

Problem-Based Learning and Medical Education Forty Years On

A Review of Its Effects on Knowledge and Clinical Performance

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Key Words

Problem-based learning · Medical education · Self-directed learning · Memory and cognitive architecture · Guided learning · Outcome assessment · Clinical competency

Abstract

Problem-based learning (PBL) has swept the world of medical education since its introduction 40 years ago, leaving a trail of unanswered or partially answered questions about its benefits. The literature is replete with systematic reviews and meta-analyses, all of which have identified some common themes; however, heterogeneity in the definition of a 'problem-based learning curriculum' and its delivery, coupled with different outcome measurements, has produced divergent opinions. Proponents and detractors continue to dispute the merits of the cognitive foundation of a PBL approach, but, despite this, there is evidence that graduates of PBL curricula demonstrate equivalent or superior professional competencies compared with graduates of more traditional curricula.

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A Brief History of Problem-Based Learning in Medical Education

McMaster University pioneered the first problem-based learning (PBL) curriculum in 1969, and within 20 years over 60 medical schools around the world have

adopted the method in whole or in part. This revolution in medical education has had a huge impact on the development of the medical school curriculum, and yet when it was introduced there was no philosophical or cognitive theoretical underpinning explicitly stated by the founders of the McMaster Medical School. Indeed, Howard Barrows [1], who developed the PBL experience at McMaster, had no background in educational psychology or cognitive science, and the rationale that he and his colleagues proposed for the McMaster curriculum, which included learning in small groups for the study of clinical problems, was that it would make medical education more interesting and relevant for their students. Even more remarkable was the widespread adoption of this educational theory and its endorsement by the Association of Medical Colleges and the World Federation of Medical Education without any real evidence at the time that the PBL-trained learner would become a better doctor [2, 3].

Over the ensuing 40 years, there has been a large number of publications related to the use of PBL, and several systematic and nonsystematic reviews of PBL curriculum outcomes appeared between 1993 and 2008 [4–10]. It is very challenging to review the effects of PBL using an outcomes approach because medical educators have historically adopted varying definitions of what constitutes a PBL curriculum, and not all have adopted the criteria for a PBL curriculum advocated by Barrows [1]. The medical education literature is replete with studies showing minimal effect sizes in one direction or another, or no

significant differences when attempting to sum the evidence for medical schools that have adopted different interpretations of the PBL approach [4–6].

Most reviews have concentrated on knowledge acquisition as the primary outcome of interest, but the comparative clinical competency of graduates of a PBL environment is certainly a relevant outcome to consider [10].

Vernon and Blake [4] noted in their review that the practice of PBL was defined in a number of different ways, which appeared to be a complex mixture of general teaching philosophy, learning objectives and goals, and faculty attitudes and values. In this sense, PBL had come to be seen as a general educational strategy rather than simply an approach to teaching [3]. Perhaps one of the most important differences between PBL curricula and traditional medical school curricula lies in the learning environment, which generally makes use of small group tutorials with a student-centered approach, active learning, the use of cases or problems and a significant amount of time for independent study [1, 3]. Thus, students learn with relatively little guidance, the emphasis being on learning from one another and from the use of learning resources provided or identified by the students themselves. In other words, the students must discover or construct essential information for themselves [1, 3]. Such a minimally guided approach to learning, which is the essence of PBL, has been called by a variety of other names, including discovery learning, enquiry learning, experiential learning and constructivist learning [11–14]. Therefore, in the company of these learning approaches, PBL certainly does have a number of theoretical underpinnings from the psychology literature. These cognitive psychological concepts, which have been proposed as the rationale for a problem-based approach to medical education, will be contrasted with arguments from the same domain suggesting that minimal guidance may in fact detract from learning [15]. These arguments will be reviewed later in the section on PBL and knowledge acquisition.

Maudsley [16] has attempted to dissipate the fog which has settled over the various definitions of PBL by looking for common ground in the literature for what constitutes PBL and problem-based curricula. Maudsley [16] identified 5 ‘ground rules’ for which there might be some consensus amongst medical educators.

PBL is both a method and a philosophy, curriculum-wide and supported by all curricular elements. It aims at efficient acquisition and structuring of knowledge arising out of working through in active, iterative and self-

directed ways. Furthermore, PBL comprises a progressive framework of problems providing context, relevance and motivation (problem-first learning), builds on prior knowledge integration, critical thinking, reflection on learning and enjoyment, achieves its goals via facilitated small-group work and independent study, and relates to problem solving only in so far as knowledge becomes more accessible and can therefore be applied more efficiently during this process [16].

Given this historical context and widespread adoption of PBL in medical schools worldwide, this review will describe the debate about the value of a PBL approach to acquisition of knowledge and clinical performance. The review concludes that PBL remains a valid and effective environment for medical education in a rapidly changing and challenging time for curriculum development.

Methods

The databases Medline (1966), PsychInfo 2000 and the Cochrane Database of Systematic Reviews (March 2008) were searched using ‘problem-based learning’, ‘inquiry learning’ and ‘self-directed learning’, cross-referenced against ‘medical education’ as primary search terms. ‘Problem-based learning’ has been an index term in Medline only since 1995.

Medline yielded 478 articles searching by ‘problem-solving/medical education’, 8 systematic reviews of PBL, 1 of which primarily addressed clinical competence; 1 review of cognitive aspects of problem-solving. Abstracts of these 478 articles were checked against the reference lists of the systematic reviews and are identified only if they are: (1) PBL methodology articles cited by most reviews or (2) published since the last systematic review (20 articles). Searching PsychoInfo yielded 7 additional articles not identified in Medline.

Results

Cognitive Basis of PBL: Is It a Sound Educational Theory?

One cannot understand the psychological basis of PBL without first addressing the goals of this form of instruction. Barrows [17] identified 4 major objectives of PBL, namely: (1) structuring of knowledge and clinical context, (2) clinical reasoning, (3) self-directed learning skills and (4) intrinsic motivation. According to Barrows [17], students work in a small group using a clinical case as a resource, with the assumption that through continuous exposure to real-life problems students will acquire the craft of evaluating a patient’s problem, deciding what the problem is and making appropriate clinical decisions to

Table 1. Cognitive attributes of PBL that promote learning

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- Knowledge acquired in relevant context is better remembered
 - Concepts are acquired in a way that they can be mobilized to solve/view similar problems
 - Acquisition over time of 'prior examples' facilitates pattern recognition
 - Promotion by PBL of prior-knowledge activation facilitates processing of new information
 - Elaboration of knowledge occurs at the time of learning
 - Provision of similarity of context for knowledge acquisition and subsequent application also facilitates recall [20]
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Table 2. PBL – a detriment to learning?

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- Problem-based searching (e.g. of a tutorial case) places a load on working memory
 - Working memory cannot 'problem solve' and be used to learn at the same time
 - The process of learning how to practise medicine and actually practising are cognitively different [15]
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manage the problem [17]. Working with cases was central to Barrow's proposition, and he described a number of different 'levels' at which cases could be used for learning across a spectrum of lecture-based cases, where cases are used simply to demonstrate the relevance of information provided by a lecture, through to PBL cases, which encourage free enquiry [17]. It appears that one of the pioneers of PBL curricula may have envisaged that this method would help students develop general problem-solving skills, based on the notions of enquiry skills prevalent in the 1960s [18]. However, the work of Elstein et al. [19] and Norman and Schmidt [20] suggest that there is no evidence that one particular form of curriculum can enhance general problem-solving skills. Norman and Schmidt [20], Martensen et al. [21] and Schmidt et al. [22] elucidated a number of cognitive attributes of PBL conducive to improving learning, as listed in table 1.

However, others are not so sure that the relatively unstructured approach to instruction embodied in PBL adequately takes account of the characteristics of working memory, long-term memory or the intricate relations between them. Kirschner et al. [15] have advocated that closer attention needs to be paid to what is known about human cognitive architecture in developing pedagogical approaches to a curriculum. They suggested that our understanding of working memory and long-term memory

should proscribe minimally guided instruction since, rather than elaborating on prior knowledge as posited by Norman and others, problem-based searching of the case makes heavy demands on working memory (table 2).

When advancing this argument, Kirschner et al. [15] drew on the work of Schulman [23] and others who have studied the integration of content expertise and pedagogical skill. In his review of instructional techniques, Mayer [24] also concluded that the evidence favors a guided approach to learning. Others have countered these arguments [25–27]. Neville [25] and Eva et al. [28] reviewed the role of the PBL tutor and presented evidence from cognitive psychology that the tutor can play a pivotal role in providing structured feedback which facilitates student learning, particularly enhancing analogous transfer, whereby concepts or problem solutions learned in one context can be recognized as applicable in what may superficially appear to be different situations. Schmidt et al. [26] have presented evidence that the arguments of Kirschner et al. [15], which were drawn in an unstructured way from individual learning settings, are not a fair comparison with the group setting of PBL, which allows for 'flexible adaptation of guidance of cognitive load'. Similar opinions have been voiced by Hmelo-Silver et al. [27], who suggested that Kirschner et al. [15] conflated PBL with discovery learning and neglected to consider the extensive 'scaffolding' used in the PBL educational setting that effectively reduces cognitive load.

As a final thought in the resolution of the debate between those who are either for or against a constructivist PBL approach, one could in fact consider the actual use of the tutorial case as focus for learning. The main argument of the anticonstructivists is that a problem-solving search is an inefficient way of altering long-term memory because its function is to find a problem solution, not alter long-term memory [15]. In other words, a problem-solving search overburdens limited working memory capacity. However, the process of working on a tutorial case in a PBL environment goes far beyond simply trying to solve a problem. Schmidt [29] described a 7-step process that typifies the PBL process:

- clarifying and agreeing on working definitions of unclear terms and concepts;
- defining the problems, agreeing which phenomena require explanation;
- analyzing component implications, suggested explanations (through brainstorming) and developing a working hypothesis;
- discussing, evaluating and arranging the possible explanations in a working hypothesis;

- generating and prioritizing learning objectives;
- going away and researching these objectives between tutorials;
- reporting back at the next tutorial, synthesizing a comprehensive explanation of the phenomena and re-applying synthesized newly acquired information to the problems.

In summary, while there are arguments from the realm of cognitive psychology, both to support and refute the validity of PBL, the weight of the experimental and empirical evidence supports this educational approach.

PBL and Knowledge Acquisition – Interpreting the Literature

The preceding section has outlined some of the controversies in the definition of PBL, as well as conflicting opinions of its educational validity. This next section will address comparisons that have been made in the literature of the effects of PBL on the knowledge and performance of graduates of PBL curricula in comparison with those trained in more traditional medical schools. However, the very fact that at least half a dozen systematic reviews or meta-analyses of PBL have been carried out over the past 15 years with differing conclusions suggests that ‘apples may have been compared with oranges’. Before trying to describe the different findings in terms of knowledge acquisition or skills demonstrated by students in different types of curricula there needs to be some examination of the factors that have complicated interpretations of comparisons.

The first factor that must be reiterated has been hinted at earlier: there is not a uniform curriculum intervention named PBL. As has been pointed out, PBL is not a single-factor intervention that can be compared with another simple intervention, such as might occur in a randomized control trial investigating the efficacy of 2 different pharmaceutical preparations. Some education researchers have therefore suggested that the randomized control trial is not an appropriate method of study for evaluating the impact of curriculum interventions such as PBL [30, 31]. These researchers would favor well-designed studies exploring the multiple variables that impact the learning processes in either a PBL or traditional setting. Newman [9], however, has advanced the argument that the randomized or true quasi-experimental approach has been somewhat overlooked in comparisons of problem-based and traditional curricula. He observed that in 74 studies of PBL – which are cited as showing evidence of the effectiveness of PBL in, for example, the domain of acquisition of knowledge as described in a number of meta-anal-

yses – only 4 were randomized experiments. Newman [9] further argues that authors have not made it a priority to establish descriptive causation as a prerequisite for assessing the effect of PBL, i.e. to establish that the difference in outcomes between 2 groups was actually caused by PBL [32]. While the debate about what type of study should be carried out to establish the putative benefits of PBL may seem somewhat arcane, it is axiomatic that one understands exactly how a comparison has been made between PBL curriculum and non-PBL curriculum, and what factor or factors have been identified that might be responsible for any differences observed in any chosen outcome, such as knowledge acquisition, skills development or clinical competencies. In espousing a causal explanation as fundamental to interpreting studies comparing PBL and traditional curricula outcomes, Newman [32] lists the 4 principles of causal explanation advanced by Blaikie [33]; these are: (1) a temporal order in which cause must precede effect, (2) an association that requires the 2 events occur together, (3) there is elimination of alternatives in order to be able to claim that the effect was due to the specified intervention and not something else and (4) causal relationships are made sense of in terms of broader medical ideas or assumptions.

If these 4 principles are the established norm for investigating PBL, Newman [9] argues that there are currently no comprehensive systematic reviews of the effectiveness of PBL available since none of the analyses published has taken this approach. Whether this unsettled debate should leave the medical school educator or curriculum planner in a state of nihilism or agnosticism about PBL is uncertain, but none of the published reviews or individual studies of PBL with their conflicting results can be interpreted without consideration of the methodologies of the studies and the definitions of PBL implied by the authors of the studies.

One further caveat in the interpretation of curriculum comparisons is the issue of using effect sizes to compare the outcomes in PBL and traditional curricula [34, 35]. Colliver [34] has argued that one should expect effect sizes of 0.8–1.0 in outcome differences between PBL and traditional curricula. In rebutting the contention of Colliver [34], Albanese [35] suggests that such effect sizes are an unreasonable expectation, and would require students at the median level of performance to move into the top third of the class distribution to create an effect size of that magnitude. Additionally, he noted that this becomes even more unlikely if one considers that ceiling effects often limit the ability of the highest-performing subjects in a control group to achieve commensurate gains upon

exposure to a new curriculum innovation [35]. While the criteria developed to assess the quality of studies of educational interventions such as PBL excite tremendous debate, the impact of the students themselves on curricular outcomes should not be forgotten. While in the Netherlands students enter medical school from high school, having been selected as potential medical students and randomly allocated to the different schools, elsewhere students can select the particular school if they receive multiple offers and might choose either a traditional curriculum or a school that offers a PBL curriculum or environment. It has been argued that irrespective of the medical school of choice, most aspiring medical students have gone to high school and have been educated in a lecture-based and competitively graded environment from which they would emerge unable to take full advantage of the PBL environment [35]. The student factor is therefore a potential bias in comparisons of traditional and PBL curricula, and constitutes another confounding factor in the interpretation of the literature.

We can perhaps get a sense of the complexity of the issues surrounding the aggregation of results from many studies of the effects of PBL in even a single domain, such as the acquisition of knowledge, by considering the heterogeneity of approaches taken in 3 meta-analyses of PBL that were all published in 1993 [4–6]. Wolf [36] pointed out, in a commentary on these 3 significant reviews of the PBL literature published up to that time, that 2 of the reviews (by Vernon and Blake [4] and Albanese and Mitchell [6]) took a quantitative approach to synthesizing the literature, while the review of Berkson [5] took a narrative approach. However, while both Albanese and Mitchell [6] and Vernon and Blake [4] chose to calculate effect sizes for the individual studies that they had analyzed, Vernon and Blake [4] aggregated data while Albanese and Mitchell [6] did not. It can be argued that combining results from studies that measure constructs by very different methods may be similar to combining ‘apples and oranges’ [36].

Within the domain of basic science examination performance, both Albanese and Mitchell [6] and Vernon and Blake [4] concluded that if one reviewed the NBME (National Board of Medical Examiners) part 1 examination data, there was a nonsignificant trend in favor of traditional curricula, but Berkson [5] suggested that from the same primary studies reviewed no-one had been able to demonstrate an important advantage of one curriculum over the other. She did however caution that early exposure to overly complex clinical problems might hinder rather than promote the development of resilient and

useful cognitive structures. For clinical science examination performance, a similar agreement existed between Albanese and Mitchell [6] and Vernon and Blake [4], and there were small but nonsignificant trends in favor of PBL students, but this evidence did not convince Berkson [5], who argued that no study had demonstrated that a small group working in an enclosed room on a paper case simulates clinical practice more closely or powerfully than a carefully prepared large-group educational session. In the area of clinical reasoning, there were very few studies to review, but Vernon and Blake [4] and Albanese and Mitchell [6] concluded that the evidence suggested that PBL students became used to engaging in backward reasoning, which did not permit them to develop an adequate cognitive scaffolding and thus led them to make more diagnostic errors and raised doubts as to the adequacy of the fund of knowledge these students were developing. Reviewing the same literature, which included a study of final-year medical students from McMaster, Berkson [5] concluded that there was no evidence that PBL teaches problem solving better than traditional schools, and that performance of the individual components of the hypothetico-deductive model were highly case specific.

When it came to reviewing comparisons of study habits of students in the PBL environment compared to traditional curricular environments, both Albanese and Mitchell [6] and Vernon and Blake [4] concluded that students in a PBL setting were less likely to study for short-term recall and more likely to study for understanding or to analyze what they needed to know for a given task. Self-directed learning was also identified as a hallmark of PBL students in the conclusions of Vernon and Blake [4]. From a different perspective, however, Berkson [5] suggested that the evidence demonstrated that particular PBL curricula did not guarantee the use of specific learning approaches. She also noted that ‘tasks that require’ comprehension for successful conclusion, whether they occur in PBL or traditional curricula, will encourage the use of comprehension-directed or deep cognitive learning approaches.

In summary, these 3 widely quoted but somewhat differing reviews reached somewhat different conclusions about acquisition and retention of knowledge in the PBL environment using a variety of test scores as outcome measures. However, it could be argued that measuring scores on multiple-choice examinations may not be a valid assessment of the acquisition or accumulation of the kind of knowledge achievable in PBL. Indeed, Hmelo and Evenson [37] have argued that knowledge gained in the

PBL environment is the kind of knowledge of contextualized practice, which is more than the accumulation of factual information and rather a transformation of the individual. However, in a pilot systematic review of the effectiveness of PBL published almost 10 years after the 3 reviews described above, Newman and the Campbell collaboration systematic review group [9] reported that in fact most studies on PBL have used the multiple-choice question format to assess students' knowledge in a PBL curriculum. Their review included study designs that were randomized control trials, controlled clinical trials, interrupted time series and controlled before and after studies, and required, as a minimum, an objective measurement of student performance. The required curricula criteria included an accumulative integrated curriculum (or learning via simulation formats so as to allow free inquiry), small-group learning with either faculty or peer tutoring and an explicit learning framework [9]. This pilot systematic review of knowledge accumulation in fact showed that overall knowledge outcomes for students in PBL groups were less favorable than in control groups. They did allow for the fact that one of the studies included in their review was a clear outlier in favoring control subjects over PBL subjects, but even excluding this particular study and performing a sensitivity analysis they could not exclude the possibility of a large negative effect size of PBL on knowledge accumulation [9].

The comments made about knowledge accumulation thus far have reflected an overall assessment of knowledge across problem-based curricula, irrespective of the extent of the problem-based approach within the curriculum. In some environments, PBL is implemented in one single course, whereas some schools have a curriculum designed in such a way that almost the entire curriculum content is delivered in a PBL format. As Albanese and Mitchell [6] have noted, the impact of PBL if applied across the curriculum is going to be more profound, yet at the same time a single course may offer a more controlled environment in which to examine the specific effects of PBL. This particular aspect of the effects of PBL and knowledge accumulation was addressed in yet another meta-analysis of the effects of PBL published by Dochy et al. [38] in 2003, in the same year as the analysis of Newman [9]. The meta-analysis by Dochy et al. [38] used far broader criteria than several of the previous systematic comparisons of PBL and traditional curricula. Their inclusion criteria were: (1) the work had to be empirical, although not necessarily randomized controlled designs; (2) the definitions of the PBL learning environment had to be similar to those implied by other authors;

(3) the dependent variables used in the study had to be an operationalization of the knowledge and/or skills of the students; (4) the authors chose only studies that had been conducted in a real-life classroom or programmatic setting in tertiary education, and did not address any artificial controlled laboratory conditions. While overall the analysis of Dochy et al. [38] confirmed other reviews that have suggested that PBL might have a negative effect on the knowledge base or knowledge acquisition of students compared to those trained in a conventional learning environment, there are similarities between their findings and those in the review of Newman [9], which showed that this negative effect of PBL on knowledge base was mainly due to the inclusion of 2 outlier results, which, when excluded from the analysis, results in the combined effect sizes approaching zero [38].

In reviewing the effects of PBL curricula, some authors have separated knowledge acquisition from knowledge application. In the meta-analysis by Dochy et al. [38], this distinction was made using an operational definition that a knowledge test primarily measures the knowledge of facts and the meaning of concepts and principles, i.e. declarative knowledge, while a test that assesses skills or knowledge application measures to what extent students can apply their knowledge. Examples of the assessment of factual knowledge include NBME part 1, progress tests, the Medical Council of Canada Part 1 Examination and scores on discipline-specific multiple-choice tests, such as anatomy or other preclinical discipline tests. Dochy et al. [38] accepted as application of knowledge the times when students were assessed on part 2 or part 3 of the national board's examinations, simulated patient exams and oral problem-solving tests or tests of clinical performance. Some might criticize such a distinction between knowledge acquisition and application of knowledge, not so much on the cognitive definition but on the assessment methods, given the great overlap between the 2 domains. Having said that, the meta-analysis of Dochy et al. [38] appears to demonstrate that while PBL had a negative effect on knowledge acquisition, there was a positive effect on knowledge application which was statistically significant. The positive effect on skills or knowledge application was not apparently affected by the degree of implementation of PBL [38].

Given these findings, is it possible to pool results from studies which have such heterogeneity in terms of assessment formats, different levels of education and even different ways of delivering what is called PBL? The answer to this is probably 'yes' because even if the format and delivery of PBL is not uniform around the world, providing

that the PBL environment can be seen as a package of components of teaching and learning, this package is clearly different from the experience of students in a traditional medical school curriculum environment. Accepting this argument, it would seem reasonable that one can aggregate effects from different kinds of PBL and PBL studies, notwithstanding the previously described debate about the magnitude of effect sizes. In summary, the effect of PBL on knowledge appears to be positive or negative depending on whether one combines application of knowledge with factual recall or separates the acquisition of knowledge from knowledge application.

Effects of PBL on Clinical Performance

Meta-analyses, systematic reviews and narrative overviews of PBL environments generally encompass a number of domains related to institutional effects such as costs and resources required, students, student satisfaction, knowledge acquisition and clinical performance both during medical school and beyond graduation as well as curricular comparisons of content and delivery. For medical school educators and administrators contemplating curricular change, however, the 2 outcomes that demand closest attention are probably knowledge acquisition and clinical performance of graduates from a PBL curriculum compared to a traditional medical school environment. While all reviews of PBL have included assessment of knowledge acquisition as described above, only 1 of the systematic reviews of PBL identified so far explicitly addresses the issue of clinical competency [6]. Albanese and Mitchell [6] identified 7 studies that reported outcomes of either medical student or postgraduate clinical performance, and most of these studies relied on supervisor ratings. Of these 7 studies, 3 came from McMaster, 2 from the University of New Mexico and 1 from Harvard Medical School. All the studies were published between 1981 and 1990 [6]. In these studies, most of the findings were not statistically significant in terms of the effect sizes achieved, but the results did suggest a clear trend toward higher ratings of clinical performance from PBL graduates as assessed by their clinical supervisors. In 1 study, nurses' ratings produced a negative effect size that approached statistical significance [6]. Albanese and Mitchell [6] concluded that given the results of the 7 studies cited and the literature on clinical reasoning alluded to earlier, it was difficult to draw any conclusions about the effects of PBL curricula on graduates' performance.

More recently Koh et al. [10] have published a systematic review of the effects of PBL during medical school on physician competency. This systematic review identified

13 studies published between 1981 and 2006. The authors employed the definition of Maudsley [16] for PBL and included nonrandomized control trials because there were very few randomized trials in medical education to review [10, 16]. Most of the control groups were either historical controls from the same school before curriculum change had occurred or were control schools with similar groups of students but a different curriculum. The authors categorized the competencies into 8 dimensions, namely, overall, technical, social, cognitive, managerial, research, teaching and knowledge. Each of the dimensions had a number of different competencies that were assessed. Subjects were assessed either by supervisors or self-assessment.

The most significant findings from this analysis relate to some of the positive benefits of PBL on the competencies assessed. There were clear disparities between self-assessment and the supervisor-observed assessment in terms of the level of evidence to support PBL. These differences were likely not unexpected given the limited self-assessment abilities of physicians as published in the literature and identified by these authors [10]. Four competencies had moderate to strong levels of evidence in support of PBL according to both self-assessments and observed assessments. These competencies were: coping with uncertainty, appreciation of legal and ethical aspects of health care, communication skills and self-directed continuing learning [10]. The authors of this analysis concluded that PBL during medical school has positive effects on physician competencies especially in the social and cognitive domains. For better or worse, the authors of this most recent meta-analysis of the effect of PBL did not attempt to calculate effect sizes for the differences in performance of graduates from PBL or traditional medical schools. In commenting on this analysis, Norman [39] speculated as to why these effects of PBL were observed. He suggested that perhaps working in small groups helps PBL graduates acquire better communication and interpersonal skills. Similarly, it may be that students in PBL curricula are more exposed to professionals such as social workers and psychologists, who might give them a better appreciation of the cultural, legal and ethical aspects of care. Norman [39] speculated whether a PBL curriculum was more likely to contain objectives that better prepared graduates to cope with uncertainty. It is interesting to note that Koh et al. [10] found that PBL graduates, accustomed as they are to working in a less-structured educational environment, encouraged to be self-directed and working with others in small groups, appear to use this behavior to good effect once in clinical practice.

PBL – Future Focus

Despite the heterogeneity of the extensive literature on PBL, there is certainly sufficient cognitive psychological evidence to validate this approach to learning and a significant amount of empirical evidence of effective learner outcomes. The flexibility inherent in the structure of PBL curricula has allowed educators to incorporate the findings from the cognitive psychological literature and the PBL literature of the past 2–3 decades [40]. The resulting curriculum of the future can be seen as a hybrid within which students are prepared didactically with fundamental concepts on which they elaborate in small-group tutorials, facilitated by knowledgeable tutors who are able to provide adequate feedback on students' understanding and learning. Such a curriculum remains integrated as PBL curricula tend to be, but fundamental disciplinary concepts are interwoven in a logical and stepwise fashion throughout the curriculum. Tutorial cases remain as a

focus for defining learning objectives in the manner originally described by Barrows [1], but students are armed with some basic vocabulary 'and prior knowledge' to elaborate their new hypotheses. Tutors are prepared to promote analogous transfer of concepts across the curriculum by the use of appropriate Socratic questioning.

Early clinical exposure and integration of the clinical experience with the classroom experience, which is prevalent in PBL environments, may be one of the factors in the recent report that PBL graduates appear to have superior skills in social and cognitive performance [10]. This aspect of PBL should be maintained and perhaps even further developed given the evidence.

The introduction of PBL 40 years ago has had a huge impact on the delivery of medical education around the world. As demands for new curricular outcomes and graduating competencies are made of medical schools, a PBL approach to learning embodies the flexibility and adaptability necessary to accommodate such challenges.

References

- 1 Barrows HS: Problem-based learning applied to medical education Springfield. Carbondale, Southern Illinois University School of Medicine, 2000.
- 2 Muller S: Physicians for the 21st century: report of the project panel of the general professional education of the physician and college preparation for medicine. *J Med Educ* 1984;59:1–200.
- 3 Walton HJ, Matthews MB: Essentials of problem-based learning. *Med Educ* 1989;23:542–558.
- 4 Vernon DT, Blake RL: Does problem-based learning work? A meta-analysis of evaluative research. *Acad Med* 1993;68:550–563.
- 5 Berkson L: Problem-based learning: have the expectations been met? *Acad Med* 1993;68: S79–S88.
- 6 Albanese MA, Mitchell S: Problem-based learning: a review of literature on its outcomes and implementation issues. *Acad Med* 1993;68:52–81.
- 7 Nandi PL, Chan JN, Chan CP, Chan P, Chan LP: Undergraduate medical education: comparison of problem-based learning and conventional teaching. *Hong Kong Med J* 2000; 6:301–306.
- 8 Smits PB, Verbeek JH, de Buissonjé CD: Problem based learning in continuing medical education: a review of controlled evaluation studies. *BMJ* 2002;324:153–156.
- 9 Newman M: A pilot systematic review and meta-analysis on the effectiveness of problem-based learning: on behalf of the Campbell Collaboration Systematic Review Group on the Effectiveness of Problem-Based Learning. Newcastle upon Tyne, University of Newcastle upon Tyne, 2003.
- 10 Koh GC, Khoo HE, Wong ML, Koh D: The effects of problem-based learning during medical school on physician competency: a systematic review. *CMAJ* 2008;178:34–41.
- 11 Anthony WS: Learning to discover rules by discovery. *J Ed Psych* 1979;64:325–328.
- 12 Rutherford FJ: The role of inquiry in science teaching. *J Res Sci Teach* 1964;2:80–84.
- 13 Kolb DA, Fry R: Toward an applied theory of experiential learning; in Cooper C (ed): *Studies of Group Process*. New York, Wiley, 1975, pp 33–57.
- 14 Steffe L, Gale J: *Constructivism in education*. Hillsdale, Lawrence Erlbaum Associates, 1995.
- 15 Kirschner PA, Sweller J, Clark RE: Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educ Psychol* 2006;41:75–86.
- 16 Maudsley G: Do we all mean the same thing by 'problem-based learning'? A review of the concepts and a formulation of the ground rules. *Acad Med* 1999;74:178–185.
- 17 Barrows HS: A taxonomy of problem-based learning methods. *Med Educ* 1986;20:481–486.
- 18 Barrows HS: A specific, problem-based, self-directed learning method designed to teach medical problem-solving skills, self-learning skills and enhance knowledge retention and recall; in Schmidt HG, DeVolder ML (eds): *Tutorials in Problem-Based Learning*. Assen, Van Gorcum, 1984.
- 19 Elstein AS, Schulman LS, Sprafka SA: *Medical problem solving: an analysis of clinical reasoning*. Cambridge, Harvard University Press, 1978.
- 20 Norman GR, Schmidt HG: The psychological basis of problem based learning: a review of the evidence. *Acad Med* 1992;67:557–565.
- 21 Martensen D, Eriksson H, Ingelman-Sundberg M: Medical chemistry: evaluation of active and problem-oriented teaching methods. *Med Educ* 1985;19:34–42.
- 22 Schmidt HG, De Volder ML, De Grave WS, Moust JHC, Patel VL: Explanatory models in the processing of science text: the role of prior knowledge activation through small group discussion. *J Educ Psychol* 1989;81: 610–619.
- 23 Schulman LS: Those who understand: knowledge growth in teaching. *Educ Res* 1986;15:4–14.
- 24 Mayer R: Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *Am Psychol* 2004;59:14–19.
- 25 Neville AJ: The problem-based learning tutor: Teacher? Facilitator? Evaluator? *Med Teach* 1999;21:393–401.

- 26 Schmidt HG, Loyens SMM, Van Gog T, Paas F: Problem-based learning is compatible with human cognitive architecture: commentary on Kirschner, Sweller, and Clark. *Educ Psychol* 2007;42:91-97.
- 27 Hmelo-Silver C, Duncan RG, Chinn CA: Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educ Psychol* 2007;42:99-107.
- 28 Eva KW, Neville AJ, Norman SR: Exploring the etiology of content specificity: factors influencing analogical transfer and problem solving. *Acad Med* 1998;73:S1-S5.
- 29 Schmidt HG: Problem-based learning: rationale and description. *Med Educ* 1983;17:11-16.
- 30 Norman SR, Schmidt HG: Effectiveness of problem-based learning curricula: theory, practice and paper darts. *Med Educ* 2000;34:721-728.
- 31 Dolmans D: The effectiveness of PBL: the debate continues. Some concerns about the BEME movement. *Med Educ* 2003;37:1129-1130.
- 32 Newman M: Fitness for purpose evaluation in problem based learning should consider the requirements for establishing descriptive causation. *Adv Health Sci Educ* 2006;11:391-402.
- 33 Blaikie N: *Designing Social Research*. London, Polity Press, 2000.
- 34 Colliver JA: Effectiveness of problem-based learning curricula: research and theory. *Acad Med* 2000;75:259-266.
- 35 Albanese M: Problem-based learning: why curricula are likely to show little effect on knowledge and clinical skills. *Med Educ* 2000;34:729-738.
- 36 Wolf FM: Problem-based learning and meta-analysis: can we see the forest through the trees? *Acad Med* 1993;68:542-544.
- 37 Hmelo C, Evenson D: Introduction to problem-based learning: gaining insights on learning interactions through multiple methods of enquiry; in Evenson D, Hmelo C (eds): *Problem-Based Learning - a Research Perspective on Learning Interactions*. Mahwah, Erlbaum, 2000.
- 38 Dochy F, Segers M, Van den Bossche P, Gijbels D: Effects of problem-based learning: a meta-analysis. *Learn Instr* 2003;13:533-568.
- 39 Norman G: Problem-based learning makes a difference. But why? *CMAJ* 2008;178:61-62.
- 40 Neville AJ, Norman GR: PBL in the undergraduate MD program at McMaster University: three iterations in three decades. *Acad Med* 2007;82:370-374.