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Is PBL really a better way to teach and learn?

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Most education leaders or developers implementing problem-based learning have probably heard the question, "Is PBL really better than other ways to teach and learn?" We, the authors, have had reasons to try to answer this question during our long experience of PBL. We have identified five areas that should be considered before an answer can be provided and we have used theory and research to shed light on these areas.

The first area is *a changing society* where students and employers expect universities to meet new challenges.

Knowledge about cognition and evidence concerning *what matters in educational practice* have shown that PBL offers opportunities to apply several of the most important principles that result in better learning.

Comparisons of PBL-curricula and "traditional" curricula initially yielded limited results, but with growing insight into the *effects of bias in comparisons* it has been shown that a well implemented PBL-curriculum does result in better outcomes beyond improvement of knowledge.

We believe that we can answer the question with a "yes", provided that PBL is implemented in a way that takes into account knowledge of what matters for learning.

Key words: Problem-based learning, small group learning, cognition, learning outcomes

Introduction

Most probably, everybody practicing or advocating problem-based learning (PBL) has been asked many times whether PBL really is a better way to teach and learn. We, the authors of this reflection, each have 25 years of experience of tutoring in PBL contexts and some ten years of experience of educating and training tutors for PBL within faculty staff development programs in medicine, biomedicine, and health care education. We also have long time personal experience of practicing as well as educating and training others for various other teaching formats, and we have noticed that similar questions are rarely asked in those contexts. Why is the effect of PBL on the outcome asked for whereas the effect of other learning or teaching formats is not? PBL can be categorized as a small group study format supporting self-directed learning (Barrows & Tamblyn, 1980; Schmidt, 1983). Students start by investigating a case or a situation in order to be able to explain the situation or to propose an educated choice of action that could be undertaken. They do so prior to having all the knowledge and higher order cognitive skills. The students themselves define the questions or study goals they need to address in order to be able to proceed, and these questions, which often relate to several subject areas, are the basis for their studies. After self-study the students meet again and discuss their findings in relation to the case. The tutor is supposed to adopt the role of a facilitator in the first place and not of a provider of information. All this is a reversal of the long standing paradigm in the history of higher education meaning knowledge before application (if any application at all!). The defini-

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tion of a teacher working within that paradigm is someone who openly demonstrates his or her superior knowledge in order to help students to learn, often assuming a process of knowledge transfer.It is perhaps not surprising that a teacher who has become used to being a "sage on the stage" finds it difficult to adapt to the role of a "guide on the side", and thus wonders if it really is possible to "cover" all subject matter within the format of PBL.

Depending on how they are applied, other teaching and learning formats such as, *e.g.*, the Harvard Business School case method and laboratory work may also often be characterized as formats supporting self-directed learning, but they are not always perceived that way. To our understanding from many discussions, the probable explanation is that such formats offer more room for teacher control. Consequently, the perceived lack of teacher control may be an important reason why the claimed merits of PBL are questioned so often.

With a history of almost fifty years, PBL has become an accepted tool among other tools for teaching and learning (Kinkade, 2005). However, despite that PBL has been used worldwide for several decades and in spite of a wealth of literature concerned with PBL, the question phrased in the title still seems to await a final answer as judged by our experience from many courses with medical teachers. In this paper we will share with you how we ourselves have approached the answer to the question using literature in the field of learning in general and PBL in particular. We present a selection of literature related to five areas that have to be taken into account in order to be able to answer the question according to our experience. These areas are: (1) demands on higher education caused by changes in the society; (2) the increasing knowledge about cognition from various disciplines; (3) results from studies of what really matters in educational practice; (4) comparisons of learning results of PBL-curricula with those of more traditionally taught curricula; (5) the importance of taking bias into account when making such comparisons. Thus, this is not a systematic review of the vast literature about PBL (by the end of October 2014, a search for "problem-based learning" resulted in more than 6,000 hits in PubMed and more than 160,000 hits in Google Scholar).

A changing society

One possible approach to deal with the question in the title used by Egidius (1999a, 1999b) is to put PBL in a broad and societal perspective to try to understand why it is being used rather than to debate the claimed or missing merits of PBL. The content under this heading is inspired by the texts by Egidius (1999a, 1999b).

During the nineteen sixties some fierce riots were orchestrated by students at Berkeley, California, in Paris and elsewhere in the western world societies. The students protested against the power of the professors and authoritarian one-sided lecturing. Teaching at universities was criticized for not allowing critical discussions about society. Research and higher education were accused of being isolated from society. The student protesters demanded democracy and to be given a voice. They wanted discussions, small group studies, and the freedom to decide what they considered interesting and important. To them the lectures were the very symbol of the authoritarian hierarchical system at universities.

Outside the world of higher education the detailed governance of production lines in industry was abandoned and the employees, individually or in groups, were given responsibility for their tasks instead of instructions. Employees turned into collaborators who networked and worked in teams. This called for skills in communication, collaboration and the ability to direct one's own work, skills that were not trained in the traditional schools and universities at the time.

Also in the nineteen sixties, protests developed against bureaucracy and the ruling by the letter of the law within the large governmental administrations. In the nineteen eighties and nineties, bureaucracy and governance by rules had to yield to governance by goals and expected outcomes. This development within society called for people who could search for and find facts, for critical appraisal, for reflection on problems, for a scientific approach, and for the ability to predict the consequences of alternate decisions. On the whole these are skills that are developed within PBL. At the new institutions for higher education, problems were not used for the application of prior knowledge but, rather, the educational programs were based on problems. PBL was a choice in opposition to the traditional pedagogy in higher education. Lectures were avoided and the education was student-centered and based on authenticity. Students became able to influence the direction and content of their studies, and skills needed in society were developed.

"Consequently, asking if PBL is effective is not a relevant question. You do not choose PBL for its effectiveness. Maybe, it is not at all effective or it is not at all good at preparing the students for their future professional careers. In the perspective of the upheavals of the nineteen sixties and seventies the choice of PBL is an ethical question. The students are given the responsibility just as the responsibility for accomplishing something is given to us as individuals in a flexible and changing professional life. This is in accordance with the principles of self-directed learning." (Egidius 1999b, p 48). At the entrance of the twenty-first century, PBL has become accepted as a way of learning that agrees with the view of our time on the human being as someone who is able to take responsibility for his or her own life, learning, and professional work.

Knowledge about cognition

Today more is known about conditions of importance for learning than was known when PBL was developed. Cognitive psychology has developed, and recently findings in neurobiology regarding learning have been compared to those in cognitive psychology and the conclusions are the same. In this section we are looking at PBL in the light of these findings.

Early in the development of and research on PBL, Schmidt (1983), then at the University of Maastricht, identified three important learning principles in cognitive psychology of relevance for PBL. In 1993 Schmidt returned to these principles and presented further support for them (Schmidt, 1993).

The first principle is *activation of prior knowledge*. Students' knowledge from previous studies has always been seen as important, but according to this principle prior knowledge has to be activated before further study in order to facilitate the processing of new information. When students have the first PBL session with a case/problem, they will try to analyze and understand the problem using their prior knowledge, which is thus activated. During the session the students identify where their prior knowledge is insufficient and this lack of knowledge forms the basis for the study goals they agree upon for their self-study.

The second principle concerns the importance of context. It is easier for students to apply knowledge further on in life if the situation for application resembles the situation where learning took place. This *encoding specificity* means that retrieval cues are stored with the information and it can be achieved with PBL by selecting cases/problems that are contextualized so as to resemble situations where knowledge needs to be retrieved. This is both a matter of how knowledge is structured in memory and of the importance of cues for availability of the stored memory. Students use their study goals for self-study and their learning is thus connected to the case, which creates opportunities for structure and cues related to the case.

The third principle is *elaboration*. Elaboration can be achieved by students explaining to each other, asking and answering questions, writing or presenting summaries *etc*. Students' understanding and retention of knowledge is increased by elaboration. This occurs when students in PBL meet for the second time, after self-study, and discuss their new understanding of the case/problem. The students then explain to each other what they learned during self-study, they compare findings and ask each other questions to able to clarify ambiguities. It is an advantage if they also draw and write on a board during this phase.

Motivation increases the time students spend on self-study and is thus also important for learning (Schmidt, Rotgans & Yew, 2011). The use of cases relevant for the future profession tends to increase students' motivation. The properties of the cases/problems are important since these have to be designed so that students know and understand enough to be able to engage in a discussion that activates prior knowledge. They should also be challenging, engaging and relevant to future practice, both to increase motivation and to make stored memory more easily available through cues.

An important conclusion of these principles is that when students meet in groups, the most critical event from the point of view of cognitive psychology is a discussion in an open climate with the participation of all the students in the group. It is important for a thorough activation of prior knowledge, for identification of lack of knowledge and for elaboration. The tutor has an important role in contributing to the open climate, in stimulating elaboration and in scaffolding learning.

A fourth principle was added by Gijselaers (1996), namely the importance of *meta-cognitive skills*. This means that students are able to self-monitor their learning including the setting and evaluation of goals, and selection of strategies. Meta-cognitive skills can be learned and there are opportunities to do so in PBL if students and their tutor engage in reflection and evaluation after group sessions. These practices probably depend on the skills of the tutor, since students will have to be well acquainted with group work to initiate evaluation themselves.

There is now further evidence in support of the principles mentioned above (Schmidt, Rotgans & Yew, 2011). This evidence supports the importance of activation of prior knowledge and opportunities for elaboration for students' motivation, comprehension and long-term memory. The scaffolding provided by tutors in the PBL setting has been found to be more effective than *e g* questions added to problems. Both collaboration in groups and self-study are important and stimulate students' regular study and thus decrease the risk of failure and drop-out.

Yew, Chng & Schmidt (2011) found that learning in the different steps of PBL was cumulative and students' prior knowledge influenced their learning as well as their achievement in the final test. The finding that learning was cumulative means that learning in one step depends on learning in the previous one, and that all steps are important for the final result, again stressing the importance of all phases of PBL (the steps being, activation of prior knowledge, self-study and elaboration after self-study).

Evidence for a positive impact of the tutor's social congruence on students' learning in all the different phases of PBL has been presented (Chng, Yew & Schmidt, 2011). The tutor's cognitive and social congruence as well as subject matter expertise influenced students' test achievement. The tutor thus has an important role for the achievement of students in PBL. The influence of the tutor has been found to be stronger on academically average students than on academically strong or weak students (Chng, Yew & Schmidt, 2014) and this is important since most students are average performers.

In a recent review, Friedlander *et al.* (2011) presented how findings from neurobiology can be applied to teaching and learning. They identified ten aspects of which some are directly applicable to PBL. *Repetition* is important for increased retention. With well-designed and sequenced cases/problems in PBL, repetition occurs when students use prior knowledge in their first group meeting. It is also easy for a skilled tutor in PBL to facilitate return to concepts from previous sessions. *Reward and reinforcement* are positive for learning and this can be achieved, *e.g.,* by passing exams. Students who find increased understanding rewarding may have a better chance of study success. A well-functioning PBL-group may increase the joy of understanding as well as giving confirmation of achievement. *Active engagement* by students enhances learning and this is one of the key features of both group sessions of PBL. *Stress* is largely negative for learning. However, mild stress has been found to have positive effects. Learning in small groups as in PBL can at best create the kind of mild stress that is positive for learning.

What matters in educational practice

In his monograph on innovations in schools that have had effects on student accomplishments, Hattie (2009) summarized studies of more than 800 meta-analyses dealing with this topic. The meta-analyses represent 52,637 original studies and 146,142 effect sizes. An effect size is the difference between the means of two distributions expressed as the number of standard deviations. It was calculated by dividing the difference between the means by the size of the pooled standard deviation for the two distributions. In all, 138 innovative influences were ranked. Among influences that scored an effect size above 0.4, the mean effect size of all effect sizes studied, 31 were categorized as "teacher" and "teaching", two of the six domains studied. At least twelve influences are actions that easily take place or could take place in small group teaching in the format of PBL and several of them are found among the most highly ranked influences. The most effective influence within these two domains is feedback to teachers (*Table 1*) and this is also one of the top influences of all the ranked influences. Some other examples are reciprocal teaching – each student takes a turn at being the teacher and practices summarizing, questioning, clarification, and prediction in a supportive dialogue with the teacher; feedback to the student from various sources; teacher-student relationships; spaced vs mass practice – increasing the number of deliberative practice opportunities rather than the time on task; meta-cognitive strategies; and, finally, self-verbalization/self-questioning by students (*Table 1*).

Table 1. Innovations that have been found to have a strong influence on student accomplishments (Hattie, 2009), and that can easily be applied in problem-based learning.

Influence on student accomplishments	Effect size
Feedback to teachers	0.90
Reciprocal teaching	0.74
Feedback	0.73
Teacher-student relationships	0.72
Spaced vs mass practice	0.71
Meta-cognitive strategies	0.69
Self-verbalization/self-questioning	0.64

Comparisons of PBL-curricula and "traditional" curricula

After the implementation of PBL several attempts were made to identify improvements from applying PBL, but small or no differences were reported (*e g* Albanese & Mitchell, 1993; Vernon & Blake, 1993; Colliver, 2000). Hattie (2009) synthesized the results of eight meta-analyses comprising 285 studies concerned with the effects of PBL on student accomplishments and found the effect size to be negligible (0.15), although the standard error of the effect sizes was large. Advocates of PBL, such as us, have often been surprised by this poor evidence for the effect of PBL on learning in the literature. The scarcity of evidence is in such contrast to the impression we get as tutors from the quality of discussions in functional PBL groups.

The nature and assessment of student accomplishment have to be looked into and understood to allow for sound conclusions regarding the effects. Hattie (2009) reports about the effect sizes on the acquisition of factual knowledge in PBL from five of the eight meta-analyses as being zero or negative as compared to traditional instructional methods. However, two of these meta-analyses exhibited very positive effect sizes, indeed, for application of knowledge (0.4), understanding principles (0.75), and skills like recall of knowledge (0.66). One meta-analysis also reported positive effect sizes for self-directed learning (0.54) and attitude toward learning (0.52).

Koh, Khoo, Wong & Koh (2008) published a review that gives support to the suspicion that one should look beyond factual knowledge achieved to find evidence of further merits of PBL. The review is based on 13 studies that met all their inclusion criteria. The studies report assessments of professional competencies among physicians whose professional experience ranged from first-year residency to 20 years of medical practice and who had graduated from medical schools applying PBL during the first two years of the curriculum or throughout the whole program. The selected studies also included control groups of graduates from medical schools adopting traditional curricula. The evidence in favor of PBL presented in the review was strong for both self-assessed and observed competencies regarding coping with uncertainty, appreciation of legal and ethical aspects of health and moderate for self-directed continuing learning. Furthermore, the evidence was strong for the observed competencies diagnostic skills or accuracy, communication skills, appreciation of cultural aspects of health care, responsibility, and self or peer appraisal. Interestingly, judging by the self-assessments there was strong evidence of lack of medical knowledge but this was not supported by the evidence from the objective assessments (*cf.* Peters, Greenberger-Rosovsky, Crowder, Block & Moore, 2000) .

Using a database of 9,000 students, van den Berg and Hofman (2005) reported results from a study of the impact of student and faculty factors on study progress at universities in the Netherlands. Among several factors showing an impact on student success, PBL was found to have a positive effect. They discussed that the interaction between students and between students and teachers become more intense in a PBL curriculum. In particular, such interactions could be helpful to students who would otherwise become isolated in a traditional academic curriculum, like those from ethnic minorities, according to van den Berg and Hofman (2005).

As a proof of the importance of the findings and conclusions by Koh *et al.* (2008), Norman from McMaster University, the birthplace of PBL, who is known for his skepticism of the common practice in education to apply pedagogical innovations without referring to evidence, wrote a commentary in the same issue of the journal as Koh *et al.* (2008) with the title "PBL makes a difference. But why? " (Norman, 2008). He had become convinced that there is evidence in support of PBL but now there is a need to know why the method works to be able to guide those who want to implement it.

The effects of bias in comparisons

It is likely that comparisons between different curricula are biased by other differences than the intervention. It is obviously not possible to carry out blinded interventions in educational contexts. However, it is also almost impossible to perform correctly designed studies comparing an intervention group to a control group since students are not likely to let themselves be randomized to different groups in a study.

Medical schools in the Netherlands lend themselves well to curriculum comparisons since the students are randomized between the eight (as of 2012) medical schools, all state-based, according to a lottery-based admission procedure regardless of their medical school preferences.

In 1974, the Maastricht medical school enrolled their first students with a PBL curriculum from the start. Over the years, many comparative studies involving the Maastricht medical school have been performed and some of them have presented comparisons of how knowledge and skills differ among students from different schools and effect sizes for differences have been calculated. These have recently been presented in a review (Schmidt, Van der Molen, Te Winkel &Wijnen, 2009, *Table 2*). This study showed high impact on students' content with their studies, on clinical and communication skills as well as on progress through studies. The effects on knowledge and clinical reasoning, however, were found to be almost negligible.

Table 2. Comparisons of results in different domains by students from on the one hand "traditional" medical schools and on the other the problem-based medical school in Maastricht (Schmidt et al. 2009).

Domain	Effect size
Knowledge acquisition	0.07
Diagnostic reasoning	0.11
Communication	1,46
Medical skills	0,83
Content with experience of school	0,66
Graduation rate	0,33
Study duration	-0,68

There are several kinds of bias that can affect such curriculum comparisons and, according to Schmidt, Muijtjens, Van der Vleuten & Norman (2012), only some of the bias was controlled for in the previous studies (*e.g.* Albanese & Mitchell, 1993; Vernon & Blake, 1993; Colliver, 2000; Koh et al., 2008). According to these authors (Schmidt et al. 2012) the following aspects of bias should be considered as well:

Differential enrollment: it has been shown that the entry qualifications of the students have a strong impact on their knowledge acquisition in medical school (Hecker & Violato, 2008). In several of the studies mentioned above (Albanese & Mitchell, 1993; Vernon & Blake, 1993; Colliver, 2000), this factor has not been controlled for. In the studies from the Netherlands this has been controlled for due to the lottery procedure.

Differential sampling: If students in curriculum studies are sampled in different ways this may affect the results. *E.g.*, students who volunteer for studies tend to belong to the group of the best performing students. If they are compared to a group that includes all students the results may not be correct. This has often not been controlled for in previous studies except in the ones from the Netherlands.

Differential attrition: If more students graduate in one school than in another, it is reasonable to assume that it is not the best performing students that drop out but rather the opposite. The results from the school that has more drop outs would thus gradually become better. This has not been controlled for in any previous study.

Differential exposure: If poorly performing students do not drop out they may instead spend more time studying and improve the results of the school. This has not been controlled for in any previous study.

We want to add a fifth bias. Based on Hattie (2009) and the experience of ourselves and others we conclude that it is important to consider how PBL has been implemented in a curriculum. PBL can be implemented in so many different ways (Kinkade, 2005) that what you may actually compare are differences in the way PBL has been implemented. The Maastricht medical school introduced PBL early and their curriculum has been the subject of research since then. Thus, we know how PBL has been implemented and the results are not biased by other forms of implementation in other schools.

Schmidt et al. (2012) recalculated the data taking all bias in some of the previous studies into consideration and found increased effect sizes in the domains where effect sizes were previously shown to be negligible (*Table 3*).

Table 3. Differences in results in the cognitive domain by students from on the one hand "traditional" medical schools and on the other the problem-based medical school in Maastricht. Results are presented before and after correction for differential attrition and exposure (Schmidt et al., 2012).

Domain	Effect size before correction for bias	Effect size after correction for bias
Knowledge acquisition	0.02	0.31
Diagnostic reasoning	0.07	0.51

DISCUSSION

After this study of the literature, we believe that we can answer the question "Is PBL really a better way to teach and learn?" with a "yes". We also believe that an answer is emerging to the question "PBL makes a difference. But why? " posed by Norman (2008).

The characteristics of PBL according to our view should be the engagement of students in a discussion about something that has to be explained or solved. This discussion depends on evoking some specific cognitive processes like, *i.e.*, activation of prior knowledge. The discussion should include the verification/falsification of student generated hypotheses. This calls for discussions between students in an open climate. PBL assumes the presentation of something to be discussed by everybody in a group and it is a procedure that scaffolds the discussions. Attention to group dynamics is also an important aspect.

We hope that it is clear from this article that "better" implies competencies that advance beyond merely gaining factual knowledge for a test. When discussing PBL it is probably also important to remember that PBL curricula often put emphasis on communication, attitudes and training of practical skills which may contribute to the results.

So why do we say that PBL is "better"? Because evidence from cognitive psychology, neurobiology and results from correctly designed comparative studies support our conclusion.

Hattie (2009) has identified what matters from his synthesis of meta-analyses based on studies of real world pedagogical innovations and their effects. Many of the identified influences can be subject to teacher control and are particularly applicable for small groups of students, be it within PBL groups or not. At the very heart of these influences is bi-directional feedback, respect, meta-cognitive awareness and self-articulation. The evidence presented by Hattie (2009) gains further support from theories of cognitive psychology. The principles from cognitive psychology presented by Schmidt (1983, 1993), Gijselaers (1996) and Schmidt, Rotgan & Yew (2011) are probably more easily adopted in PBL than in other less formalized small group teaching formats. And, finally, the studies from the Netherlands have shown that the outcomes from a PBL-school were better than the ones from more traditional schools. The improvements of factual knowledge were, however, not as impressive as those of other competencies.

The emerging answer to Norman's question "why" is that PBL provides a scaffold to case-based small group work, as supported by the evidence presented above.

Norman (2008) also comments on the fact that PBL, once it was implemented at McMaster University, "caught on like fire" and spread all over the world despite the lack of convincing evidence for its effectiveness. Probably, PBL has often been implemented because of the reasons presented by Egidius (1999a,1999b). The introduction of PBL has been a logical consequence of currents of change in modern society to the extent that, to many early adopters, the alternatives have almost been unthinkable.

Maybe we should consider ourselves lucky that medical education leaders and teachers did not ask for evidence at the time. The early studies, where there were no convincing effects of PBL, all focused on factual knowledge, since the outcome measure was usually standardized knowledge tests. Medical schools were included in most studies, partly because they were the main adopters of PBL and perhaps also because the national tests in North America could be used for comparisons. Students' entry qualifications have an impact on the outcome of their studies (Hecker & Violato, 2008). When entry qualifications were corrected for, the difference between medical schools with different curricula was small, *i.e.* the individual differences between students' entry qualifications explained most of the variance (Hecker & Violato, 2008). Their study was performed with data from medical schools in the USA where national entry qualification tests as well as national exams can be used. In the USA and in most of Western Europe medical schools attract many students and high grades are needed to enter. These students have adopted strategies to cope with understanding and learning what is demanded by them. It is thus likely that curricular reforms will have limited effect on students who will graduate to a large extent irrespective of educational policies. Results from students with lower school grades might improve more (*cf.* Van den Berg & Hofman, 2005). Still, as we have seen above, substantial improvements have been shown from medical schools that have adopted PBL (Schmidt *et al.*, 2012). Also, the average medical student gains from PBL (Chng *et al.*, 2014).
However, the implementation of PBL requires careful planning. It has been shown that the quality of the cases and the competences of the tutors are the most important factors for the small-group learning in PBL curricula (Schmidt & Moust, 2000). Cases have to be designed so that the students will reach the intended learning outcomes and so that the level is well adapted to the knowledge and understanding of the students. Tutors need to learn how to best facilitate the processes in PBL. For both the development of cases and tutors, a support organization for faculty development is needed.

After having presented the arguments from the literature supporting the application of PBL for teaching and learning, we must also bear in mind that calling a learning activity PBL is not what matters for the outcome. It is the understanding and application of some critical learning principles that matter. These principles can easily be included in the PBL practice but also to some extent in lectures, group work and other forms of case based studies. What matters for learning is what students do, not what you call their activities!

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