Problem-based learning: future challenges for educational practice and research

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CONTEXT Problem-based learning (PBL) is widely used in higher education. There is evidence available that students and faculty are highly satisfied with PBL. Nevertheless, in educational practice problems are often encountered, such as tutors who are too directive, problems that are too well-structured, and dysfunctional tutorial groups.

PURPOSE The aim of this paper is to demonstrate that PBL has the potential to prepare students more effectively for future learning because it is based on four modern insights into learning: constructive, self-directed, collaborative and contextual. These four learning principles are described and it is explained how they apply to PBL. In addition, available research is reviewed and the current debate in research on PBL is described.

DISCUSSION It is argued that problems encountered in educational practice usually stem from poor implementation of PBL. In many cases the way in which PBL is implemented is not consistent with the current insights on learning. Furthermore, it is argued that research on PBL should contribute towards a better understanding of why and how the concepts of constructive, self-directed, collaborative and contextual learning work or do not work and under what circumstances. Examples of studies are given to illustrate this issue.

KEYWORDS problem-based learning/ *trends/ organisation & administration/ standards; education, medical/ *trends/ organisation & administration/ standards; consumer participation; motivation.

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INTRODUCTION

Problem-based learning (PBL) represents a major, complex and widespread change in educational practice within higher education, especially in professional education. Many medical schools from all over the world have implemented PBL. The central argument of this paper is that PBL is based on four modern insights on learning: constructive, self-directed, collaborative and contextual learning. In Part 1 of this paper, the key learning principles behind PBL are outlined.

PART 1: LEARNING PRINCIPLES

Key learning principles

Modern insights on learning emphasise that learning should be a constructive, self-directed, collaborative and contextual process. These four key principles are explained below.

Learning should be a constructive process

The constructive learning principle emphasises that learning is an active process in which students actively construct or reconstruct their knowledge networks. Learning is a process of creating meaning and building personal interpretations of the world based on individual experiences and interactions.[1] Competence is fostered not primarily by teaching to deliver knowledge, but through teaching to stimulate specific kinds of cognitive activities.[2] Elaboration is an example of such an activity. Elaboration can take several forms, such as discussion, note-taking or answering questions. Elaborations play an important

Overview

What is already known on this subject

Review studies on PBL demonstrate that students and faculty are highly satisfied with PBL and that there is some evidence that PBL seems to work.

What this study adds

This paper demonstrates how modern learning principles of constructive, self-directed, collaborative and contextual learning apply to PBL. The available research evidence is reviewed and debated as well as problems encountered in practice.

Suggestions for further research

Design-based research is needed in which it is investigated how theoretical claims can be transformed into effective learning in PBL is investigated: research that enriches our understanding of the nature of PBL.

role in activating existing or prior knowledge structures. It helps learners to relate new information to existing knowledge. This will lead to rich knowledge structures, because it increases the number of relations between concepts and facilitates activation of knowledge. In other words, learners should be involved actively and should be stimulated towards activation of prior knowledge, elaborations and deep learning because this leads to deeper and richer understanding and better use of knowledge.[3]

Learning should be a self-directed process

Self-directed learning implies that learners play an active role in planning, monitoring and evaluating the learning process.[4] Planning implies that a learner starts with considering a variety of ways to approach a task, sets a clear goal, selects strategies for achieving the goal and identifies potential obstacles to successful attainment of the goal. Monitoring implies that the learner is aware of what he or she is doing and anticipates what ought to be done next, by looking back and forward. After completion, evaluation takes place of both the process and the product of the learning process. Reflection plays an important role in the process of self-regulation.[4] Self-directed or lifelong learners plan, monitor and evaluate their own learning and direct or regulate their own learning process. Self-regulation involves not only cognitive self-regulation but also motivational self-regulation, and both are interwoven aspects of self-regulated learning. Motivation plays an important role in promoting and sustaining self-regulated learning.[5] In addition, prior knowledge is an essential prerequisite for self-regulated learning because it is needed to plan a learning goal and monitor the learning process.[6] In other words, learners should be stimulated to be aware of their prior knowledge and should be stimulated to regulate or direct their learning process both from a motivational and a cognitive perspective. Learners should be prepared to become lifelong learners who are able to acquire new knowledge and skills rapidly.

Learning should be a collaborative process

Collaboration is a social structure in which two or more people interact with each other and, in some circumstances, some types of interactions occur that have a positive effect. Collaboration is not a matter of division of tasks among learners, but involves mutual interaction and a shared understanding of a problem.[7] Collaborative learning takes place when the following conditions are met: participants have a common goal, share responsibilities, are mutually dependent and need to reach agreement through open interaction.[8] Factors within the collaborative learning situation which may enhance learning are elaborations, verbalisations, co-construction, mutual support and criticism and tuning in cognitively and socially.[8] In other words, learners should be stimulated to interact with each other because these interactions may positively influence learning.

Learning should be a contextual process

Learning always takes place in a context or, in other words, all learning is situated. The situation in which knowledge is acquired determines the use of this knowledge. Knowledge transfers less easily across different types of situations.[9] However, transfer can be facilitated by anchoring learning in meaningful contexts, revisiting content at different times in rearranged contexts, for different purposes and from different perspectives.[1] Viewing problem environments from multiple perspectives increases transfer of knowledge or the flexibility with which learners can deal with new sets of events and as such prepares learners for future learning. Viewing problem environments from multiple perspectives stimulates learners to appreciate critical features of the cases

presented to them, and helps them to abandon previous assumptions.[10] In conclusion, learners are preferably exposed to a professionally relevant context and confronted with cases or problems from multiple perspectives, because this stimulates transfer of knowledge.

In the following section, how the learning process within PBL is organised and fits with these learning principles will be outlined.

Learning principles applied to PBL

Although PBL differs in various schools, three characteristics can be considered as essential: problems as a stimulus for learning, tutors as facilitators and group work as stimulus for interaction.

(Patient) problems as stimulus for learning

In order to stimulate students' learning, students in PBL are confronted with problems. These problems consist of a description of some phenomena that need to be explained. When trying to explain the phenomena in the problem students discover what they already know about the problem, but they also discover what they do not yet know or which questions still need to be answered and require study. Problems are the driving force behind students' learning in PBL and are used to engage students actively in their own learning. Problems are used in PBL to stimulate students to construct new knowledge actively that is linked strongly with their previous knowledge. The problem is the focus for acquiring knowledge and fosters flexible thinking.[11] Problems used in PBL are often realistic problems that are presented in the context of a patient problem. The use of problems in PBL makes learning in PBL a constructive and contextual process.

Tutors as facilitators

A second important feature of PBL is that teachers are facilitators who stimulate students towards self-directed learning. The tutor's task is to keep the learning process going, to probe the students' knowledge deeply, to ensure that all students are involved in the process, to monitor educational progress of each student in the group and to modulate the challenge of the problem.[12] The role of the tutor is to scaffold student learning, which implies that the tutor stimulates elaboration, integration of knowledge and interaction between students by means of asking for questions, asking for clarifications and application of knowledge.[13] In order to stimulate students towards self-directed learning, a tutor should not transmit his expert knowledge to the student, but should probe students' knowledge by encouraging specific kinds of cognitive activities. The role of the tutor as being a facilitator of the learning process in PBL makes learning in PBL a self-directed process.

Group work as stimulus for interactions

A third important characteristic of PBL is that learning takes place in small groups. In PBL, problems are discussed in small groups of students. In this collaborative learning environment students learn from interacting with each other, e.g. by explaining the materials to another student and by asking and answering questions and by discussion. In PBL groups, students work together to construct collaborative explanations. In addition, students learn to work together, which may help them to become better collaborators.[11] Finally, a group is assumed to motivate students. Thus, the tutorial group work in PBL makes learning in PBL a collaborative process aimed at stimulating students towards interactions that are intended to have a positive effect on learning.

PART 2: PBL IN PRACTICE

Problems in educational practice

PBL is a complex learning environment in which different variables influence each other mutually. In this sense it is not a surprise that, in practice, problems are often encountered.

The central message of this second part is that these problems usually stem from a poor implementation of PBL. In order to illustrate this message, three examples of problems that are often encountered in educational practice are described. The examples given are related closely to the three main characteristics of PBL as described above: problems as stimulus for learning, tutors as facilitators and group work as stimulus for interactions. These problems are selected to demonstrate that PBL does not always stimulate students towards constructive, self-directed, collaborative and contextual learning as will be outlined below.

Too well-structured problems

Designing effective problems is not an easy task. In some PBL curricula students are confronted with problems that are too well-structured, too close-ended and too simple, due to which students are

not challenged to construct knowledge actively. Furthermore, problems are all too often not realistic. The problems used are mainly paper problems; real patients are seldom used. In this situation, PBL does not stimulate students' towards constructive or contextual learning. However, there is a trend to make more use of real patients.[14,15]

Too directive tutors

Another problem is that some tutors in PBL are too dominant. Hendry, Ryan and Harris[16] reported that a dominant tutor causes tension and conflict in groups which leads to lack of commitment, cynicism or student absenteeism. Conversely, if the degree of tutor regulation is too loose, e.g. a tutor who is too passive, there is also a problem. Dominant tutors in the group hinder the learning process, but the quiet or passive tutor who is probably trying not to teach also hinders the learning process. In both situations, PBL cannot be characterised as self-directed.

Dysfunctional tutorial groups

Many faculty members and also students in PBL have experienced dysfunctional tutorial groups. Various studies have been conducted investigating this problem. Hitchcock and Anderson[17] described apathetic groups, groups cynical about PBL not discussing problems, and groups with passive tutors. Dolmans *et al.*[18,19] describe situations in which PBL leads to ritual behaviour, being a group in which specific kinds of cognitive activities such as elaborations and activation of prior knowledge do not take place. In these groups, new ideas are brought into the discussion without connections being made to other ideas. Students in these groups maintain an appearance of being involved, but their behaviour is ritual. Another discouraging experience is a group that is faced with some group members who do not prepare for the meeting and let others do the work in the group, which might lead to less involvement from those students who were motivated initially. De Grave, Dolmans and van der Vleuten[20,21] investigated the occurrence of critical incidents in tutorial groups. These studies demonstrated that lack of elaboration, lack of cohesion and lack of motivation highly inhibited the learning process in PBL. In conclusion, dysfunctional tutorial groups can be considered as a situation in which learning is not a collaborative process that has positive effects on student learning.

Two remarks should be made; first, the three problems described here are examples of problems that are often encountered in practice. There are, of course, other problems encountered in daily practice, such as problems with assessment, but these are not described here. Secondly, the problems described are related closely to each other. Problems that are too well-structured do not fit with students' prior knowledge, therefore they do not require students to actively construct their own knowledge which might lead to dysfunctional tutorial groups. Tutors who are too directive or too passive hinder the learning process, which might lead to dysfunctional groups. In the following paragraph, what is needed in educational practice in order to deal with the problems described above is described.

How to solve problems with PBL in educational practice

The problems of educational practice described above might convince critics of PBL that PBL does not work. However, we would argue that these problems are in fact implementation problems. Due to poor implementation of PBL, the learning process does not stimulate students towards constructive, self-directed, collaborative and contextual learning. In the next paragraphs we explain how the three problems described above need to be solved in practice, in order to implement more effectively the learning principles behind PBL.

In order to stimulate students towards constructive and contextual learning more complex, realistic, open-ended, and ill-structured problems are needed that fit with students' prior knowledge.[11,22] In addition, students should be confronted with contrasting problems, because they are helped to appreciate the critical features of new information, to evaluate new information critically and to change their views when necessary.[10] Steinert[23] investigated students' perceptions about effective small group teaching and found that students emphasised the importance of clinical relevance of problems and that they appreciate tutors who expanded the problem to another clinical situation. Arts, Gijselaers and Segers[24] conducted a study in which they redesigned a PBL course by optimising the authenticity of the problems and used ill-structured real-life information, gave students increased control over their learning as they worked more independently and in which they had to work in small groups and measured the outcomes. They found that the redesigned PBL format contributed significantly to improved cognitive gains compared to the regular PBL setting.

In order to challenge students and stimulate them towards self-directed learning, there should be a

constructive friction between the degree of student and tutor regulation.[25] What is needed in PBL is a transition from tutor regulation, or external guidance through shared guidance in which the student and the tutor together guide the learning process to student regulation or internal guidance.[26] This implies that PBL curricula should be characterised by more tutor guidance at the beginning through shared guidance of both the student and the tutor to more student guidance at the end. A tutor should orientate his teaching towards the students' learning process. The best tutor knows when and how to intervene and has the students' learning as his top priority.[27]

In order to improve tutorial group functioning and stimulate students towards collaborative learning, tutors should evaluate the functioning of their group on a regular basis. Furthermore, tutors should learn how to deal with problems of group dynamics.[18,19] If the problems used are more complex and ill-structured and if there is constructive friction between student and tutor guidance, there is a better chance that interactions in the group that enhance student learning and the collaborative learning process will occur. In addition, learning and assessment should be better integrated, which implies that assessment instruments need to be used that are consistent with the learning principles described above. This implies that more authentic assessment, more self-assessment, more peer-assessment, group assessment and assessment of professional behaviour is needed.

In conclusion, the key to successful implementation of PBL lies in designing a learning environment that stimulates students towards constructive, self-directed, collaborative and contextual learning and in consistency in or alignment between all aspects of the curriculum, such as the problems used, the tutors' guidance and the assessment employed.[18]

PART 3: PBL RESEARCH

In this third part, the available research evidence will be reviewed as well as the current debate in research on PBL. In addition, what is needed in future research will be argued.

Review studies on PBL

Several review studies have appeared in the literature on PBL in the early 1990s and since 2000. The type of reviews conducted differs remarkably between the two periods.

The early 1990s reviews

In 1992, Norman and Schmidt[28] reviewed the evidence behind some theoretical advantages claimed for PBL. These advantages are that activation of prior knowledge facilitates processing of new information and that elaboration enhances the use of knowledge: two advantages that are linked closely to the key principles of constructive and collaborative learning. Another advantage claimed is that learning in context in PBL stimulates transfer of knowledge and that PBL stimulates self-directed and lifelong learning, two advantages that are linked closely with the key principles of self-directed and contextual learning. Norman and Schmidt[28] conclude in their review that there is a strong theoretical basis for the idea that PBL students may be better able to transfer concepts to new problems, and that there is some preliminary evidence to this effect. Thus, PBL stimulates contextual learning in the sense that it enhances transfer of concepts to new problems. This does not imply that PBL curricula result in better general content-free problem-solving skills, because these skills are content-specific, i.e. they are not independent of the acquisition of knowledge. Furthermore, they conclude that there is evidence that group discussion in PBL stimulates the activation and elaboration of prior knowledge which facilitates increased retention of knowledge. Thus PBL stimulates students towards constructive and collaborative processes which influence learning positively. Norman and Schmidt[28] conclude furthermore that PBL appears to enhance self-directed learning skills. They refer to a study conducted by Blumberg and Michael,[29] in which it is reported that PBL students make more frequent use of the library to access information and borrowed more material from the library than students involved in a traditional curriculum. Thus, PBL stimulates students to become self-directed learners. Evidence for this claim and the key learning principle of self-directed learning also comes from a more recent study conducted by Schmidt and van der Molen.[30] In this study, PBL graduates rated themselves as better prepared than colleagues who were trained with conventional curricula for collaboration skills, problem-solving skills, skills relevant to run meetings and the ability to work independently. Thus, there is some evidence available that PBL does indeed prepare more effectively for lifelong or self-directed learning.

Another important review in the early 1990s was written by Albanese and Mitchell.[31] They examined the effects of PBL and reviewed many studies conducted between 1972 and 1992. They concluded that PBL produced some very positive outcomes in

schools, in that students are highly satisfied. In addition, graduates of PBL curricula view themselves as being better prepared in independent learning skills and some studies demonstrate that PBL students demonstrate self-directed study behaviour. Furthermore, teachers find PBL a satisfying way to teach. In 1993, two other important reviews on PBL appeared. One review was written by Vernon and Blake[32] and the other by Berkson.[33] In these two reviews it was also concluded that PBL students are highly satisfied.

In general, the reviews conducted in the early 1990s demonstrate not only that students and faculty are highly satisfied with PBL, but they also demonstrate that PBL stimulates students towards constructive, collaborative and self-directed learning. In addition, these reviews demonstrate that there is some preliminary evidence that another learning principle, namely contextual learning stimulating transfer, also seems to work. The strengths of these reviews are that they focus on the theoretical claims behind PBL.

Reviews since 2000

Since 2000, several new reviews have appeared in the literature. In 2000, Colliver[34] reviewed eight studies on PBL conducted in the period 1992–1998. All eight studies involved comparisons of curriculum tracks. Three studies were randomised and five were non-randomised. Based on these eight studies, Colliver concluded that the literature revealed no convincing evidence that PBL improves knowledge and clinical performance, at least not of the magnitude of effectiveness hoped for with this major curriculum intervention.[34] A more recent review was conducted by Newman and others.[35] In this review, only randomised controlled trials and quasi-experimental studies were included in which student performance or other outcomes are objectively measured. They identified 91 citations, but based their conclusions on only 14 studies that met the inclusion criteria. Based on these 14 studies they concluded that outcomes for students in the PBL groups were less favourable than those in the control group. Another recent meta-analysis of the effects of PBL was written by Dochy *et al.*[36] For this study, 43 articles were selected. The results demonstrated that there is a positive effect from PBL on skills (i.e. knowledge application) of students. No effect on knowledge was found.

In general, the reviews conducted since 2000 focused mainly on comparing conventional and PBL curricula and measuring the outcomes or effects of PBL. The weakness of these reviews is that they do not focus on the theoretical claims behind PBL, due to which they do not provide us with better insights into why or why not PBL might work under which circumstances.

The current debate on research in PBL

The current trend in research to compare PBL with conventional curricula has led to a debate in the literature. Norman and Schmidt[37] argue that trials of curriculum level interventions are a waste of time and resources because there is no such thing as a blinded intervention, neither a pure nor a uniform intervention. In these complex and multifactorial environments, effects are inevitably diffused by a myriad of unexplained variables, due to which it is impossible to attribute success or failure solely to the intervention.[37] The review by Newman led to a similar critique by Farrow and Norman[38] and Dolmans.[39] In these critiques it is argued that randomised controlled trials are not the most appropriate tool for evaluating educational interventions, because of its complexities.[38] Research in which interventions are treated as one variable lead all too often to inconclusive results in which some studies report positive findings, some negative findings and some zero findings.[39] Or, as Berliner has written: 'To think that randomised experiments are the only ones that yield trustworthy evidence is a misunderstanding of educational research'.[40] Thus, the reviews that have appeared since 2000 have been criticised because of their strictness in including only studies in which conventional and PBL curricula are compared. In these reviews only whether PBL works in terms of end-goals is investigated, but the underlying theoretical foundations of PBL are not addressed.[38] They focus too much on scientific methods and less on the process of science or theory-building.

What is needed now and in future research?

Research needs to be grounded firmly in literature which has been derived and organised around major theoretical constructs.[41] Modern theories on learning emphasise that learning should be a constructive, self-directed, collaborative and contextual process, as outlined previously. These concepts are the ingredients of the theoretical basis for PBL. Research on PBL should contribute towards a better understanding of why and how these theories or concepts work or not in PBL and under what circumstances. There are studies available that contribute towards science or theory-building and shed some light on aspects of

PBL that do make a difference, as will be outlined below; examples of these studies are described.

Examples of studies focusing on the constructive learning principle

An important stimulus within PBL for students' learning is the problems presented to students. From process-orientated studies in which the relationship between different key aspects of PBL was investigated, such as students' prior knowledge, quality of problems, tutor functioning, group functioning and student achievement, it is known that the quality of the problems influences to a high degree the quality of the tutorial group process and learning outcomes of PBL or that problems are a key aspect of PBL.[42] Van den Hurk *et al.* investigated the relationship between individual study and group discussion.[43] Preparing extensively for the tutorial meeting is especially important for the depth of the reporting phase. In another study, Van den Hurk tested a causal model in which the relationship between quality of learning issues, an explanation-orientated approach, depth of reporting and breath of reporting on student achievement was investigated.[44] The results of this study demonstrate that in-depth reporting leads to higher achievement. Making summaries and explaining concepts to other students in their own words will lead to deeper understanding.

These studies are examples of process-orientated studies that have shed some light on how the different variables in PBL influence each other and contribute towards the learning principle of constructive learning. Another interesting study focusing on the principle of constructive learning was conducted by De Grave, Boshuizen and Schmidt,[45] who investigated cognitive processes during problem analysis. Interactions taking place in tutorial groups were videotaped and these interactions were analysed. The results of this study demonstrated that the discussion concerned mainly theory building, e.g. causal reasoning. In addition, stimulated recall sessions were conducted with individual students after discussion in the tutorial group to investigate what happened within an individual student's thinking during the group discussion. The data demonstrated that PBL induces cognitive conflict within students leading to conceptual change. This latter study is an excellent example, which provides us with clearer insight into the interaction processes taking place in tutorial groups and how the learning principle of constructive learning in PBL leads to more effective learning.

Examples of studies focusing on the self-directed learning principle

The tutor role in PBL has attracted the interest of many researchers and has led to an abundance of literature. The findings of these studies are often contradictory. In some studies it is concluded that an expert tutor is the best solution and in others the opposite is shown. Because many studies on tutoring revealed contradictory findings, some researchers began to conduct studies in which the relationship between tutor characteristics and differential contextual circumstances were investigated.[46] The idea behind these studies is that PBL is a complex learning environment in which different variables influence each other mutually. Schmidt investigated whether there is an effect of tutor expertise on test scores under conditions of PBL courses with low or high structure and curricular materials that match poorly or well to students' level of prior knowledge.[47] He concluded that when the structure of a course is low and/or students lack prior knowledge, the impact of a tutor's expertise on student performances is greater. In other words, a tutor's expertise compensates for lack of structure and prior knowledge. Thus, content expert tutors are better able to deal with courses that are less structured and fit less with students' level of prior knowledge. This type of research has shown that a tutor's performance is partly situation-specific and dependent on contextual circumstances, such as the quality of the problems, the structure of the unit, link with students' prior knowledge.[47] Next to the studies focusing upon the influence of the structure of curricula, Dolmans *et al.*[48] conducted a study in which it was demonstrated that tutorial groups with relatively low levels of productivity require much more input from a tutor than highly productive groups. These studies help us to explain more clearly how the principle of self-directed learning works in PBL and demonstrate that constructive friction between tutor and student regulation should differ in various circumstances.

Examples of studies focusing on the collaborative learning principle

Miflin argues in a recent paper that, before we throw the baby out with the bathwater, we need to understand more clearly how the teacher–learning process works in small groups.[49] An example of a study focusing on the collaborative learning principle is that conducted by Dolmans *et al.*, in which motivational and cognitive processes influencing tutorial groups were investigated.[50] In this study, theories described by Slavin[51] on collaborative learning are

used. This author distinguishes four major theoretical perspectives on collaborative learning that might be useful for a better understanding of tutorial group functioning in PBL. The first theoretical perspective is a motivational one, in which a group motivates its group members to exert maximum effort because a member can attain its personal goals only if the group succeeds, so group members help each other because it is in their own interest to do so. The second theoretical perspective is a cohesiveness perspective, which implies that a group develops team spirit. In other words, students help their group because they want the group to succeed. The third is a developmental perspective which implies that interactions play an important role in student learning. The opportunity to discuss, argue, present and hear each others' viewpoints stimulates students learning. The fourth is a cognitive elaboration perspective, in which it is emphasised that student learning is enhanced by students explaining material to someone else, providing feedback and by linking information to students' prior knowledge. The first two perspectives emphasise motivation, the second two focus on cognitive explanations. In the study conducted by Dolmans *et al.* motivational and cognitive processes influencing tutorial groups were investigated based on these four major theoretical constructs.[50] The major finding of this study was that there are linear relationships between a tutorial group's success and all motivational and cognitive processes and that the interaction dimension had the highest weight in predicting that success. This study provides an example in which theories on motivation and cognition are used to understand more clearly the collaborative learning process that takes place in tutorial groups in PBL. In a more recent study conducted by Visschers-Pleijers *et al.*, a method was explored to analyse group interactions in PBL.[52] The focus was on elaborations and co-constructions, which are indicators of individual and collaborative knowledge construction. Videotapes were transcribed and the results demonstrated that co-constructions seemed most easy to elicit from the transcripts. This study can also be considered as an example of one which contributes towards theory building and which sheds more light on the theoretical claim that PBL stimulates students towards collaborative learning.

CONCLUSION: THE BRIDGE BETWEEN THEORY AND PRACTICE

What is needed now and in the future is research that focuses on the theoretical concepts underlying PBL and is aimed at a clearer understanding of how PBL does or does not work and under which circumstances. These studies should also provide us with guidelines on how to deal with problems encountered in PBL practice, as described in Part 2 of this paper. Thus, more research needs to be conducted to find out how PBL stimulates students towards constructive, self-directed, collaborative and contextual learning. More theory-based research does not only imply research that is detached from practice. What is needed is research that bridges theory and practice and extends knowledge about developing and improving PBL in everyday practice. Design-based research is needed which blends empirical educational research with the theory-driven design of learning environments that helps us to understand how, when and why educational innovations work in practice[53]. In design-based research, the design of learning environments and developing theories of learning are intertwined. Development and research within this type of research take place through cycles of design, enactment, analysis and redesign. In design-based research how theoretical claims can be transformed into effective learning in educational practice is investigated.[54] Design-based research goes beyond merely designing and testing particular interventions. It makes use of mixed methods, triangulates multiple sources and types of data and does not rely on a single method such as randomised trials or laboratory studies, or a single source of data such as outcomes. Research is needed in which practitioners and researchers work closely together.

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