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Innovations in Problem-based Learning: What can we Learn from Recent Studies?

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Abstract. This article aims at discussing the six papers included in this special issue on innovations in Problem-based learning (PBL). The papers address different aspects related to the implementation and the development of PBL. This discussion article highlights the relevance of the theme explored by each of the papers, the contributions emerging from the study to what is already known about that topic, and its limitations, particularly those that suggest directions for future research. Emphasis is given to new insights brought by the papers for better understanding tutorial group processes and self-study phase in PBL. The contributions provided by the papers are discussed in the light of pertinent literature and also in relation to their companion articles in this issue when indicated.

Key words: Problem-based learning, discussion article

Introduction

Problem-based learning (PBL) represents a major and widespread change in health professions education. During the last three decades, higher education institutions from various countries have initiated new programs or restructuring existing ones based on PBL. Interestingly, this spread of PBL all over the world has not been supported by empirical evidence coming out from studies aimed at comparing traditional and PBL curricula. Reviews conducted in the early 90s and in 2000 did not show large differences in favor of PBL students when compared with their peers from traditional curricula on conventional measurements of knowledge such as national licensing exams (Albanese and Mitchell, 1993; Colliver, 2000). These studies suggested an effect of PBL on students' satisfaction and on their ability for clinical problem-solving. These benefits, however, seemed to be, for some researchers, not enough to justify costs involved in changing traditional educational

approaches towards PBL (Colliver, 2000). More recent reviews using large educational trials to examine the effectiveness of PBL have contributed to raise the debate again. As an example, a systematic review conducted in 2003 presented mixed results in measures of accumulation of knowledge, with some studies indicating advantages for PBL and others for conventional curricula (Newman, 2003). In the same year, another review pointed to positive effects of PBL on students' ability to apply knowledge, although no significant differences on measurements of knowledge have been found (Dochy et al., 2003). At this point, readers might be feeling lost by being confronted with these confounding, sometimes contradictory, apparently inconclusive findings. What do all these studies on effectiveness of PBL versus traditional curricula, at the end, have to tell us? Where do the scientific bases for the spreading of PBL come from, if not from these studies? Indeed, the first question has led to an intense, challenging debate suggesting research approaches that can better contribute to generating new knowledge on PBL (e.g., Dolmans, 2003; Norman, 2003; Dolmans et al., 2005; Norman and Schmidt, 2000). This question is explored by the paper by Newman (this issue), and we will come back to it later on in our article. By now, let us move to the second one. What could explain the dissemination of PBL all over the world?

Arguments in support of PBL have emerged, in fact, from another research perspective oriented towards examining evidence of theoretical foundations underlying PBL. In line with this perspective studies have investigated whether, why and how the several variables present in a PBL curriculum interfere and relate to each other to promote constructive, collaborative, self-directed, contextual learning (Dolmans et al., 2005). A variety of theory-driven studies followed the initial ones conducted in the early 90s. Many of them were experiments carried out under controlled, laboratory conditions. Multiple research methods, however, have been used to generate an accumulation of knowledge on processes occurring on the several phases of PBL and their effects on learning (Norman, 2003; Norman and Schmidt, 2000). For instance, causal models for learning in PBL have been tested. The first attempt to visualize the relationships between several variables acting in PBL was the study conducted by Gijselaers and Schmidt (1990). A model was conceptualized relating input variables (the quality of the problems, tutor performance and students' prior knowledge), process variables (group functioning and time spent on individual study) and outcomes of the learning process (interest in subject matter and achievement). It was demonstrated that the quality of the problems influences the functioning of the tutorial groups, which, by its turn, strongly influences time spent in individual study. As expected, time invested in study positively influences learning outcomes. This model has provided a basis for further studies aimed at exploring more in depth what happens during the diverse PBL phases. Van der Hurk and colleagues (2001), for example, refined this model to

examine relationships between learning issues generated in tutorial group discussions, learning approaches adopted by students during their individual study time, discussions in tutorial group reporting meetings, and achievements. These studies have shown the influence on learning of two main components of the learning cycle: Tutorial groups and the preparation phase in which students individually search for relevant learning resources and acquire new information to be shared with colleagues in the reporting group meeting.

These studies exemplify a research perspective that has concentrated efforts in fostering understanding on why, how and in which conditions the educational principles and learning mechanisms underlying PBL work in practice. By using multiple methods and approaches, replicating studies in different conditions, triangulating data from diverse sources, these research efforts have led to important advances in knowledge required to guide the development of PBL programs. Most of the papers included in this special issue fit in with this perspective. Dolmans and Schmidt (this issue) presented a synthesis of the literature on small group learning in PBL. Three other articles (Loyens et al., this issue; Te Winkel et al., this issue; Verkoeijen et al., this issue) reported studies that used different methodological approaches to explore several aspects of the learning process in PBL. The contributions provided by these papers are particularly relevant for better understanding variables affecting two main components of PBL: Tutorial-group learning and individual learning process. It can be easily perceived that these elements are not isolated and the studies indeed explored their relationship. O'Neill and colleagues (this issue) reported a study aimed at exploring the link between clinical experience and learning in PBL, an aspect that may have implications that go beyond the PBL phases themselves. The paper by Newman (this issue) addressed the discussion on research strategies appropriate for developing knowledge on PBL.

In this discussion paper we present comments to each of these articles, by calling attention particularly to new insights brought to what is already known about tutorial group processes and self-study phase in PBL. Their contributions are discussed in the light of pertinent literature and also in relation to their companion articles in this issue when indicated. Limitations of the articles that suggest themes for further investigation are also highlighted. By commenting on the paper by Newman (this issue) we discuss the arguments on research that can better contribute to educational development, which closes our article.

New Contributions to Understanding Learning Processes in Tutorial Groups in PBL

An important part of learning in PBL takes place in small tutorial groups. Early studies have well demonstrated that discussions in tutorial groups

facilitate activation of prior knowledge and elaboration of newly acquired information, thereby enhancing retention of knowledge (Norman and Schmidt, 1992). Both the discussion meeting, in which students analyze the problem, and the reporting meeting, when they report back results of their individual study, provide students with opportunities for explaining own ideas, facing other points of view, enriching understandings about a problem, and restructuring their knowledge networks. Small tutorial group processes are indeed considered a main strategy for promoting constructive, collaborative learning in PBL (Van den Hurk et al., 2001; Dolmans et al., 2005). Tutorial group functioning was also shown to influence other components of the PBL cycle, such as the individual study, and to affect outcomes of the learning process (Gijselaers and Schmidt, 1990; Van den Hurk et al., 2001).

Interest in examining processes that take place in tutorial groups and how they affect learning in PBL has grown associated to increasing importance recently attributed to collaborative learning. The paper by Dolmans and Schmidt (this issue) provides a relevant contribution to better understanding cognitive and motivational effects of tutorial groups on students' learning in PBL environments. Through reviewing pertinent articles published in the major medical education journals over the last 18 years, the authors synthesize what is known about small group learning in PBL. Cognitive contributions of tutorial group processes are reinforced. Several studies have indeed reaffirmed the potential role of tutorial groups in promoting activation of prior knowledge, recall of information, theory building, conceptual change, and collaborative construction of knowledge. Evidence of positive effects of tutorial groups on students' motivation is also presented.

The distinction made by the authors between theoretical, potential contributions of tutorial groups and their effects in practice (and signs of cautious emerging from it) represents probably the most interesting message of the paper. Attention is called to factors that can prevent effectiveness of tutorial group processes and hinder learning. Two aspects could be highlighted as coming out from the synthesis presented in the article. First, the two dimensions (cognitive and motivational) explored when studying the contributions of tutorial groups in learning are strictly related. Discussions in tutorial groups may indeed play an important motivational role in stimulating students' engagement in learning process. This seems to depend, however, on the extent to which the potential cognitive contributions of the tutorial group processes in fact come out. This aspect is related to the second one: How students interact with each other and with the learning materials in tutorial groups emerges from this review of the literature as a main issue of concern. It is not sufficient to organize learning cycle in small tutorial groups for ensuring their potential benefits. Positive effects of tutorial groups depend largely on processes taking place during the discussion and reporting phases.

The article calls attention to the crucial role played by students' interactions during tutorial group meetings, an aspect that has been increasingly examined. Recent studies have tried to bring light to these interactions and have pointed to the importance of elaboration and co-construction for an effective functioning of tutorial groups (Visschers-Pleijers et al., 2004). Elaboration, a process that occurs within an individual but as a result of interactions with others, leads to reconsidering a topic in a richer or wider way. Co-construction occurs when two or more students engage in discussion to reach a shared understanding about a problem. Lack of elaboration and co-construction together with disorganized or haphazard tutorial discussions have been recognized, both by students and tutors, as hindering learning and motivation. They have been also related to surface study and to the so-called "ritual behavior", when students are apparently involved in discussions in group meetings, without, however, effectively engage in cognitive activities such as elaboration and interaction (Dolmans et al., 2005). Ritual behaviors have been suggested to occur when students do not study in depth and, therefore, during the reporting phase, new ideas are brought to discussion without connections with other ideas, and themes are superficially addressed (Dolmans et al., 2001). As a consequence, quality of reporting phase decreases, with negative effects on learning outcomes (Van den Hurk et al., 2001).

Innovations that have been adopted to deal with these difficulties and revitalize tutorial groups functioning are presented by Dolmans and Schmidt in their paper (Dolmans and Schmidt, this issue). They restricted this discussion, however, only to two possible interventions, which are, the introduction of study teams for enhancing students' motivation during the self-study phase and the use of instruments to evaluate group functioning and students' professional behaviors in tutorial groups. Other alternatives could have been considered at least from a theoretical point of view and as a means to identify themes for further exploration. An example refers to strategies to address students' view about learning interactions. Studies have suggested that students perceive in a negative way the arising of conflictive arguments or contradictions on the topics under discussion in the tutorial groups. Reasons underlying this view are not presently clear but they may certainly restrict students' engagement in conflictive discussions with their peers about a topic. Conflicts, however, favor conceptual change and are, in fact, desirable from a cognitive point of view. There seems to be room for acting here both in terms of research aimed at better understanding students' perceptions and with respect to interventions to change them. The tutor performance could also be expected to play a role in improvement of tutorial groups functioning. Students referred to disorganized or haphazard discussions as hindering learning. Influences of tutors' approaches on learning interactions may require further exploration.

Other articles in this issue also provide insights for better understanding processes taking place in tutorial groups, factors influencing them, and ways for enhancing cognitive and motivational contributions of tutorial groups for learning. The following sections explore these contributions.

How Does Type of Problems Influence Tutorial Groups and Individual Learning Processes?

The quality of the problem presented to the tutorial groups has been considered to influence tutorial group discussions and learning outcomes in PBL environments. In one of the first studies aimed at testing causal models of PBL, the quality of the problem was shown to affect group functioning and interest in subject-matter (Gijselaers and Schmidt, 1990). Moreover, it indirectly influenced the amount of time dedicated to individual study and, therefore, achievement.

The quality of the problem depends on a range of criteria. One of them has been suggested to be the extent to which the problem is ill-structured, open-ended, requires collaborative work, and favors generation of learning issues that are meaningful to the students (Miflin et al., 2000; Hmelo-Silver, 2004). These characteristics of a high-quality problem are consistent with the active involvement in learning expected from students in PBL. They have been considered conditions for promoting motivation and engagement in self-directed learning during the individual study phase. It is reasonable to expect, therefore, that problems that require students to collaboratively identify and negotiate learning issues respond better to these criteria than those that provide students with their expected learning goals.

Verkoeijen and colleagues (this issue) started from this assumption and used an experimental approach to investigate the effects of the type of problem (with regards to provision or non-provision of learning issues) on variables related to learning processes during tutorial group and individual study phases. They measured time spent on individual study, number of articles read during this phase, time used for the discussion and the reporting meetings in tutorial groups, and quality of aspects of the PBL cycle as perceived by the students. Findings suggested a positive influence of goal-free problem on study time, number of articles read, and time used for the reporting phase. Comparisons regarding quality of aspects of the PBL cycle did not reach statistical significance. The authors, however, called attention to ''statistical trends'' suggesting that students who had worked with the goal-specified version of the problem evaluated their discussion meeting more positively than their colleagues who had received the goal-free problem. They considered to have discussed the problem more deeply, with more extensive elaborations, and assessed the quality of their discussion phase higher than

their colleagues in the other condition. On the other hand, students who had worked with the goal-free version of the problem perceived to have more mastery of the subject-matter after the reporting phase. Although none of these comparisons have reached statistical significance, they were considered as suggesting trends that were used to explain findings related to increasing study time, higher number of articles read and more time for reporting phase associated to goal-free problem. Two possible mechanisms were presented as potentially explaining these findings. First, a ''discrepancy-reduction'' mechanism: Students working with the goal-free problem would engage in additional study led by the need to reduce either uncertainty about learning objectives or a less perceived mastery of the subject-matter. Second, a motivational mechanism through which students in the goal-free condition, as they could generate their own learning issues, would develop more ownership of the learning process.

The study represents an interesting example of an experiment conducted in a naturalistic environment aimed at examining the influence of one variable on other variables related to the learning process in PBL. Study findings apparently reinforce the benefits potentially obtainable by maintaining coherence between learning materials used (in that case, the type of problem in terms of provision or non-provision of learning issues) and self-directedness in learning, one of the main theoretical foundations underlying PBL. The two mechanisms through which the authors explained their findings could reasonably be expected to influence students' engagement in self-directed learning during the preparatory phase. However, questionings may be generated by analyzing insights provided by the literature on variables affecting tutorial group processes and individual study in PBL. Let us consider, for example, the synthesis of what is known about small group learning in PBL conducted by Dolmans and Schmidt (this issue), previously discussed, and some questions come out. First, the potentially positive influence of tutorial groups on students' motivation to learning has been considered, both by students and tutors, to depend largely on the quality of interactions in tutorial group meetings, represented mainly by students' engagement in elaboration and co-construction (Dolmans et al., 2001, 2005). If the findings of students' evaluation of the quality of the PBL cycle are taken into consideration, as the authors did, students who worked with the goal-specified version of the problem apparently engaged in richer learning interactions during the discussion phase. This would, indeed, be expected to positively influence their motivation to study. Moreover, studies have suggested that the quality of the discussions during the analysis of the problem influences the extent to which students select the literature on the basis of the learning issues and prepare themselves to the following discussion. This approach used by students during their individual study, by its turn, influences the

quality of the reporting phase (Van den Hurk et al., 2001). Second, disorganized and haphazard discussions have been suggested to decrease motivation and to lead to surface study, thereby hindering learning. Learning issues that do not clearly specify what is to be studied have also been associated to ritual behaviors in tutorial groups, which are also expected to reduce motivation. Would it not be reasonable to consider that students who had the goal-free version of the problem were more likely to face these situations than their colleagues? Third, time allotted for the reporting phase, one of the variables studied, does not necessarily represent quality of the phase. A recent study explored two aspects related to the reporting session: Depth of the discussion (indicating the extent to which the newly learned information was integrated with each other) and breadth of the discussion (indicating the extent to which a variety of topics related to the problem was discussed) (Van den Hurk et al., 2001). Although time had not been reported, apparently both factors could lead to increasing time of reporting meeting. However, while the depth of the discussion in the reporting phase was associated to higher achievement, the breadth of the discussion was not related to the scores in the tests. The questions presented above suggest that more investigation would be important to better explain findings, their underlying mechanisms and their implications. Some limitations of the study may also suggest directions for future research.

A first comment regarding limitations of the study refers to subjects, who were restricted to first-year students, and to the fact that only one problem was taken into consideration. Results could apply specifically to this problem. Time dedicated to individual study and the number of articles read indeed showed to be extremely, surprisingly low. This suggests limitations to generalize findings and indicates the importance of extending investigation to involve other students and problems. The authors attempted to explore quality of phases and components of the learning process. This is a strong point of the study as it opens perspectives for exploring interactions between several variables. Indeed various aspects were measured, but only the perception of the students was considered. Aspects such as ''quality of the discussion phase'' and ''quality of the reporting phase'' could certainly be further explored, in future studies, in terms of their cognitive and emotional elements. Besides that, as the authors acknowledge, outcomes of the learning process in terms of achievement were not evaluated. The study reinforces, therefore, the importance of future research to gradually improve understanding of how these several variables relate to type of the problem and influence learning.

Linking Clinical Experience to Discussions in Tutorial Group: Does it Matter?

The relationship between tutorial group processes in PBL and students' clinical experiences has been rarely explored by the literature. Curricula that

maintain PBL tutorial activities when students are already working in clinical settings may be limited in number. It may also be possible that strategies aimed at facilitating the link between clinical experiences and problems discussed during tutorial groups are not inserted in the curricula. Few studies have, therefore, explored the theme. However, potential benefits of linking students' experiences in clinical settings to problems studied in their tutorial groups may be easily perceived. Making use of their own individual experiences with patients or situations encountered in clinical activities while analyzing problems in tutorial groups may lead students to more easily build personal interpretations of the problems. The contextual nature of learning expected in PBL is also probably enhanced by relating the paper case at hand to real problems faced in real, sometimes diverse, clinical settings. Using clinical experiences could, therefore, contribute for tutorial groups to play their role in favoring contextual, constructive, active learning, which are basic educational principles of PBL.

The study reported by O'Neill and colleagues (this issue) builds on a previous work in which the authors constructed a theoretical model of how students link clinical experience to PBL (O'Neill et al., 2002). In both studies, subjects are students from the Manchester Medical School, where tutorial groups continue into the later years of the curriculum, when students are based in clinical environments. In their previous study, it was shown that students linked paper cases discussed in tutorial groups to real patients or other types of clinical contacts, thereby elaborating on their knowledge. Through elaboration, as already discussed in a previous section of this article, students retrieve and enrich their prior knowledge and view problems in a richer or wider perspective. It was also shown that elaboration could occur either when encountering a new patient, that is, outside the group, or by bringing their experiences back to the group discussion. In the present work, O'Neill and colleagues (this issue) went a step further to explore how students use their clinical experience during PBL groups. A strong point of the study is the use of direct observation and record of tutorial groups meetings, which could avoid difficulties emerging from the use of participants' recalls of discussions. Clinical experiences were found to be frequently inserted in the discussions in tutorial groups, and the types of experiences brought to the meetings were identified. Among them, encounters with specific patients emerged as a powerful influence on students' thinking. Community attachments were found to be an environment that creates opportunities for enriching experiences. Examples of clinical contacts were shown to be used in three different ways: Confirmatory (when students describe an experience to confirm what is being discussed), extending (when a particular experience is brought to the discussion to broaden thinking around a problem), and disconfirming (when an experience led to disconfirm the understanding that the

group was developing). Clinical experiences were found to be used by students for interactions that involved not only elaboration but also co-construction of learning. Apparently, they did not only illustrate biomedical knowledge. They rather helped in bridging between paper cases and real problems and contexts, therefore contributing to contextualize the discussion into real medical practice. Moreover, personal experiences with clinical contacts were brought to the discussion usually by using emotive phrases that expresses their affective effects on students.

It is time now to turn back to the discussion on tutorial group functioning and conditions for enhancing their potential cognitive and motivational contributions to learning in PBL, synthesized by Dolmans and Schmidt (this issue). Apparently retrieving and linking students' clinical experiences to the discussion of problems in tutorial groups may play a role in improving learning interactions by stimulating elaboration and co-construction. Emotional dimensions of clinical contacts with real patients and the contexts of medical practice could also be expected to affect students' motivation. Attention might be given, as O'Neill and colleagues (this issue) discussed, to the potential distortions leading to incorrect conceptualizations, which highlights the importance of careful planning and expected organizational obstacles. However, there seems to be room for further exploring the use of clinical experiences as a means to improve tutorial group functioning and thereby enhancing its contributions to learning in PBL environments.

The study aimed at identifying how students use their clinical experiences, and, therefore, aspects such as their effects on students' motivation to learning were not explored. They remain as issues requiring further investigation. Observations in the study were limited to tutorial groups from a particular year and based in the same clinical setting. It would be relevant, therefore, to extend investigation to other years and environments.

Theoretically, the structured use of students' clinical experience in tutorial group discussions could have implications for the development of clinical reasoning. Such implications may represent themes for future investigation. Research on medical expertise and clinical reasoning has shown that expertise is associated with multiple representations of knowledge and flexible use of analytical and non-analytical reasoning strategies (Eva, 2004; Norman, 2005). Effective clinical reasoning has been suggested to combine, in an interactive and optimal way, pattern-recognition based reasoning (i.e., reasoning strategies based on recognition of similarities between the actual case and previously seen patients) and analytical reasoning (i.e., reflective reasoning aimed at carefully analyzing characteristics of the problem and checking own thinking). There would be, therefore, a need to provide students with opportunities to acquire an array of strategies that make it easier for them to flexibly adapt to situations demands. This assumption has some

implications for clinical teaching. First, the importance of teaching around examples has been recognized (Eva, 2004). Students need to build up an adequate mental database of cases from which to reason by way of analogy. This depends on experiential learning, whose role in clinical reasoning has been well demonstrated. It requires strategies to promote reflection upon personal clinical experiences and enrichment of cognitive structures based on them. Not only students should have opportunities to encounter many examples of clinical cases, but they should also engage in problem-solving processes and gradually understand the different presentations that a clinical problem may have. Articulating tutorial group discussions with students' experience with real patients may be a means to promote reflection on practice and experiential learning. A second implication for clinical teaching is that educational approaches aimed at enhancing the development of analytical reasoning strategies should be adopted. Usually students based on clinical settings in their final years of medical curricula have few, if any, opportunities to engage in reflective thinking on problems encountered and on their own reactions to them. Maintaining tutorial groups during the last years of the curricula and bringing back students' clinical experience to the group discussion could create opportunities for developing reflective reasoning approaches. By now, these are, however, only conjectures that could be explored by future research on the theme.

Exploring Students' Conceptions of Learning

Over the last years researchers have fruitfully direct efforts to understanding relationships between several variables influencing learning processes and outcomes in PBL environments. As research progresses, models explaining factors that affect learning have been refined. More variables tend to be taken into consideration, and mechanisms through which they act have been increasingly explored. Most of the studies, however, have explored what happens during the several phases of the PBL cycle and their consequences, by assuming, as input variables, aspects related to the tutor (e.g. tutor expertise) or to learning materials (e.g. the problem presented to the group). More recently, approaches adopted by students both during group discussions and during their self-study have attracted researchers' attention. Students' conceptions of learning, that is, the way in which students understand the nature of learning, remained, however, as a highly unexplored issue.

Students are expected to play an active role in learning in PBL. A main educational principle underlying PBL is self-directedness in generation of learning goals, selection of learning strategies and resources, monitoring and evaluation of the learning process (Miflin et al., 2000; Dolmans et al., 2005). Learning in PBL is viewed as a constructive process in which students actively engage in interpretation of problems and reconstruct their own

cognitive structures (Dolmans et al., 2005). Studies have demonstrated that students' conceptions of learning, the strategies selected to study, and learning outcomes are intertwined (Loyens et al., this issue). How students perceive their learning environment and tasks presented to them do not depend only on "objective" characteristics of the learning context itself, presented to students, for example, through course program, assessment system and working processes (Dochy et al., 2005). Students' perceptions have shown to be indeed a result of an interaction between their preconceived ideas about learning and the learning environment itself. These conceptions that students bring to their new learning context when they enter the university are highly influenced by their previous learning experiences. PBL requires students to actively construct their knowledge, which may contradict, for students who come from traditional teaching programs, their own ideas on how learning takes place. Understanding students' conceptions of learning and the extent to which they are consistent with constructivist learning principles, becomes, therefore, even more important in PBL. The study conducted by Loyens and colleagues (Loyens et al., this issue) attempted to respond to this need by examining conceptions of constructivist learning of first-year students in a traditional and a PBL psychology curriculum. Aimed on that, they used a questionnaire to measure students' ideas about core assumptions in a theoretical model of constructivist learning: Knowledge construction, cooperative learning, self-regulation, motivation to learn, self-perceived inability to learn, and the use of authentic problems in learning.

Results provided empirical support for the hypothesized model of constructivist learning. They also reinforced findings of a previous study in which the questionnaire appeared as an appropriate instrument for measuring students' conceptions of constructivist learning. It was also shown that students who opted for a PBL curriculum tended to agree more on the cooperative learning and the practical application of learning through the use of authentic problems. Their peers on the traditional curriculum, on the other side, valued more motivation to learning.

Inferences for a PBL curriculum may be made from studies in other domains that have indicated associations between conceptions of learning, study strategy and learning outcomes, as explored by Loyens et al. (this issue). It could be expected that students who attribute a high value to cooperative learning would probably be more motivated to intervene in discussions in tutorial groups and to interact with their peers. This preparedness could facilitate co-construction and enrich learning interactions. Acknowledgment of the relevance of practical application of knowledge by working with authentic problems could also play a role in motivating students both for collaborative activities in tutorial groups and for self-study.

These statements, however, are presently only theoretically based. The study provided a relevant contribution, firstly by calling attention to the importance of exploring students' conceptions of learning as a variable that affects learning processes and results in PBL. As a second contribution, a model of constructivist learning conceptions and a questionnaire to measure students' ideas on that emerged from the study. They can provide a starting-point for those interested in exploring students' conceptions elsewhere, although concerns with external validity should obviously be taken into consideration. It is still to be explored, however, whether and how students' conceptions of learning affect other variables in PBL activities such as their behaviors in tutorial groups, their motivation to self-study and their approaches to tasks during the preparation phase. The authors themselves pointed to the need to examine also whether these conceptions brought by students when they enter the university change throughout their program. Possible interventions aimed at changing students' conceptions represent another relevant theme for study. The door is open for further investigations.

Does Provision of more Learning Resources Affect Learning in PBL?

Processes taking place during the individual study phase play a crucial role in the learning cycle in PBL. They are strictly related to tutorial group activities, which constitute the other phases of the cycle. Learning issues formulated when students discuss a problem in tutorial groups are expected to guide individual study (Van den Hurk et al., 1999). During this later phase, students search for diverse sources of information, select and study relevant learning resources and prepare themselves for the reporting group meeting. Students are expected to engage in activities that comprise consulting different resources, comparing information to identify discrepancies and appraise relevance, taking notes and making summaries of the new information. Through these processes, in which they prepare themselves to give explanations of their findings to their colleagues, students can recognize gaps in their own knowledge, construct new, enriched conceptualizations about problems and reorganize their knowledge structures. The extent to which students engage in these activities during individual study affects the quality of the next tutorial group meeting, when they report back their results, and, consequently, influences learning. It has already been demonstrated, for example, that the use of an explanation-oriented approach during the study phase positively influences the depth of the reporting phase and, through that, achievement (Van den Hurk et al., 2001). Indeed, much more is still to be known about what actually occurs during individual study and its consequences. However, several studies have reinforced the notion that the *way* how students prepare themselves during the individual study has an impact on learning (Van den Hurk et al., 2001; Dolmans et al., 2005; Dolmans and

Schmidt, this issue). Undoubtedly, discussion tends to be less rich in reporting meetings when students did not consult diverse sources of information during their prior individual study. Exchange of different findings encountered in the literature in response to their learning issues would certainly be restricted by a use of a similar set of few learning resources. It is important to emphasize, however, that what students do with the information encountered during the individual study does not necessarily relate to the quantity and the variety of learning resources identified. A key aspect here refers to how they deal with this information, how far they engage in cognitive processes aimed at enriching their understanding about a problem and reconstructing their knowledge structures by adding new concepts and relationships. The amount of resources available per se could be seen as a variable that has a limited value if not considered in association with the way how students make use of them. Nevertheless, it is a relevant aspect to be taken into consideration. An assumption of a PBL curriculum is that students should develop the skills for identifying, accessing and using learning resources in an effective way. The extent to which students engage in such activities is usually considered an indicator of self-directed learning (Van den Hurk et al., 1999; Miflin et al., 2000). It would be reasonable to expect that it is influenced by availability of learning resources.

The study conducted by Te Winkel and colleagues (this issue) aimed at exploring the influence of number of learning resources available for students on two variables: Time dedicated to individual study and achievement expressed by scores obtained in the course tests. Learning resources were classified either as primary resources (i.e., resources that students were instructed to study) or supplementary resources (i.e., resources that students were oriented to study when there was time available). Information on study time was obtained by means of a questionnaire administered to the students. Findings showed a borderline significant main effect of primary resources on study time. Regarding achievements, results indicated that students obtained higher grades when courses offered more primary learning resources. Supplementary resources, however, were associated with higher grades only in those courses that offer few primary resources.

The study calls attention for the potential influence of provision of learning resources on individual study and achievements. This aspect has not been frequently explored, and the study brought new insights on it. Careful analysis of the study findings, however, can point to limitations that might be seen as topics requiring further investigation. A first point of concern refers to the distinction between the *number* of resources available and the *use* that students made of them. As the authors recognized, it is not known whether students used the available resources. As resources are considered only in terms of quantity, they can represent various types of resources. Some of

them might require hours of study, whereas others demand few minutes. Time dedicated to individual study could have been concentrated, for example, in studying a few key, complex textbooks or articles, despite the availability of other resources. And, which may be even more important, there is no information on *how* students used the resources. Considering the studies showing the effects of the way how students prepare themselves on learning (Van den Hurk et al., 2001), the number of resources offered seems to provide a weak representation of what is happening during the study phase. It would be important to explore how students work with the various resources. Without taking these aspects into consideration, inferences based on associations between availability of resources per course and grades obtained in courses test per se have a limited value.

The so-called primary resources apparently play a more important role in students' view, and this indeed may be seen as an expected finding. When faced with limitations of study time, which is a very common situation, students would make a choice in favor of resources that were considered more relevant by the teachers. Although it may be seen as contradicting expectations of self-directed students, this behavior is in fact an efficient response to the demands of the situation and would be reasonably expected in real contexts. The article does not explicitly refer to that, but it seems that the degree of guidance provided by the teachers with regards to learning resources does not vary over the years of the program. This progressive reliance on students' skills to select sources of information has been suggested by some authors as a means to prevent adverse effects that may come from extreme views of self-directedness expected from students in PBL (Miflin et al., 2000). Frameworks have been proposed to provide higher support by teachers in the beginning of the programs while students are helped for developing self-directed skills for searching learning resources and working with them (Miflin et al., 2000). In their study, Te Winkel and colleagues (this issue) did not explore students' perceptions regarding how availability of resources, or the need to make choice among them, affected their study. Authors' statement that their findings differ from previous studies that suggested possible negative influences of increasing amount of resources on students' motivation is to be seen, therefore, with caution. By now it is only an inference based on study time. Taken in isolation, this variable has all the limitations already discussed. And it points to topics for further investigation such as the use that students make of the variety of resources available and their effects on students' motivation and achievements. This final remark reinforces the importance of examining more complex models of learning in PBL, in which interactions between several variables can be explored, thereby favoring a better understanding of their effects. This turns attention to the

last article presented in this issue, which discusses appropriate approaches for study design in research on PBL (Newman, this issue).

How can we Learn more from Research on PBL?

Since its introduction in the 60s, PBL has raised intense debate amongst those involved in medical education community. Changing to a new educational perspective requires considerable resources, time and efforts, and many have questioned whether moving from conventional curricula to PBL would be justified. More recently these questionings have been nurtured by reviews of studies aimed at examining the effectiveness of PBL against traditional curricula. By analyzing eight studies comparing curriculum tracks, in a review published in 2000, Colliver concluded that the literature did not provide enough evidence of the effects of PBL (Colliver, 2000). Indeed, findings of his review are similar to the ones obtained by the major comprehensive reviews conducted in the early 90s. Students from PBL curricula showed better performance on assessment of clinical skills and problem-solving. They were also more satisfied with their learning environments. There were, however, no differences between PBL students and their peers in traditional curricula with respect to measures of knowledge accumulation. These findings led to Colliver's conclusions that effects in favor of PBL were not so expressive to justify moving to this approach (Colliver, 2000). Debate increased in the following years, stimulated by another review conducted by Newman on behalf of the Campbell Collaboration (Newman, 2003). Fifteen studies considered to fulfill the inclusion criteria were selected from 91 papers included in 5 previous reviews of the literature on PBL. Inclusion criteria required the study to be a controlled comparison of PBL against a conventional curriculum in which outcomes had been measured in terms of students' achievements on several tests. Outcomes from this review vary, with advantages for PBL students in some measures, such as study approaches and satisfaction, and mixed results in terms of application and accumulation of knowledge, the latter speaking in favor of traditional curricula in some studies.

This later review has been seen as representing the Best Evidence in Medical Education (BEME) movement, which has recently stimulated randomized, controlled experiments, particularly trials of curriculum-level interventions, as the recommended approach to construct trustful evidence in the educational domain (Dolmans, 2003). An intense debate has emerged between different viewpoints about research that can lead to development of knowledge relevant to guide decisions in medical education. In our introductory section to this paper, we referred to this debate. PBL has been nurtured by knowledge emerging from a major tradition of research represented by theory-driven studies aimed at examining whether, how and why the theoretical constructs of PBL work in practice. These studies have

explored effects of interactions between the several variables acting in a PBL curriculum, and an accumulation of knowledge has come out from them. The other viewpoint in this debate has been represented by those that advocate large trials of curriculum-level interventions comparing PBL and conventional curricula as the preferable way to examine effectiveness of PBL. The article by Newman in this issue argues in favor of this latter view.

The paper starts by advocating that decisions regarding which is the most appropriate study design should be guided by the question intended to be answered, that is, the study design should match the research question. This is certainly a statement that would not raise controversy. The question to be answered, or at least the one to which researchers should direct their efforts, in the author's view, is what is the impact of PBL. Adopting this starting point, the article discusses principles that should guide research oriented towards establishing causality. To meet these principles, the author argues, researchers must do their best to minimize threats to validity in their studies. These threats and ways to deal with them are discussed in the light of literature on research design. Newman (this issue) acknowledges existence of different threats to validity of studies (e.g. to construct validity, to external validity) but opted to focus on those referring to internal validity in his discussion of approaches to minimize threats through study design. The randomized experimental design emerges from his analysis as the optimal strategy for enhancing internal validity of studies aimed at establishing causality. Although recognizing the difficulties in making distinction between results and noise in evaluations of curriculum level interventions, it is argued that evidence of descriptive causality of PBL is required. Despite emphasizing that randomized experiments should not be seen as a panacea and recognizing that not always conditions required for their implementation are given, efforts to conduct them appear as justifiable.

Arguments presented by Newman (this issue) in support of the strengths of experimental approaches in educational research are not to be questioned. Indeed, controversy regarding the appropriateness of educational trials does not rely on the question whether or not experimentation has a crucial role in educational research. Researchers in education have conducted experiments for a long time, and an accumulation of knowledge about learning in PBL has been generated by series of carefully designed experimental studies. Experiments in medical education have, in fact, been successfully used to address a broad range of themes going from examining evidence of theoretical advantages of PBL in the early 1990s (Norman and Schmidt, 1992) to recent experimental studies aimed at exploring clinical diagnostic reasoning (Norman, 2005). Reaffirming the strengths of experimentation does not imply, however, that large randomized curriculum experiments make sense. These are two different statements, and the second is not the logical consequence of

the first. In our view, educational trials of curriculum-level interventions cannot provide valuable information because, despite their apparent reliance on methodological rigor, they are based on wrong assumptions. First, these trials adopt as one single variable what in fact is an unspecified combination of several variables. PBL, or any other type of curriculum dealt with as one single intervention in these educational trials, encompasses in reality multiple components. The treatment, therefore, has in fact multiple non-controlled components, with complex interactions among them. The consequence is that attempts to examine causality become unavoidably confounded by a myriad of multiple factors that could contribute to results. This cannot be solved by simple randomization strategies. Indeed, and this is the second misunderstanding underlying curriculum-level trials, random allocation required to maintain blinding is not possible in educational interventions. Teachers and students in the experimental and the control group would certainly differ not only with regards to the independent variable, but also with regards to other variables. Outcomes could not be attributed, therefore, to the intervention. Finally, as Newman states in his paper (Newman, this issue), theories underlying PBL may be translated into practice in various ways in different contexts. Indeed, there is not a uniform intervention named PBL. Since PBL entails multiple components, they may be translated into different ways in different institutions. Tutor's role and background differ in different programs, and the same applies to the degree of self-directedness expected from students, the type of problems used, the way how tutorial groups work, the learning resources, and a variety of other characteristics.

These reasons have led several researchers to questioning the value of large randomized trials of curriculum-level interventions (e.g., Norman and Schmidt, 2000; Farrow and Norman, 2003; Norman, 2003). A different research perspective has been proposed as a means to reach further advances in knowledge that can better guide decision-making in education. It articulates two main directions for research. In one of them, efforts should be oriented towards testing and elaboration of theories through well-designed studies aimed at carefully and systematically exploring multiple variables interfering in learning processes. These efforts would extend knowledge basis and could guide attempts to link theory and practice. A second research direction should be oriented towards better understanding of whether, why and how the theoretical constructs underlying PBL work in practice. Aimed on that, attention should be directed to examining relationships between the several components in PBL, and the effects of their interactions. Knowledge required for pursuing practical goals, such as the development and improvement of PBL in everyday practice, would come out from these types of studies. Experimental approaches play a particularly important role for accomplishing these goals. They should certainly be adopted in studies aimed at

exploring, in series of experiments conducted under controlled conditions, various factors interfering in learning. Other methodological approaches, however, should also be used, for investigations oriented to examine the several variables potentially acting in realistic settings and their complex interactions. In our view, these goals and methodological approaches constitute a research agenda that might lead to learning on PBL.

Conclusions

Thirty years after its introduction, PBL represents a major change in medical education, presently widespread all over the world. As such, it has called the attention of researchers who have directed their efforts to building and testing theory underlying PBL and to examine several aspects related to its implementation. As a result of these efforts multiple variables that influence learning in PBL and their interactions are presently better understood. The debate on research perspectives that could lead to new advances has grown in the literature in recent years. This special issue brings a set of articles that well represent this debate. A variety of aspects related to learning in PBL were examined in the studies reported. Some of the studies addressed issues that had remained highly unexplored until now. Apparently the accumulation of knowledge has provided bases for broadening the spectrum of research questions. The discussion on research strategies required for new advances on PBL was also represented. Taken together, the papers provide a contribution both to what is known about PBL and to the debate about a research program that can lead to further advances in the field.

References

Albanese, M.A. & Mitchell, S. (1993). Problem-based learning: a review of literature on its outcomes and implementation issues. *Academic Medicine* **68**: 52–79.

Colliver, J.A. (2000). Effectiveness of problem-based learning curricula: research and theory. *Academic Medicine* **75**: 259–266.

Dochy, F., Segers, M., Bossche, P.V. & Gijbels, D. (2003). Effects of PBL: a meta-analysis. *Learning and Instruction* **13**(5): 533–568.

Dochy, F., Segers, M., Bossche, P.V. & Struyven, K. (2005). Students' perceptions of a problem-based learning environment. *Learning Environments Research* **8**: 41–66.

Dolmans, D. (2003). The effectiveness of PBL: the debate continues. Some concerns about the BEME movement. *Medical Education* **37**: 1129–1130.

Dolmans, D.H.J.M., De Grave, W., Wolfhagen, I.H.A.P. & Van der Vleuten, C.P.M. (2005). Problem-based learning: future challenges for educational research and practice. *Medical Education* **39**: 732–741.

Dolmans, D.H.J.M., Wolfhagen, I.H.A.P., van der Vleuten, C.P.M. & Wijnen, W.H.F. (2001). Solving problems with group work in problem-based learning: hold on to the philosophy. *Medical Education* **35**: 884–889.

Dolmans, D.H.J.M. & Schmidt. H.G. (this issue). What do we know about small group tutorials in problem-based learning? *Advances in Health Sciences Education.*

Eva, K.W. (2004). What every teacher needs to know about clinical reasoning. *Medical Education* **39**: 98–106.

Farrow, R. & Norman, G. (2003). The effectiveness of PBL: the debate continues. Is meta-analysis helpful?. *Medical Education* **37**: 1131–1132.

Gijselaers, W.H. & Schmidt, H.G. (1990). The development and evaluation of a causal model of problem-based learning. In Z. Noorman, H.G. Schmidt & E. Ezzat (eds.), *Innovation In Medical Education: An Evaluation Of Its Present Status*, pp. 95–113. New York, NY: Springer Publishing Company.

Hmelo-Silver, C.E. (2004). Problem-based learning: What and how do students learn. *Educational Psychology Review* **16**: 235–266.

Loyens, S.M.M., Rikers, R.M.J.P. & Schmidt, H.G. (this issue). Students' conceptions of constructivist learning: a comparison between a traditional and a problem-based learning curriculum. *Advances in Health Sciences Education*.

Miflin, B.M., Campbell, C.B. & Price, D.A. (2000). A conceptual framework to guide the development of self-directed, lifelong learning in problem-based medical curricula. *Medical Education* **34**: 299–306.

Newman, M. (2003). *A Pilot Systematic Review and Meta-analysis on the Effectiveness of Problem Based Learning* Newcastle: Learning & Teaching Subject Network for Medicine, Dentistry and Veterinary Medicine.

Newman, M. (this issue). Establishing descriptive causation in evaluations of Problem Based Learning: the case for a fitness for purpose approach to study design. *Advances in Health Sciences Education*.

Norman, G. (2003). RCT = results confounded and trivial: the Perils of grand educational experiment. *Medical Education* **37**: 582–584.

Norman, G. (2005). Research in clinical reasoning: past history and current trends. *Medical Education* **39**: 418–427.

Norman, G.R. & Schmidt, H.G. (1992). The psychological basis of PBL. A review of the evidence. *Academic Medicine* **67**: 557–565.

Norman, G.R. & Schmidt, H.G. (2000). Effectiveness of problem-based learning curricula: theory, practice and paper darts. *Academic Medicine* **34**: 721–728.

O'Neill, P., Duplock, A. & Willis, S. (this issue). Using clinical experience in discussion within problem-based learning groups. *Advances in Health Sciences Education*.

O'Neill, P.A., Willis, S. & Jones, A. (2002). A model of how students link problem-based learning with clinical experience through elaboration. *Academic Medicine* **77**: 552–561.

Te Winkel, W.W.R., Rikers, R.M.J.P., Loyens, S.M.M. & Schmidt, H.G. (this issue). Influence of number of learning resources on self-directed learning in a problem-based curriculum. *Advances in Health Sciences Education*.

Van den Hurk, M.M., Dolmans, D.H.J.M., Wolfhagen, H.A.P., Muijtjens, A.M.M. & Van der Vleuten, C.P.M. (1999). Impact of individual study on tutorial group discussion. *Teaching and Learning in Medicine* **11**: 196–201.

Van den Hurk, M.M., Dolmans, D.H.J.M., Wolfhagen, I.H.A.P. & van der Vleuten, C.P.M. (2001). Testing a causal model for learning in a problem-based curriculum. *Advances in Health Sciences Education* **6**: 141–149.

Verkoeijen, P.P.J.L., Rikers, R.M.J.P., Te Winkel, W.W.R. & Van den Hurk, M.M. (this issue). On the necessity of student-generated learning issues: an experimental approach. *Advances in Health Sciences Education*.

Visschers-Pleijers, A.J.S.F., Dolmans, D.H.J.M., Wolfhagen, H.A.P. & van der Vleuten, C.P.M. (2004). Exploration of a method to analyze group interactions in problem-based learning. *Medical Teacher* **26**(5): 471–478.