Interdisciplinary Journal of Problem-Based Learning

Volume 6 | Issue 1 Article 7

Published online: 3-27-2012

The Impact of Concept Mapping on the Process of Problem-based Learning

Wichard Zwaal

Hans Otting

Recommended Citation

Zwaal, W. , & Otting, H. (2012). The Impact of Concept Mapping on the Process of Problem-based Learning. *Interdisciplinary Journal of Problem-Based Learning, 6*(1).
Available at: https://doi.org/10.7771/1541-5015.1314

The Impact of Concept Mapping on the Process of Problem-based Learning

Wichard Zwaal and Hans Otting

Abstract

A concept map is a graphical tool to activate and elaborate on prior knowledge, to support problem solving, promote conceptual thinking and understanding, and to organize and memorize knowledge. The aim of this study is to determine if the use of concept mapping (CM) in a problem-based learning (PBL) curriculum enhances the PBL process. The paper reports on two studies. The first study was conducted with four PBL groups, with two groups using concept mapping. In the second study, three of seven groups were assigned to use concept mapping. All PBL groups were audio- and videotaped. Results show that concept mapping did not lead to more or better matching learning goals. Neither did it affect the time spent on step 4 of the seven-step method. When evaluating the PBL session, students working with concept mapping were more satisfied with the execution of step 4, the decision-making process, and the communication within the group. Though indications exist that concept mapping might be a useful tool to enhance the process of PBL, further research is needed, controlling for the impact of the quality of the problems and the tutor interventions.

Keywords: concept mapping, learning goals, seven-step method, problem-based learning

http://dx.doi.org/10.7771/1541-5015.1314

Introduction

The PBL format implemented in 1987 by the hotel school at Stenden University of Applied Sciences in Leeuwarden included the adoption of the seven-step method that was developed at Maastricht University. A recurring observation during the more than 20 years of working with PBL at our institute is that students often tend to show serious failures in executing step 3 (generating and analyzing possible explanations for the problem) and step 4 (constructing a schematic representation of the concepts and mechanisms involved) with potentially harmful consequences for all subsequent steps in the process.

Although little research is published on the functioning of the seven-step method, our observations with respect to the insufficient execution of steps 3 and 4 were confirmed by Moust, van Berkel, and Schmidt (2005). One of the signs of erosion they observed, based on more than three decades of experience with PBL at Maastricht University, was: "Skipping the brainstorming and elaboration phases (steps 3 and 4). In this case the problems defined by the students (step 2) are immediately transformed into learning issues (step 5)" (p. 670). This skipping of steps 3 and 4 would imply an incomplete analysis and a premature formulation of learning goals. Furthermore, those learning goals are most likely to become a series of questions without paying proper attention to the mutual relations between the separate concepts and issues involved. Step 4 is explicitly meant to investigate, conceptualize, and visualize the connections and interactions between the several concepts, variables, mechanisms, principles, explanations, and speculations listed in step 3. "By omitting an in-depth analysis of the problem(s) based on their prior knowledge, students do not elaborate, which is a condition *sine qua non* for restructuring their knowledge. Therefore, the acquisition of new information will be less efficient" (Moust et al., 2005, p. 670). Activation of prior knowledge and elaboration on the knowledge network are quintessential processes in PBL (Schmidt, 1983).

Research on the cognitive benefits of PBL shows that students in a PBL curriculum develop a) more accurate, elaborate, and coherent knowledge; b) more flexible understanding; and c) lifelong learning skills (Hmelo, 1998a; 1998b; Hmelo, Gotterer, & Bransford, 1997; Hmelo-Silver, 2004). However, inadequate problem exploration and insufficient structuring of prior knowledge may result in unclear or ambiguous learning objectives (Zanolli, Boshuizen, & De Grave, 2002; Van den Hurk, Dolmans, Wolfhagen, & Van der Vleuten, 2001). A poor brainstorming phase with few explanations leads to a superficial problem analysis (De Grave, Boshuizen, & Schmidt, 1996) and may lead to less depth and breadth of learning, fragmented and less accessible knowledge, and a stronger focus on rote learning than on learning for understanding (All & Havens, 1997; Moust et al., 2005). Schematizing promotes integration, abstraction, and generalization of knowledge. Moreover, it is assumed to support the collaborative construction of knowledge and understanding (Hong Gao, Losh, & Turner, 2007; Van Boxtel, Van der Linden, & Kanselaar, 2000; Van Boxtel, Van der Linden, Roelofs, & Erkens, 2002). From that perspective, step 4 might not just be the midpoint in the seven-step method, but might play a pivotal role in the entire process of PBL.

This study is an attempt to add to the body of knowledge on PBL and CM in several ways: 1) by clarifying, improving, and operationalizing step 4 of the seven-step method; 2) by conducting empirical research on the seven-step method in a naturalistic setting; 3) by applying CM in PBL in a non-medical context; and 4) by exploring ways to promote meaningful, conceptual learning in higher education.

Problem-based Learning

Problem-based learning was designed for and introduced to the pre-clinical phase of the medical curriculum at McMaster University, Canada, in 1968 (Barrows, 1996; Barrows & Tamblyn, 1980; Taylor & Miflin, 2008). PBL was introduced to medical education because students experienced difficulties in applying scientific knowledge to clinical practice. Moreover, the rapid technological developments in the medical profession called for new approaches to medical education. The effective preparation of students for their future profession is not only a pressing problem in medical education, but is a challenge to higher professional education in general. Notwithstanding the fact that the effectiveness of PBL has been an issue of debate, and results from meta-analyses of PBL research did not reach universal agreement (Albanese, 2000; 2009; Albanese & Mitchell, 1993; Colliver, 2000; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hartling, Spooner, Tjosvold, & Oswald, 2010; Norman & Schmidt, 2000; Vernon & Blake, 1993), many universities all over the world have introduced problem-based learning.

Various interpretations that deviate from the original PBL approach to the curriculum have emerged and many different modes of PBL can be distinguished (Savin-Baden, 2004; 2007; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009; Taylor & Miflin, 2008). What counts as pure or as hybrid PBL (Hung, 2011; Savin-Baden, 2000; 2007) and the development of new models like the "one-day-one-problem" model of PBL (Rotgans, O'Grady, & Alwis, 2011) complicate the discussion about what PBL really is. In spite of the fact that different interpretations of PBL exist, several common factors can be identified (Dolmans, De Grave, Wolfhagen, & Van der Vleuten, 2005).

The starting point for the learning process is the analysis of a problem that is exemplary for a field of study or a professional context to ensure that the students' learning activities and the acquired knowledge and skills are relevant to their future profession. Students gain, apply, and evaluate knowledge by solving problems and expand insight in the broader problem field (Barrows & Tamblyn 1980; Jonassen, 1997; 2000). The quality of problems, students' prior knowledge, and tutor behavior are generally assumed as the main factors that influence the functioning of PBL groups (Schmidt & Gijselaers, 1990). It has been demonstrated that by analyzing a problem, the students' prior knowledge is triggered, which helps him or her to build a theory about a problem and enables the student to understand a variety of aspects that are relevant for their professional career (Savin-Baden, 2000). In his conceptual framework for designing optimal PBL problems, Hung (2006) proposed three content-related components (content, context, connection) and three processing components (researching, reasoning, and reflecting). Jonassen (2000) focused on two main characteristics of problems: structuredness and complexity. However, research by Jacobs, Dolmans, Wolfhagen, and Scherpbier (2003) could not find evidence for a two-factor model with structuredness and complexity. It was found that students rated structuredness as more important compared to complexity, but empirical evidence for the problem characteristic complexity as such could not be established (Otting & Zwaal, 2006).

The main ideas in PBL are in line with ideas from cognitive and social constructivist conceptions of education (Hendry, Frommer, & Walker, 1999; Savery & Duffy, 1996). From a constructivist perspective on education, learning takes place in a rich environment that challenges students to self-directed and collaborative learning by active engagement in the construction of knowledge and understanding. PBL challenges students to become active, self-directed learners, who in collaboration with their fellow students take responsibility for their learning process, share knowledge with one another, plan individual and joint study activities, and monitor the learning process to achieve results (Dochy, Segers, Van den Bossche, & Struyven, 2005; Hmelo-Silver 2004; Hmelo-Silver & Barrows, 2008; Van den Hurk 2006). Students identify knowledge gaps, formulate what they need to learn, and decide which resources they will use to address the formulated learning goals.

At Stenden University of Applied Sciences, PBL is the primary approach to education. Students meet twice a week in groups of 12 students to discuss and report about authentic tasks and problems that have been presented to them. Following the Maastricht model of problem-based learning, the PBL group uses a systematic approach to working on problems called the seven-step method (Moust et al., 2005; Schmidt et al., 2009). The seven steps are:

1. Clarify terms and concepts of the problem description that are unclear or not readily comprehensible.
2. Define the core issue of the problem and describe the different aspects of the problem that need explanation.
3. Use relevant prior knowledge to analyze the problem and find possible explanations.
4. Draw a systematic inventory of the explanations, ideas, and suggestions inferred from step 3.

5. Formulate learning objectives and questions for self-study.
6. Collect additional information, study relevant literature, and try to make connections with what you already know.
7. Share the information and knowledge with the PBL group. Examine if sufficient knowledge has been gained to solve the problem and evaluate the learning process.

The confrontation with real-life problems can be very demanding and without sufficient guidance and support may induce a high cognitive load (Kirschner, Sweller, & Clark, 2006). The seven-step method was designed as a systematic procedure to support the learning process (Schmidt, 1983). It is frequently used as a scaffolding technique for applied problem solving. Scaffolding reduces the cognitive load by structuring the problem-solving process and enhances the opportunities for learning for understanding (Hmelo-Silver, Duncan, & Chinn, 2007). However, the application of the seven-step approach is not without problems. Especially, step 3 and 4 of the seven-step method can be problematic, because students pay little attention to or even skip the analysis of the problem and do not sufficiently elaborate on prior knowledge. Students tend to directly formulate learning goals (step 5) after the problem definition (step 2) with the risk that the problem is superficially analyzed, prior knowledge is insufficiently activated, elaborated, or restructured preventing higher level learning (understanding) and hampering the integration of new knowledge into the existent knowledge base (Moust et al., 2005).

Not only students, but also instructional designers can equally underrate step 4. In tutor instructions, accompanying every PBL problem, steps 3 and particularly step 4 often happen to be superficially explained or missing as well. Sometimes step 4 is simply referred to as "inventory" without any further explanation (Dochy et al., 2005). But step 4 of the seven-step method is more than just an inventory of the results of the preceding step because relationships between relevant concepts and ideas must be established to reveal a comprehensive structure and a systematic overview of the problem that can be used to identify the gaps between students' prior knowledge and the essential knowledge that has to be gained for understanding or solving the problem.

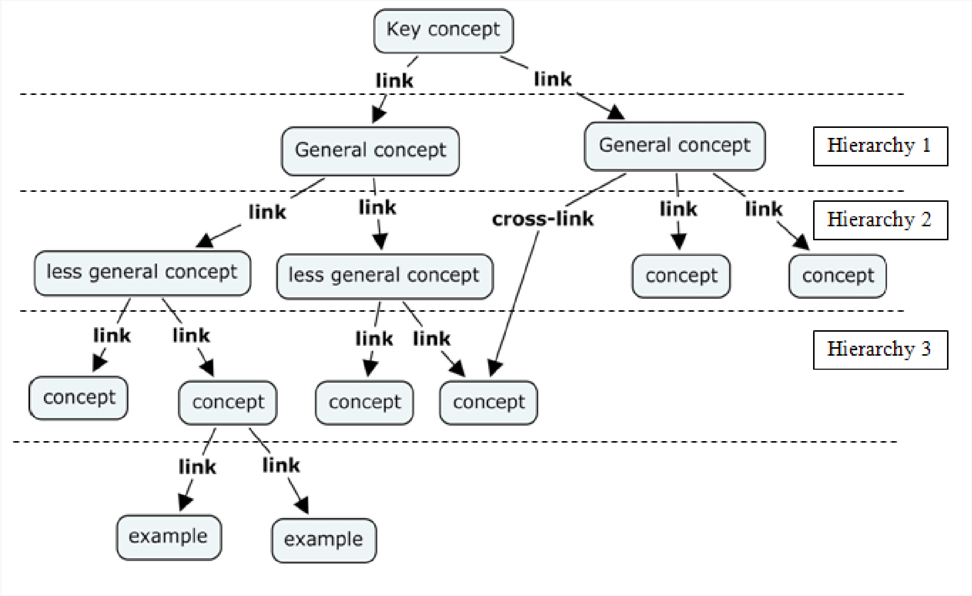
One of the major benefits of PBL lies in the restructuring of the existing cognitive knowledge structures and the integration of new concepts in the student's knowledge base. Students have to reflect on how their new findings relate to what they already know and determine how the knowledge they have gained could prepare them for solving similar problems (Capon & Kuhn, 2004). Therefore, we looked for tools that might make student learning visible in step 4 of the seven-step method. Concept mapping seems to be a promising and powerful tool to visualize the students' prior knowledge structures and to advance meaningful learning (Hay, 2007; Hay, Kinchin, & Lygo-Baker, 2008).

Concept Mapping

A concept map is a graphical tool for improving meaningful learning and understanding by activation of and elaboration on prior knowledge. CM supports problem-solving processes and promotes conceptual thinking and understanding. A concept map is a useful tool to organize and memorize knowledge (Novak & Gowin, 1984). The activation of prior knowledge is an essential part of learning because students learn more efficiently and effectively if they are able to connect and integrate new knowledge with already existing knowledge. Concept maps are useful personal learning tools that reflect the student's cognitive structure. They are not static and change over time as students' knowledge grows. Concept maps reflect students' knowledge (Daley & Torre, 2010). Research by Johnstone and Otis (2006) showed that students who used concept maps for planning, study, and revision achieved higher results than students who did not use CM.

Concept maps start with a key concept. Students link concepts using lines and linking words to form statements and propositions (Novak & Cañas, 2006). The hierarchy is indicated by putting the more general concepts at the top and more specific concepts below or extending outward. Arrangement of a series of related concept-links in a hierarchical chain represents a domain of knowledge. The relationship between different domains of knowledge is indicated by cross-links, which are also connected using labeled lines, describing the nature of the relationship. Finally, examples could be added, linked to the related concept in the most subordinate position on the map. Figure 1 shows an example of the components of a concept map.

Figure 1. Model of a Concept Map (Novak & Gowin, 1984)



A meta-analysis of research on concept and knowledge maps shows that students with low verbal ability or students that study in a second language might benefit from CM because it does not require extensive writing. The simple syntax of a concept map enables easy construction, sustains meaningful discourse, and enhances comprehension during collaborative CM (Nesbit & Adesope, 2006). CM requires student interaction, provokes discussion, supports collaboration, and enhances elaboration to come to a joint agreement on the concept definition (Van Boxtel et al., 2000; Van Boxtel et al., 2002). Chiou (2009) examined the effect of CM on students' performance in business and economics statistics and found that compared to traditional textbook study, a CM strategy improved students' achievement. Results showed that a collaborative CM strategy yielded higher student achievement than individual CM. Concept mapping seems to be a tool that fits the need for more collaborative and elaborative learning in step 4 of the seven-step method. Moreover, Nesbit and Adesope's (2006) meta-analysis on concept maps concludes that there is a need for more research on CM in small groups. However, relatively few studies have researched concept mapping in PBL.

Concept Maps in Problem-based Learning

Concept mapping has been implemented in problem-based learning in medical and nursing education to enhance the quality of students' learning processes (Hsu, 2004; Johnstone & Otis, 2006; Pinto & Zeitz, 1997; Rendas, Fonseca, & Rosado Pinto, 2006). The reason why CM is considered to be beneficial for the PBL process is that it promotes the activation and elaboration of prior knowledge and makes students spend more time on the steps of the seven-step method.

By implementing CM in step 4 of the PBL process, students have to visualize their prior knowledge in the form of a concept map, which helps them to separate what is already known from what needs to be researched to better understand the problem and its underlying mechanisms (Johnstone & Otis, 2006). By activating and elaborating on prior knowledge, CM is expected to enhance and facilitate the production of learning goals in step 5. Since CM is expected to elicit a more extensive discussion and in-depth analysis of the concepts, propositions, mechanisms, and interrelations, we would expect to find both more and more adequate learning goals in groups working with CM. An indicator for the effectiveness of CM in step 4 of the seven-step method is the correspondence between the student-generated learning goals and the learning goals that are formulated by the problem designers. Curriculum aims and module objectives set boundaries for problem designers. They will have to operate within the constraints of the module theme and the module objectives, by triggering a PBL process that contributes to meeting the performance goals of that specific educational unit. The intended learning goals as listed by the problem designer are not necessarily exhaustive or exclusively correct, but they are generally considered to be a valid criterion for checking the performance of PBL groups. The problem designer as content expert is expected to be able to formulate the learning goals in the most effective and efficient way. Research on the correspondence between learning issues generated by PBL groups and the faculty objectives showed an average overlap of 64% (Dolmans, Gijselaers, Schmidt, & Van der Meer, 1993; Dolmans, Schmidt, & Gijselaers, 1995). The use of CM in step 4 of the seven-step method might stimulate students as self-directed and collaborative learners to formulate additional learning issues than the ones that were intended by the problem designers. These additional learning issues could fall within the scope of the problem and the module or reflect personal interests of the students.

Concept mapping prevents students from jumping to learning goals by spending too little time and attention on step 3 and 4. The amount of time spent by students on the learning process is a necessary prerequisite for making significant learning gains (Koury et al., 2009). Research on the different phases in the PBL process shows that each phase influences the next phase and learning shows a cumulative pattern (Yew, Chng, & Schmidt, 2011). The measurement of time spent on the seven-step method gives an indication of the time PBL groups devote to the first five steps of the seven-step method. In other words, it provides insight in the time students invest in working on a problem as an indicator of the amount of attention students pay to active cognitive engagement in PBL (Rotgans & Schmidt, 2011; Zwaal & Otting, 2010).

By influencing the type of activities and time spent in step 4, CM is also expected to affect students' opinions about working with PBL in general and with the seven-step method in particular. It would be interesting to monitor whether students consider CM as a useful tool to enhance the quality of the learning process in PBL and whether increased exposure to and experience with CM changes their attitude, achievements, and competence in creating concept maps. Research by Kassab and Hussain (2010) has shown that the quality of students' concept maps increased as students progressed from year two to year four in a problem-based curriculum.

Aim of the Study

The aim of this study is to investigate the impact of CM on PBL in general and on step four and five of the seven-step method in particular. The problem statement of this study is: does the implementation of concept mapping enhance the process of PBL? More specifically, the following research questions will be addressed:

1. Do PBL groups who use concept maps generate more learning goals than the ones who do not?
2. Do PBL groups who use concept maps produce learning goals that are more in line with the ones intended by the problem designer?

3. Do PBL groups who use concept mapping spend more time on step 4 of the seven-step method?
4. How do students experience and evaluate working with concept mapping?

Method

Research Design

Two studies were conducted in a naturalistic setting *using a quasi-experimental* posttest-only control group design with CM as the treatment variable (Campbell & Stanley, 1963; Cooper & Schindler, 1998). The experimental groups were required to create concept maps in step 4 of the seven-step method. The groups received an outline developed by Novak (1998) describing the 10-step approach for creating a concept map. The control groups did not use CM in step 4. Two studies were conducted in two different first-year modules of a four-year hospitality management program in the academic year 2009-2010. Every academic year consists of four 10-week module periods. The first study, including four PBL groups, was done in the first-year module "Resources" in module period 3. The second study, including seven PBL groups, was done in another first year module "Guest Experience" during module period 4. Both modules are comparable with respect to the position in the curriculum (first year), and structure of the unit (combination of PBL sessions, self-study, and workshops). Every first-year semester consists of one "theory" module and one "practice" module. Consequently, none of the students could have participated in two theoretical modules in the same semester. The random allocation of students to PBL groups prevents substantial and systematic differences in prior knowledge or competences to occur between the PBL groups included in the studies. By lack of a pretest this could not be empirically checked.

All 11 PBL groups were videotaped during the start-up session of a preselected PBL problem. In study 1, the selected problem was called "Greening the business," and in study 2, the problem was titled "Groupthink: Barriers in upward communication." The "Greening the business" problem was focusing on legal issues related to creating and preserving a green and healthy environment. The problem on "Groupthink" targeted the relationship between organizational structure, communication, and decision making. Both problems were labeled as explanation problems in the tutor instructions accompanying both modules. Both modules and problems have been incorporated in the curriculum for several years and have been evaluated in the yearly quality control cycle. Therefore, we refrained from further investigations into the quality of the modules and problems.

During the weekly meeting with the module coordinators, the tutors were informed about the study on the impact of CM in PBL. They were not informed about the specific research questions.

In this study, student learning outputs could not be used as output measure because the current assessment system focuses on progress tests that cannot be directly linked to particular PBL problems.

The PBL classroom was set up in a circle that allowed group members to discuss and share information. A whiteboard was used to write down information during the session.

Sample and Data Collection

Eleven first-year PBL groups of an international hotel school participated in this study. Study 1 included four first-year PBL groups. Groups 1 and 2 were working with concept maps, while groups 3 and 4 were not. The total number of participants in the first study was 35. In study 2, seven first-year PBL groups participated. The three experimental groups (1, 2, and 3) worked with concept maps; the other four groups did not. The number of participants in the second study was 58.

A video camera and voice recorder were used to record the PBL sessions. A member of the research team installed and operated the equipment and observed the sessions. Minutes containing the output of step 1 to 5 of the seven-step method were also collected and used for analysis.

Learning Goals

The learning goals formulated in step 5 were compared with the learning goals provided by the problem designers. The research team independently scored if a match could be established between the learning goals as generated by the students and the learning goals formulated by the problem designers.

The number of learning goals was also compared to examine whether differences existed in the amount of learning goals produced by the groups that used CM and the ones that did not. SPSS 18 was used to analyze the data to find out whether any significant differences occurred between the numbers of learning goals provided by the different groups.

Concept Maps

Experimental groups were required to use CM in step 4 of the seven-step method. They were provided with an outline containing the 10-step approach for creating a concept map. The tool was derived from Novak's (1998) guidelines on how to build a concept map:

1. Identify a focus question that addresses the problem, issues, or knowledge domain you wish to map.

2. Guided by this question, identify 10 to 20 concepts that are pertinent to the question and list these. Concept labels should be a single word, or at most two or three words.
3. Rank order the concepts by placing the broadest and most inclusive idea at the top of the map.
4. Work down the list and add more concepts as needed.
5. Begin to build your map by placing the most inclusive, most general concept(s) at the top. Usually there will be only one, two, or three most general concepts at the top of the map.
6. Next, select the two, three, or four sub-concepts to place under each general concept.
7. Connect the concepts by lines. Label the lines with one or a few linking words. The linking words should define the relationship between the two concepts so that it reads as a valid statement or proposition.
8. Rework the structure of your map, which may include adding, subtracting, or changing super-ordinate concepts.
9. Look for cross-links between concepts in different sections of the map and label these lines.
10. Concept maps could be made in many different forms for the same set of concepts. There is no one way to draw a concept map. As your understanding of relationships between concepts changes, so will your maps.

Evaluation of the PBL Session

At the end of each PBL session students were asked to fill out a questionnaire to evaluate the process of the session. The questionnaire consisted of three sections with 17 questions in total. The first section (five questions) was about students' opinions on the execution of step 1 to 5, which were scored on a 10-point scale ranging from 1 (poor) to 10 (excellent). The second section contained six questions about the evaluation of the problem, the tutor, the context, and the communication. In the final section, the focus was on students' opinions about working with CM. In this section, students were asked to evaluate the use of CM, with questions like whether concept mapping supported and triggered the activation of prior knowledge. The second and the third section were scored on a scale from 1 (strongly disagree) to 5 (strongly agree).

Finally, the time spent in PBL steps 1 to 5 was registered in order to compare the groups working with or without CM.

Results

Learning Goals

Table 1 shows to which extent the learning goals as formulated by the PBL groups in the first study match with the seven learning goals listed in the tutor instructions (LG TI). Groups 1 and 2 used concept mapping (CM), and groups 3 and 4 did not (non-CM).

Table 1. Results Learning Goal Correspondence (Study 1)

	CM		Non-CM		
LG TI	Group 1	Group 2	Group 3	Group 4	Mean
1	100%	70%	100%	100%	**93%**
2	15%	20%	30%	20%	**21%**
3	0%	0%	0%	0%	**0%**
4	100%	90%	100%	90%	**95%**
5	90%	0%	90%	80%	**65%**
6	10%	100%	70%	0%	**45%**
7	0%	0%	0%	0%	**0%**
Mean	**45%**	**40%**	**56%**	**41%**	

The learning goals as formulated by the PBL group were compared with the seven learning goals included in the tutor instruction, and the match was expressed in a percentage score. The higher the similarity between the learning goals of the problem constructor and those generated by the students in the PBL group, the higher the correspondence score. Six raters performed a consensual assessment of the match between the intended and the student-generated learning goals. The inter-rater agreement in classifying the student-generated learning goals was 96%, indicating that the raters strongly agreed on the allocation of student-generated learning goals to each of the seven learning goals listed in the tutor instruction. The percentage scores per learning goal had a range of maximum 15 points. Since the seven learning goals are considered to be of equal importance, no differential weighting was applied.

Looking at Table 1, it can be concluded that none of the student-generated learning goals matched with learning goal 3 and 7 as proposed by the problem designers in the tutor instructions. The learning goals with the best match are learning goals 1 (93%) and 4 (95%). Learning goals 2, 5, and 6 were only partly covered by the students. The average match for groups working with or without concept mapping did not show any significant difference ($t = -.802$; $df = 2$; $p = .547$).

Table 2 shows to which extent the learning goals of the groups in the second study match with the learning goals listed by the problem designers. The first three groups used CM, while the last four groups did not.

Table 2. Results Learning Goal Correspondence (Study 2)

	CM			Non-CM				
LG TI	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Mean
1	100%	100%	80%	80%	100%	100%	100%	**94%**
2	0%	100%	100%	100%	100%	100%	100%	**86%**
3	40%	0%	80%	100%	100%	100%	0%	**60%**
4	0%	0%	0%	100%	0%	50%	0%	**21%**
5	0%	0%	0%	0%	0%	0%	0%	**0%**
6	0%	50%	0%	50%	50%	0%	50%	**29%**
Mean	**23%**	**42%**	**43%**	**72%**	**58%**	**58%**	**42%**	

It can be concluded that none of the groups produced learning goals that match with learning goal 5 of the problem designers. Learning goals 1 (94%) and 2 (86%) have the highest overall match. Overall, the average match for the three groups working with CM (36%) did not significantly differ from the mean match in the four groups working without CM (57.5%) (t = -2.368; df = 2; p = .064).

Apart from the match between learning goals generated by the PBL groups and those listed in the tutor instructions, we also checked for the number of learning goals generated by the groups working with or without CM. Results are shown in Table 3.

Table 3. Amount of Learning Goals Provided by the PBL Groups

	Study 1		Study 2	
	CM	Non-CM	CM	Non-CM
	8	6	4	6
	9	11	4	6
			5	8
				10
Mean	8.5	8.5	4.3	7.5

In the first study, the two groups working with CM generated 8 and 9 learning goals respectively. The groups working without CM generated 11 and 6 learning goals. In both conditions an average of 8.5 learning goals were generated. In study 2, the average number of learning goals generated in both conditions was 4.3 (CM) and 7.5 (non-CM), indicating a significant difference between both conditions (t = 2.714; df = 5; p = .042) in favor of the non-CM group. Concept mapping does not seem to generate more learning goals.

Time Spent on Step 4

The time (in minutes) spent on the different steps in the PBL process of the groups who used CM and the groups who did not use concept maps are displayed in Table 5.

Table 5. Time Spent on Step 1-5 (Study 1)

	CM		Non-CM	
	Group 1	Group 2	Group 3	Group 4
Step 1	7	8	7	8
Step 2	4	4	5	18
Step 3	8	7	8	18
Step 4	14	14	25	0
Step 5	17	17	3	15
Total	50	50	48	59

In study 1, the groups spent on average 51.75 minutes for steps 1 to 5 of the PBL process. The groups who created concept maps spent an average of 50 minutes for the five steps. The groups without concept maps spent on average 53.5 minutes for the five steps. Only one group spent the most time on step 4. One of the non-CM groups skipped this step altogether. There was no significant difference in total time spent on step 4 between the CM-groups and the non-CM groups (t =.120; df =2; p = .915).

Table 6 shows the time spent on each step in study 2. The groups used on average 51.57 minutes for steps 1 to 5 of the PBL process. The groups who created a concept map spent on average of 51.33 minutes for these steps. The groups without concept mapping used on average 51.75 minutes for analyzing the problem and creating learning goals. There was no significant difference in total time spent on steps 1 to 5 between the CM and the non-CM groups (t = .052; df = 5; p = .961). Five out of the seven groups spent most of their time on step 4. However, there was no significant difference in time spent on step 4 between the CM groups (M = 16.33) and non-CM groups (M = 17) (t =-.111; df =5; p =.916).

Table 6. Time Spent on Step 1-5 (Study 2)

	CM			N-CM			
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Step 1	6	10	8	5	6	11	4
Step 2	5	3	14	4	9	10	3
Step 3	0	9	12	6	0	12	12
Step 4	23	6	20	17	18	8	25
Step 5	21	7	10	12	17	14	14
Total	55	35	64	44	50	55	58

Evaluation of the Session

The first section of Table 7 shows students' opinions about the execution of the first five steps of the seven-step method. The results from the 35 questionnaires filled out by the students in study 1 indicated that, compared to the groups working without CM, the groups that used CM were significantly more satisfied about the execution of step 3 (t = 2.33; df = 25.162; p = .028) and step 4 (t = 3.33; df =26.454; p =.003). In study 2, the results from the 58 questionnaires showed no significant differences in opinion about executing the five steps between the groups working with or without CM.

The second section of Table 7 shows students' opinions about the problem, tutor interventions, and the communication within the group. In study 1, a significant difference (t = 2.43; df = 32.991; p = .021) could be observed with regard to statement 6 (the decision-making process worked well in this group) between the CM groups (M = 3.88) and the non-CM groups (M = 3.42) In study 2, significant differences between the two conditions appeared in their opinion about statement 3 "The tutor directed the group good within the PBL process" (t = -2.61; df = 20.152; p = .017) and statement 5 "The communication within the group was good" (t = 3.34; df = 48.452 ; p = .002). For statement 3, the non-CM groups scored higher than the CM groups, while for statement 5 the opposite occurred (see Table 7).

The last section of Table 7 shows the opinion of the CM groups about concept maps. In study 1, the students' opinion is that CM supports the construction of learning goals, activates prior knowledge, helps in constructing learning goals, promotes a better understanding of the problem, and enhances the process of PBL. The results from study 2 show that students neither agree nor disagree that CM supports construction of learning goals, activates prior knowledge, promotes a better understanding of the problem, or enhances the process of PBL.

Table 7. Results of the Questionnaire

	Study 1	Study 1	Study 2	Study 2
Section 1: Students' opinion of executing steps 1-5	CM	N-CM	CM	N-CM
Step 1: Exploring problem text and context	7,44	7,42	6,58	6,84
Step 2: Defining the core issue of the problem presented	7,63	6,89	6,50	6,47
Step 3: Analyzing the problem	7,50	6,37	6,12	6,38
Step 4: Systematically restructuring the outcome of step 3	7,25	5,68	5,65	6,16
Step 5: Formulating learning objectives	7,31	6,37	6,88	6,78
Mean	7.42	6.55	6.35	6.53
Section 2: Students' opinion about problem, tutor interventions and communication				
1.The main problem/issue was stated clearly in the text	3,94	3,58	2,81	2,97
2.The problem challenged me to further study and analysis	3,63	3,58	3,31	3,45
3.The tutor directed the group good within the PBL process	4,06	4,17	3,33	4,87
4.The tutor explained so much that I myself am left doing less than usual	2,13	2,16	2,44	2,26
5.The communication within the group was good	4,25	3,89	3,81	3,52
6.The decision-making process worked well in this group	3,88	3,42	3,35	3,26
Mean	3.65	3.47	3.18	3.39
Section 3: Students' opinion about working with CM				
1.CM supported the construction of learning goals	3,94		3,23	
2.CM stimulated the activation of prior knowledge	3,63		3,38	
3.CM helped in creating a better understanding of the problem	3,75		3,12	
4.CM enhanced the process of PBL	3,94		3,00	
5.CM enhanced my interest in the subject matter	3,56		3,04	
6.CM will help me to memorize relevant information for the test	3,88		2,96	
Mean	3.78		3.12	

Discussion

Does implementation of CM enhance the process of PBL? To find the answer to that question two studies were conducted. The expectations were that by using CM, students would produce more and better matching learning goals, devote more time to step 4, gain a better understanding of the problem, and be more satisfied about the PBL session, which altogether should lead to the ultimate goal of improved student learning.

The first two research questions about the impact of CM on formulating learning goals were related to the quantity and quality of the learning goals generated by the PBL groups. The questions were: a) Do PBL groups who use concept maps generate more learning goals than the ones who do not?; and b) Do PBL groups who use concept maps formulate learning goals which show more correspondence with the ones intended by the problem designer?

The answers to both research questions are negative. The PBL groups who used CM did not produce more learning goals than the ones who did not use CM. The PBL groups who did use concept maps did not have learning goals that were more in line with the goals formulated by the problem designer. Inspection of the study materials showed that the problems that were used in this study were realistic and relevant for practice, were well-structured, and contained sufficient information and cues to enable students to work in a meaningful way. Though ill-structured and authentic problems are generally advisable in PBL (Savery & Duffy, 1996) well-structured and not-to-difficult problems provide first-year students with direction for what and how to learn in a PBL setting. Nevertheless, the learning goals that were formulated by the students did not always match the learning goals that were set by the problem designers. For instance, the learning goals correspondence of the problem "Greening the business" showed that two learning goals were not mentioned by the seven PBL groups. Inspection of these two learning goals showed that learning goal 5 focused on "Exchange of knowledge among the students on best hotel environment practices." Exchange of knowledge is typically something that must always take place in step 7, and there is no need to formulate exchange of knowledge as a learning goal. Learning goal 7 (i.e., "What aspects influence the European hoteliers' environmental attitudes?") required the students to look beyond the problem situation that was presented and they were unable to make inferences and generalizations. Learning goal correspondence not only depends on the students' efforts and capacities to formulate relevant and corresponding goals, but also depends on the quality of the problems and the quality of the related learning goals that are produced by the problem designers.

Some PBL groups formulated more learning goals than the problem designers. Inspection of students' learning goals showed that many "What is" questions referring to factual knowledge rather than in-depth understanding were formulated. For instance, the factual information and clues in the problem "Greening the business" were used by the students to formulate the learning goals and little elaboration took place; consequently, many learning goals were formulated that aimed at gaining factual knowledge. It appears to be difficult for first-year students to formulate more sophisticated learning issues.

Results might also have been affected by tutor interventions. When and how to intervene in tutorial groups are amongst the most often expressed tutor challenges. Observations of tutor behaviors showed that the amount of tutor interventions and the way tutors intervened differed from each other, which might have influenced the number and the quality of learning goals that were formulated by the students. Some tutors applied a questioning approach and focused on process interventions to enable the progress of group work. Other tutors were more directive and focused on learning contents. For example, two CM groups in study 2 had to make the concept map and formulate learning goals without much help from their tutor, while in some non-CM groups tutors happened to guide students to the learning goals listed in the tutor instructions. This is also reflected in the high scores on tutor directions and guidance by the non-CM groups in study 2 (M =4.87). When tutors in the non-CM groups provided the appropriate learning goals and tutors in CM groups did not, the effect of CM will be suppressed or obscured. Since the current studies were conducted in a naturalistic setting, we could not properly control for the differential impact of tutor interventions. For further research we recommend a more rigid experimental design, controlling for equivalence of tutors, problems, and PBL groups. Those studies should also investigate to what extent CM generates (additional) learning goals that emerge from the problem, match the overall module objectives, and reflect students' personal and professional interests but are not listed in the tutor instructions.

Since the problem designers did not provide any standards for the required output of step 4, no definitive conclusions could be drawn with respect to the quality of the concept maps produced by the groups. Assessment of the quality of the concept maps and its relations to the other steps of the seven-step method might be an interesting topic for further research.

The second part of the study focused on the time spent on step 4 of the seven-step method. No significant differences were found in time spent on step 4 in the pre-discussion of the problems. In future research it would be interesting to not only look at the time spent in step 4, but to also monitor both the feedback and feed forward function that CM might have. The feedback function would occur when students—while working on their concept map—decide to return to earlier stages of the PBL process, for instance, when it turns out that the problem statement as formulated in step 2 needs to be adapted. A feed forward effect would occur when students who worked with CM before, already start anticipating on it in step 1.

The final part of the study focused on the impact of CM on the evaluation of the PBL session. The evaluation of the session was done with a questionnaire. In study 1, the groups using CM were significantly more satisfied about the execution of two crucial steps in the process of PBL: generating and analyzing preliminary ideas about the problem (step 3) and systematically structuring the results of the analysis in a conceptual network (step 4). These are exactly the two steps that Moust et al. (2005) identified as weak spots in the routine approach applied by students. Although these effects could not be replicated in study 2 due to unequal tutor guidance in both conditions, we consider these findings promising.

In the second section of the questionnaire, students indicated to what extent they agreed with particular statements about the problem, the tutor, the communication, and decision making in the group. In study 1, the groups using CM were significantly more satisfied with the decision-making process in the group. In study 2, groups working with or without CM differed in their opinions about the degree of tutor direction and the communication within the group. The groups working with CM were more positive about the communication within their groups, while the groups working without CM indicated that their tutor provided significantly more direction. The directive role of the tutor could have seriously influenced the results of our study. If tutors facilitate the learning process and provide help by focusing on the right issues or even listing the intended learning goals, the impact of CM might be dissolved. If PBL becomes tutor-centered instead of student-centered, an additional confounding factor would be introduced related to the level of expertise of the tutors involved.

Previous research showed that CM could bring about more creativity and a better understanding of certain problems. However, this study does not show empirical evidence that implementing CM enhances the process of PBL. Before implementing CM in step 4 of the PBL process, further research needs to be done taking the following factors into consideration.

First, the study attitudes, learning styles, and prior education of the students must be taken into account. When students do not feel comfortable with a constructivist approach to education like PBL and hold on to a traditional conception of education, CM might be perceived as inefficient and a waste of time. Likewise, students with a pragmatic learning style could be less interested in conceptual learning and the construction of complicated models.

Second, the problem should meet the design criteria for PBL problems. Problems should address key professional issues in an authentic context and should be tailored to the competences and level of prior knowledge of the students. Our study clearly shows that the learning goals that were generated by PBL groups often did not match those of the problem designers. When learning goals are not detected by any PBL group, both the problem and its learning goals have to be reconsidered by the problem designer.

A third factor is the tutor. The tutor is supposed to coach the students in analyzing the PBL problem from different perspectives, determining the problem statement, formulating research questions, self-study activities, data collection, information processing, and synthesizing new viewpoints and information into a coherent conceptual framework. Consistency in tutors' behaviors in different PBL groups might be enhanced by adequate tutor instructions. All tutors should have sufficient expertise and should understand the rationale for the module theme and the objectives of the individual problems. Furthermore, tutors should be well-trained in monitoring and managing group dynamics, and in promoting student-centered and self-directed learning. At the moment, the way that tutors perform their role in guiding the learning process differs greatly. Some tutors remain silent and do not intervene until the end of the session and give the learning goals from the tutor instructions to the students. Other tutors actively contribute to the learning process and intervene during the PBL session. Though individual differences in tutor behavior must be acknowledged, all groups should receive adequate guidance empowering them to meet the educational objectives.

Our major recommendation for further research would be to replicate the study with an extended sample size in an experimental setting, controlling for the impact of the quality of the problem and tutor interventions. A PBL lab, which is currently under construction at our institute, will create an optimal setting for such continued studies on the impact of CM on the process of PBL. We also recommend for further studies to include additional measures for students' learning outcomes.

Acknowledgments

The authors like to acknowledge the contribution of the following students who in the context of their Bachelor Dissertation participated in the process of data collection: Irina Yaneva, Stéphanie van Wilpe, Jascha Broermann, Hoa Huynh, Rick Kiebert, Peerapon Namjumjang.

References

Albanese, M. A. (2000). Problem-based learning: Why curricula are likely to show little effect on knowledge and clinical skills. *Medical Education, 34*(9), 729-738. doi:10.1046/j.1365-2923.2000.00753.x

Albanese, M. A. (2009). Life is tough for curriculum researchers. *Medical Education, 43*(3), 199-201. doi:10.1111/j.1365-2923.2008.03289.x

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine*, *68*(1), 52-81. doi:10.1097/00001888-199301000-00012

All, A. C., & Havens, R. L. (1997). Cognitive/concept mapping: A teaching strategy for nursing. *Journal of Advanced Nursing, 25*(6), 1210-1219. doi:10.1046/j.1365-2648.1997.19970251210.x

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 68*, 3-11. doi:10.1002/tl.37219966804

Barrows, H. S., & Tamblyn, R. (1980). *Problem-based learning: An approach to medical education.* New York: Springer.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally.

Capon, N., & Kuhn, D. (2004). What's so good about problem-based learning? *Cognition and Instruction*, *22*(1), 61-79. doi:10.1207/s1532690Xci2201_3

Chiou, C. C. (2009). Effects of concept mapping strategy on learning performance in business and economics statistics. *Teaching in Higher Education, 14*(1), 55-69. doi:10.1080/13562510802602582

Colliver J. A. (2000). Effectiveness of problem-based learning curricula: Research and theory. *Academic Medicine, 75*(3), 259-266. doi:10.1097/00001888-200003000-00017

Cooper, R. D., & Schindler S. P. (1998). *Business Research Methods* (6th ed.). New York: McGraw-Hill.

Daley, B. J., & Torre, D. M. (2010). Concept maps in medical education: An analytical literature review. *Medical Education, 44*(5), 440-448. doi:10.1111/j.1365-2923.2010.03628.x

De Grave, W. S., Boshuizen, H. P. A., & Schmidt, H. G. (1996). Problem-based learning: Cognitive and metacognitive processes during problem analysis. *Instructional Science, 24*(5), 321-341. doi:10.1007/BF00118111

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction, 13*(5), 533-568. doi:10.1016/S0959-4752(02)00025-7

Dochy, F., Segers, M., Van den Bossche, P., & Struyven, K. (2005). Students' perceptions of a problem-based learning environment. *Learning Environments Research, 8*(1), 41-66. doi:10.1007/s10984-005-7948-x

Dolmans, D. H. J. M., De Grave, W. S., Wolfhagen, I. H. A. P., & Van der Vleuten, C. P. M. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education, 39*(7), 732-741. doi:10.1111/j.1365-2929.2005.02205.x

Dolmans, D. H. J. M., Gijselaers, W. H., Schmidt, H. G., & Van der Meer, S. B. (1993). Problem effectiveness in a course using problem-based learning. *Academic Medicine, 68*(3), 207-213. doi:10.1097/00001888-199303000-00013

Dolmans, D. H. J. M., Schmidt, H. G., & Gijselaers, W. H. (1995). The relationship between student-generated learning issues and self-study in problem-based learning. *Instructional Science, 22*(4), 251-267. doi:10.1007/BF00891779

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75*(1), 27-61. doi:10.3102/00346543075001027

Hartling, L., Spooner, C., Tjosvold, L., & Oswald, A. (2010). Problem-based learning in pre-clinical medical education: 22 years of outcome research. *Medical Teacher, 32*(1), 28-35. doi:10.3109/01421590903200789

Hay, D. B. (2007). Using concept maps to measure deep, surface and non-learning outcomes. *Studies in Higher Education, 32*(1), 39-57. doi:10.1080/03075070601099432

Hay, D. B., Kinchin, I., & Lygo-Baker, S. (2008). Making learning visible: The role of concept mapping in higher education. *Studies in Higher Education, 33*(3), 295-311. doi:10.1080/03075070802049251

Hendry, G. D., Frommer, M., & Walker, R. A. (1999). Constructivism and problem-based learning. *Journal of Further and Higher Education, 23*(3), 359-371. doi:10.1080/0309877990230306

Hmelo, C. E. (1998a). Cognitive consequences of problem-based learning for the early development of medical expertise. *Teaching and Learning in Medicine, 10*(2), 92-100. doi:10.1207/S15328015TLM1002_7

Hmelo, C. E. (1998b). Problem-based learning: Effects on the early acquisition of cognitive skill in medicine. *Journal of the Learning Sciences, 7*(2), 173-208. doi:10.1207/s15327809jls0702_2

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Education Psychology Review, 16*(3), 235-266. doi:10.1207/s15327809jls0702_2

Hmelo-Silver, C. E., & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction, 26*(1), 48-94. doi:10.1080/07370000701798495

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107. doi:10.1080/00461520701263368

Hmelo, C. E., Gotterer, G. S., & Bransford, J. D. (1997). A theory-driven approach to assessing the cognitive effects of PBL. *Instructional Science, 25*(6), 387-408. doi:10.1023/A:1003013126262

Hong Gao, E. S., Losh, S., & Turner, J. (2007). A review of studies on collaborative concept mapping: What have we learned about the technique and what is next? *Journal of Interactive Learning Research, 18*, 479-492.

Hsu, L. L. (2004). Developing concept maps from problem-based learning scenario discussions. *Journal of Advanced Nursing, 48*(5), 510-518. doi:10.1111/j.1365-2648.2004.03233.x

Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. *The Interdisciplinary Journal of Problem-based Learning*, *1*, 55-77.

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development, 59*(4), 529-552. doi:10.1007/s11423-011-9198-1

Jacobs, A. E. J. P., Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & Scherpbier, A. J. J. A. (2003). Validation of a short questionnaire to assess the degree of complexity and structuredness of PBL problems. *Medical Education, 37*(11), 1001-1007. doi:10.1046/j.1365-2923.2003.01630.x

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*(1), 65-94. doi:10.1046/j.1365-2923.2003.01630.x

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85. doi:10.1007/BF02300500

Johnstone, A. H., & Otis, K. H. (2006). Concept mapping in problem based learning: A cautionary tale. *Chemistry Education Research and Practice*, *7*(2), 84-95. doi:10.1039/B5RP90017D

Kassab, S. E., & Hussain, S. (2010). Concept mapping assessment in a problem-based medical curriculum. *Medical Teacher, 32*(11), 926-931. doi:10.3109/0142159X.2010.497824

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75-86. doi:10.1207/s15326985ep4102_1

Koury, K., Hollingsead, C., Fitzgerald, G., Miller, K., Mitchem, K., Tsai, H-H., & Zha, S. (2009). Case-based instruction in different delivery contexts: The impact of time in cases. *Journal of Interactive Learning Research, 20*(4), 445-467.

McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. *Journal of Research in Science Teaching*, *36*(4), 475-492. doi:10.1002/(SICI)1098-2736(199904)36:4<475::AID-TEA5>3.0.CO;2-O

Moust, J. H. C., van Berkel, H. J. M., & Schmidt, H. G. (2005). Signs of erosion: Reflections on three decades of problem-based learning at Maastricht University. *Higher Education*, *50*(4), 665-683. doi:10.1007/s10734-004-6371-z

Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research, 76*(3), 413-448. doi:10.3102/00346543076003413

Norman, G. R., & Schmidt, H. G. (2000). Effectiveness of problem-based learning curricula: Theory, practice and paper darts. *Medical Education*, *34*(9), 721-728. doi:10.1046/j.1365-2923.2000.00749.x

Novak, D. J. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations.* Mahwah: Lawrence Erlbaum Associates.

Novak, D. J., & Cañas, A. J. (2006). *The theory underlying concept maps and how to construct them.* Technical Report IHMC CmapTools 2006-01. Florida Institute for Human and Machine Cognition. Retrieved from http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf.

Novak, D. J., & Gowin, B. (1984). *Learning how to learn.* New York: Cambridge University Press.

Otting, H., & Zwaal, W. (2006). Critical task characteristics in problem-based learning. *Industry & Higher Education, 20*(5), 347-357. doi:10.5367/000000006778702283

Pinto, A. J., & Zeitz, H. J. (1997). Concept mapping: A strategy for promoting meaningful learning in medical education. *Medical Teacher, 19*(2), 114-121. doi:10.3109/01421599709019363

Rendas, B., Fonseca, M., & Rosado Pinto, P. (2006). Toward meaningful learning in undergraduate medical education using concept maps in a PBL pathophysiology course. *Advances in Physiology Education*, *30*(1), 23-29. doi:10.1152/advan.00036.2005

Rotgans, J. I., O'Grady, G., & Alwis, W. A. M. (2011). Introduction: Studies on the learning process in the one-day, one-problem approach to problem-based learning. *Advances in Health Sciences Education, 16*(4), 443-448. doi:10.1007/s10459-011-9299-y

Rotgans, J. I., & Schmidt, H. G. (2011). Cognitive engagement in the problem-based classroom. *Advances in Health Sciences Education, 16*(4), 465-479. doi:10.1007/s10459-011-9299-y

Savery, J. R., & Duffy, T. M. (1996). Problem based learning: An instructional model and its constructivist framework. In B. G. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 35–48). Englewood Cliffs, NJ: Educational Technology Publications.

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. Buckingham: Society for Research into Higher Education & Open University Press.

Savin-Baden, M. (2004). Understanding the impact of assessment on students in problem-based learning. *Innovations in Education and Teaching International, 41*(2), 221-233. doi:10.1080/1470329042000208729

Savin-Baden, M. (2007). Challenging models and perspectives of problem-based learning. In E. de Graaff & A. Kolmos (Eds.), *Management of change: Implementation of problem-based learning and project-based learning in engineering* (pp. 9-30). Rotterdam, the Netherlands: Sense Publishers.

Schmidt, H. G. (1983). Problem-based learning: Rationale and description. *Medical Education, 17*(1), 11-16. doi:10.1111/j.1365-2923.1983.tb01086.x

Schmidt, H. G., & Gijselaers, W. H. (1990). *Causal modeling of problem-based learning.* Boston: Paper presented at the Annual Meeting of the American Educational Research Association.

Schmidt, H. G., Van der Molen, H. T., Te Winkel, W. W. R., & Wijnen, W. H. F. W. (2009). Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school. *Educational Psychologist*, *44*(4), 227–249. doi:10.1080/00461520903213592

Taylor, D., & Miflin, B. (2008). Problem-based learning: Where are we now? *Medical Teacher, 30*(8), 742-763. doi:10.1080/01421590802217199

Van Boxtel, C., Van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration on conceptual knowledge. *Learning and Instruction, 10*(4), 311-330. doi:10.1016/S0959-4752(00)00002-5

Van Boxtel, C., Van der Linden, J., Roelofs, E., & Erkens, G. (2002). Collaborative concept mapping: Provoking and supporting meaningful discourse. *Theory into Practice, 41*(1), 40-46. doi:10.1207/s15430421tip4101_7

Van den Hurk, M. (2006). The relation between self-regulated strategies and individual study time, prepared participation and achievement in a problem-based curriculum. *Active Learning in Higher Education, 7*(2), 155-169. doi:10.1177/1469787406064752

Van den Hurk, M., Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & Van der Vleuten, C. P. M. (2001). Quality of student-generated learning issues in a problem-based curriculum. *Medical Teacher, 23*(6), 567-571. doi:10.1080/01421590120090998

Vernon, D. T. A., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550-563. doi:10.1097/00001888-199307000-00015

West, D. C., Park, J. K., Pomeroy, J. R., & Sandoval, J. (2002). Concept map assessment in medical education: A comparison of two scoring systems. *Medical Education, 36*(9), 820-826. doi:10.1046/j.1365-2923.2002.01292.x

Yew, E. H. J., Chng, E., & Schmidt, H. G. (2011). Is learning in problem-based learning cumulative? *Advances in Health Sciences Education, 16*(4), 449-464. doi:10.1007/s10459-010-9267-y

Zanolli, M. B., Boshuizen, H. P. A., & De Grave, W. S. (2002). Students' and tutors' perceptions of problems in PBL tutorial groups at a Brazilian medical school. *Education for Health, 15*(2), 189-201.

Zwaal, W., & Otting, H. (2010). The process of problem-based hospitality management education. *Journal of Hospitality, Leisure, Sport, and Tourism Education, 9*(2), 17-30. doi:10.3794/johlste.92.188

Wichard Zwaal is senior lecturer at the International Hospitality Management School. He graduated as an educational psychologist specializing in educational measurement and assessment, and he has worked in several positions as a teacher and consultant. His current research focuses on concept mapping as a tool to improve problem-based hospitality management education. Correspondence concerning this article should be addressed to Wichard Zwaal, Stenden University of Applied Sciences, Rengerslaan 8, 8917 DD Leeuwarden, The Netherlands, PO Box1298, 8900 CG; E-mail: wichard.zwaal@stenden.com.

Hans Otting was founder (in 1987) and dean of the International Hospitality Management School, where he introduced problem-based learning as the leading approach in the program. In 1999, he moved to the position of senior consultant at Stenden University's Centre for Educational Research and Development. In 2009, he obtained his PhD based on the thesis "Knowledge, learning, and teaching: Studies on the application of constructivist principles in higher education."