wk for 7 wks	Interprof learning	5	Y	Pre/post	M	Feasible, change in attitude	x	x		
Loving & Siow	2005	J Nurs Educ	N Am	Nurse			Pharmacol		Y	Post	S	Helpful	x			
Lyon et al.	1991	J Med Syst	N Am	Medical	328	Online	Haem/cardiology			Pre/post	M	No difference	x		x	*
Maleck et al.	2001	Radiographics	Eur	Medical	225	Online	Radiology			Post	M	No difference			x	*
Massonetto et al.	2004	BMC Med Educ	S Am	Medical	113	120 hours	Obs/gynae	10		Post	S	Positive	x			
Mayo	2002	J Constr Psychol	N Am	Psychol	136	2/52 course	Intro psychol	5–7		Post	M	Positive, better results	x		x	
Mayo	2004	J Constr Psychol	N Am	Psychol	122	Case series	Psychol adjust	1?		Post	M	Positive, better results	x		x	*
McBride & Prayson	2008	Anat Sci Educ	N Am	Medical	32	33 hrs	Histol/microanat	4–32	Y	Post	MH	Above average USMLE	x		x	
Morrow et al.	2010	Fam Med	N Am	Medical	210	3 cases over 4/52	Fam med	1		Post	M	No change in knowledge	x		x	*
Novak	1971	J Med Educ	N Am	Medical			Pathology	Whole class		Post	S	Well accepted	x			
Owen et al.	2007	Med Educ	Aust	Medical		Last 2 yrs	Clinical			Post	S	Appreciated	x			
Patterson	2006	J Vet Med Educ	N Am	Vet	365	15 wks of 2 × 2 hrs	Vet sci reasoning	8–9	Y	Pre/post	MY	Increased confidence & reasoning	x		x	
Peplow	1990	Med Educ	Aust	Medical	159	3 × 1 hr	Anatomy	10		Post	S	Satisfied	x			
Peplow	1992	Med Educ	Aust	Medical		3 × 1 hr	Anatomy	10		Post	S	Superficial satisfaction	x			
Peplow	1996	Med Teach	Aust	Medical	391	5 cases 2 sessions	Anatomy			Post	M	Satisfied, no difference in marks	x		x	
Peplow	1998	Med Teach	Aust	Medical	162		Anatomy	11		Post	S	Gender difference in marks	x			
Quattrochi et al.	2002	J Sci Educ Technol	N Am	Medical	12?	Online 8 cases	Neurosci			Post	S	Liked	x			
Rabe & Cadrona-Carlos	2007	Med Educ	Asia	Medical	165	3 voluntary	Paeds			Post	S	Helps	x			
Radon et al.	2006	Ann Agric Environ Med	Eur	Medical	337	2 online	Occup med	1		Post	S	Enjoyed	x			
Reimer et al.	2006	Rheumatol Int	Eur	Medical	92	3 online courses	Rheumatol	1 (e)	Y	Pre/post	S	Exceeded expectations	x			
Richards & Inglehart	2006	J Dent Educ	N Am	Dental	204	12 × 50 mins	Care management	5		Pre/post	M	Showed increased importance or psychosocial and cultural issues		x		*
Richardson & Birge	2000	Adv Physiol Educ	N Am	Mixed	36	1 hr/week	Physiol	Up to 11		Post	M	Satisfied, increased marks	x		x	
Rodríguez-Barbero & López-Novoa	2008	Adv Physiol Educ	Eur	Medical	150/yr	25% of practicals	Circ physiol	1		Post	S	Variable	x			
Rybarczyk et al.	2007	Biochem Mol Biol Educ	N Am	Pre-med	157	1 case	Cellular resp			Pre/post	M	Enhanced learning & collaboration	x		x	*
Schoeman et al.	2009	J S Afr Vet Assoc	Africa	Vet	130	4 cases in yr 4	Intro clin sci	7	Y	Post	S	Increased problem solving	x			
Schwartz et al.	1994	Acad Med	N Am	Medical						Post	S	Rated well	x			
Schwart et al.	2007	Acad Emerg Med	Aust	Medical	102	Month long clerkship	Chest pain	52 + 50	Y	Post	M	No difference in simulation and CBL			x	*
Scott	1994	Med Educ	N Am	Medical		22 cases in 8 hrs	Anatomy	2–8	Y	Post	S	Broadly positive, anatomy relevant	x			
Sheehan et al.	2000	Am Surg	N Am	Medical	63	23 cases in 12 wks	Surgery	30		Post	MY	Does not help with concepts			x	
Simonsohn & Fischer	2004	Deutch Med Wochenschr	Eur	Medical	380	Online	Int med	1		Post	S	Increased motivation & satisfaction	x			*
Smith Jr & Christie	2004	J Am Diet Assoc	N Am	Physio/nutr	28	1 case?	Nutrition	? 1 + 1	Y	Post	S	Enhanced teamwork & communication	x			
Srinivasan et al.	2007	Acad Med	N Am	Medical	286	12–15 sessions				Post	M	Preferred CBL to PBL	x		x	*

(continued)

Table 9. Continued.

Authors	Year	Journal	Location	Students	No	CBL type	Topic	Group size	LO's	Design	Groups	Outcomes	Level 1	Level 2a	Level 2b	Qualitysignif
Steinberg et al.	2002	Acta Cytol	N Am	Medical		10 × 15/20 mins	Cytopathology			Post	S	Enjoyed practical application	x			
Stewart & Gonzalez	2006	Commun Disord Q	N Am	Speech path	29	10 cases studies	Profess issues	2–3 + large	Y	Post	S	Learned analysis & synthesis	x			
Stjernquist & Crang-Svalenius	2007	Med Teach	Eur	Medical	254	Whole curric	Clinical			Post	S	High satisfaction of PBL	x			
Street et al.	2007	Med Educ	UK	Med/nurse	94/66	2 weeks	Child disability, IPL	2	Y	Pre/post	M	Enhanced learning	x	x		
Struck & Teasdale	2008	Gerontol Geriatr Educ	N Am	Medical	167	4/52 geriatrics	Geriatrics	8–12	Y	Post	MY	Effective to cover concepts	x			
Sutphen et al.	2003	Am J Prev Med	N Am	Medical	144	5 cases	Prevent med			Post	S	Liked, helped with preventative medicine	x		x	
Sutyak et al.	1996	Am J Surg	N Am	Medical	36	1 session	Surgery	15 + 21		Pre/post	M	Unstructured more enjoyable than structured	x		x	
Sutyak et al.	1998	Am J Surg	N Am	Medical	42	4 cases	Surgery			Pre/post	M	Effective with knowledge, mixed results	x		x	
Tarnvik	2002	Med Teach	Eur	Medical	> 1000	2 hrs	Infect dis			Post	MY	Highly valued	x			
Thurman et al.	2009	J Vet Med Educ	Aust	Vet	105	7 wks	Physiol	6	Y	Pre/post	S	More positive to group work	x	x		*
Tian et al.	2008	Int Cong	Asia	Medical	122	3–5 cases	ENT	15		Post	M	Better with CBL and multimedia			x	
Trevena & Clarke	2002	Am J Prev Med	Aust	Medical	130	8 wks	Population health	2	Y	Post	S	Traditional case presentation useful	x			
Waydhas et al.	2004	Med Teach	Eur	Medical	136	6 × 45 mins	Surgical exam	6–9	Y	Post	M	Helped students prepare	x			
Williams	2006	J Emerg Prim Health Care	Aust	Para-med	69	Weekly online	Clin pract			Post	MY	Enjoyable	x			
Williams	2009	Australas J Educ Technol	Aust	Para-med	247	E-tutorial 8 cases	Clinical	10–25		Post	S	Improved and enjoyed	x			
Wilson et al.	2006	Rheumatology	UK	Medical	31	Online	Rheumatol	1 (e)		Post	S	Liked, some knowledge gained	x		x	
Chan et al.	2008	Ann Acad Med Singapore	Asia	Medical						Post	S	Helps learning	x			
Zebrack et al.	2004	J Gen Intern Med	N Am	Medical	115	1 month	Women's health	8–10	Y	Pre/post	S	Mainly about web-based evaluation	x		x	

Note authors in bold: Though both Horsch et al. (1999) and Horsch et al. (2000); and Peplow et al. (1990) and Peplow et al. (1992) are included as four separate papers, in the analysis there are counted as two papers only because of duplicate data.