Enhancing small group functioning in problem based learning using a visual organiser

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Problem based learning allows students to learn from each other while they co-construct meaning. Learning can be hampered, however, when group discussion of issues is superficial, incoherent, or biased towards common knowledge. Visual organisers may improve the quality of group discussions. Mind maps have been integrated in the PBL environment of first and second year bachelor students. Students indicated mapping enriched their learning environment.

Keywords: Problem-based learning, mind maps

Introduction

Problem-based learning (PBL) allows students to learn from each other while they co-construct meaning. Active, constructivist, interactive learning approaches like PBL are believed to yield important cognitive and motivational benefits (Chi, 2009). PBL motivates students to integrate new information with prior knowledge and personal experience that is activated by discussing authentic problems in small groups. In a typical session, students clarify unknown concepts in the problem description, formulate a problem definition, and engage in problem analysis by brainstorming and then elaborating on and clustering the results of the brainstorm. Next, learning goals are formulated and students start their individual study. When they return to the tutorial group, students report their findings and try to synthesize and integrate new information (cf. Dolmans & Schmidt, 2010). PBL has been adopted in various fields of study, including medical education, economics, engineering, biology, psychology and law. Positive curricular effects of PBL have been reported on graduation rate and study duration. In addition, PBL students have been reported to possess better practical and interpersonal skills (Schmidt et al., 2009; Schmidt, 2010).

Tutorial groups in PBL offer a safe and challenging environment in which students can debate and critically analyze contributions of fellow students and writings of experts. Unfortunately, conditions for group work and cooperative learning in a PBL environment can be suboptimal (e.g., Dolmans, Wolfhagen, Van der Vleuten, and Wijnen, 2001). There are many reasons why groups are less effective than they could be. For instance, when groups are large, free riders may fake active involvement or group members may not be motivated to share information (Wittenbaum, Hollingshead & Botero, 2004). Information exchange is often biased towards common knowledge (cf. Stasser & Titus, 2003; Mesmer-Magnus & DeChurch, 2009). Information can be omitted from group products, because individuals choose to withhold it or because groups fail to incorporate it (Ekeocha & Brennan, 2008). In diverse PBL groups, students often do not interact fluently, especially when they have low

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verbal ability or when group dynamics create tensions. Group members are less willing to share information with members that are perceived to be different (cf. Van Knippenberg, De Dreu, & Homan, 2004; Mesmer-Magnus & DeChurch, 2009). Problem analysis in small groups can be frustrated because turn taking (production blocking) interferes with knowledge activation and idea generation. The resulting cognitive failures affect brainstorming persistence, enjoyment and productivity (Nijstad & Stroebe, 2006). Problem analysis and group discussions are often superficial, or incoherent (e.g., Visschers-Pleijers, Dolmans, De Grave, et al., 2006). According to students in PBL, effective discussions should allow room for the exchange of explanations and for integration and application of knowledge. Discussions are perceived to be effective when they help students structure knowledge and relate concepts and when differences with regard to learning content are analysed (Visschers-Pleijers et al., 2006).

The present study aims to clarify to whether visual organisers may improve group work in PBL. Concept maps (Novak, 1998), arguments maps (Van Gelder, 2003) and mind maps (Buzan & Buzan, 2000) are examples of visual organisers that have successfully supported constructive learning activities and yielded valuable insights in group knowledge representations (Mohammed, 2010). In addition, use of concept maps has been shown to improve learning outcomes (e.g., Gonzalez, Palencia, Umana, et al., 2008). Maps invite students to explicitly judge and analyze relationships between key concepts. Hilbert and Renkl (2008) identified four important functions of visual maps:

1. elaboration function – mapping forces a learner to relate new information to prior knowledge and determine whether and how concepts interrelate;
2. reduction function – learners first determine the relevance of each new addition to the map before adding a concept; this may enhance the acquisition of macrolevel ideas;
3. coherence function – maps externalise knowledge structures using nonverbal cues (spatial proximity, colour codes, icons) to indicate relationships between concepts;
4. metacognitive function – learners become more aware of knowledge gaps when they construct maps

In addition, visualizing interrelationships between concepts should facilitate recall and comprehension (Mayer, 2001; Paivio, 1986). Contrary to a linear, text-based presentation of arguments, a nonsequential presentation can make argument structure more salient (Van Gelder, 2003). Maps can be used to facilitate exchange of ideas in groups: they challenge perceptions and help negotiate meaning. Visual representations offer continuous (visual) access to products of other team members, which can serve as memory cues or competitive stimuli. When a group member explicitizes a concept in a map, mental models of other team members are changed, which in turn can trigger novel ideas and further enrich the map, thus stimulating knowledge creation (Rentsch, Mello & Delise, 2010). Finally, the limited amount of text in maps appears to stimulate students to express their thoughts more carefully, and seems to help level the playing field for non-native speakers.

In PBL, maps can be constructed when learning activities are initiated (e.g., during idea generation and problem elaboration) and when group members synthesize and integrate newly found information. For individual students, maps may also provide more detailed directions for self study and serve as an advance organizer for the reporting session, facilitating the subsequent exchange of ideas. Depending on the type of problems, students or instructors may prefer the use of concept maps or argument maps, which typically place constraints on the types of relations between concept nodes, over less constraining mind maps. Finally, group maps can provide teachers with more detailed feedback on learning processes and outcomes.

Method

The present study contrasted the effects of mind map construction and manipulation with traditional note taking by a scribe on tutorial group outcomes. Participants were first and second year bachelor students who were randomly assigned to medium-sized groups of 9-12 students. During each of eight tutorial group meetings, students used mind and concept mapping software (MindManager, see http://www.mindjet.com) to construct a map during problem analysis and elaborate on this map during reporting. Students interacted with the mapping software by means of an interactive digital whiteboard. Mapping software was used in 20 groups of psychology students (12 groups comprising 118 first year students, and 8 groups comprising 74 second year students). In the control condition, traditional note-taking occurred in 36 groups of psychology students (N=243; 19 groups comprising 180 first year students and 17 groups comprising 162 second year students).

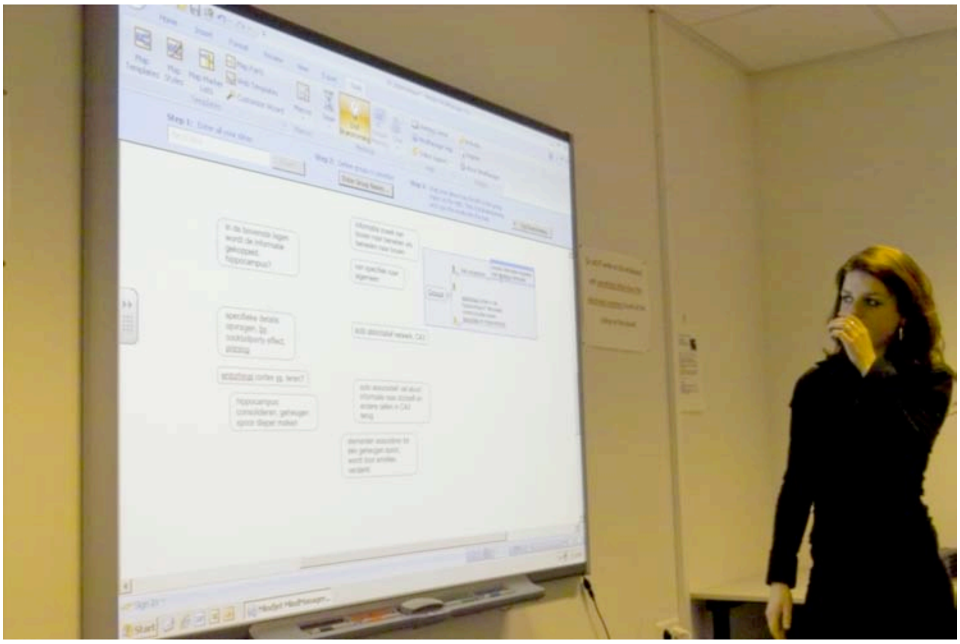

Figure 1: Scribe on the verge of interacting with a mind map on a digital whiteboard

All students engaged in regular PBL activities, viz, problem definition, brainstorming, elaborating and clustering, defining learning objectives, self study, and reporting. The scribe controlled the digital whiteboard, entered concepts during brainstorming, manipulated objects during clustering and revised the map or created a new one during problem synthesis, always under guidance of the tutorial group (see figure 1). PBL activities were part of two second semester modules of the bachelor of psychology course at Maastricht University (viz., cognitive psychology and cognitive science) and were assessed for academic credit. Tutors were asked to provide oral feedback on the use of maps during weekly meetings. At the end of the module, students filled out evaluation questionnaires. The questionnaires contained a series of 7-point Likert-scale items gauging satisfaction with process, difficulty of brainstorm, motivation to generate ideas, apprehension to generate ideas, satisfaction with the number and quality of ideas, satisfaction with the quality of mind maps, usefulness of clustering/elaboration, usefulness of mind mapping during brainstorm and reporting phase, whether clustering/elaboration improved the organisation of generated ideas, and whether student would like to use maps again in other modules. Choice of questionnaire items was based on a review of prior literature (e.g., Dennis & Valacich, 1993; Gallupe, Bastianutti, &

Cooper, 1991). In addition, the questionnaires invited students to comment on the effects of mapping on the group process and to judge the quality of the learning tasks / problems. The duration of the brainstorm and clustering phases were measured by the tutor at the end of each tutorial group session. A rudimentary analysis of the maps yielded data on the number of concepts and branches of student maps (for more advanced analysis, see Hay & Kinchin, 2006). Exam scores and scores on related items in a test administered three months later (a progress test) were gathered to assess possible learning effects.

Results

Tables 1 and 2 show main results of the student evaluation of the problem analysis sessions. Multivariate analysis of variance showed that second year students in groups using mapping tools were significantly less dissatisfied with the idea generation process and the number and quality of ideas they produced than subjects in the control groups. They were clearly less dissatisfied with group activities during problem elaboration/clustering, and they were more convinced of the usefulness of problem elaboration/clustering than control group students. First year students using maps were not significantly more satisfied with the problem analysis session, but they were more appreciative of the use of the mapping tool during problem elaboration/clustering than students in the control group.

Table 1: First year students' evaluation of problem analysis

7-point Likert-type item	Mapping N=113 M(SD)	Control N=176 M(SD)	Sig.
I felt satisfied with problem analysis	4.5(1.5)	3.3(1.4)	ns
I felt comfortable during problem analysis	4.6(1.4)	4.7(1.4)	ns
I felt motivated to generate ideas	4.0(1.4)	4.2(1.3)	ns
I felt satisfied with number of ideas	5.0(1.1)	4.7(1.2)	ns
I felt satisfied with the quality of ideas	5.0(1.1)	4.8(1.1)	ns
Clustering was a useful activity	3.9(1.8)	2.6(1.5)	.000
Clustering improved organization of learning material	3.9(1.9)	2.6(1.4)	.000

Table 2: Second year student's evaluation of problem analysis

7-point Likert-type item	Mapping N=74 M(SD)	Control N=148 M(SD)	Sig.
I felt satisfied with problem analysis	4.0(1.5)	3.4(1.4)	.001
I felt comfortable during problem analysis	4.5(1.4)	4.0(1.3)	.001
I felt motivated to generate ideas	4.1(1.3)	3.6(1.3)	.005
I felt satisfied with number of ideas	4.9(1.4)	4.3(1.3)	.003
I felt satisfied with the quality of ideas	5.1(1.1)	4.5(1.2)	.001
Clustering was a useful activity	3.7(1.9)	2.1(1.3)	.000
Clustering improved organization of learning material	3.8(1.7)	2.2(1.3)	.000

Table 3 shows how students evaluated the use of mind maps during problem synthesis. Analysis of variance confirmed there were no significant differences between first and second year students. Highest ratings were obtained for usefulness of mapping and satisfaction with the quality of maps constructed during reporting and synthesis of novel information.

Table 3: Student evaluation of mapping

7-point Likert-type item	Year 1 N=113 M(SD)	Year 2 N=70 M(SD)
I felt comfortable working with the mapping tool	5.2(1.7)	5.0(1.6)
I used a mapping tool during individual study (1=never, 7=always)	2.6(2.0)	2.1(1.7)
Mapping improved organization of learning material	5.4(1.5)	4.9(1.5)
I felt satisfied with the quality of mind maps of problem analysis	4.8(1.5)	5.0(1.3)
I felt satisfied with the quality of mind maps drawn during reporting	5.6(1.2)	5.5(1.3)
During problem analysis, mapping was a useful activity	4.3(1.7)	4.3(1.7)
During reporting, mapping was a useful activity	5.8(1.3)	5.4(1.5)

A large majority of students indicated they would like to continue the use of maps during the reporting phase of PBL sessions in other course modules (70% in favour, 10% opposed, 20% undecided in year 2, and 81% in favour, 9% opposed, 10% undecided in year 1). About half the students favored continuing the use of maps during problem analysis (49% in favour, 19% opposed, 32% undecided in year 2, and 46% in favour, 19% opposed, 32% undecided in year 1). Most students agreed that mapping changed the group process (75% in year 1, 78% in year 2). Student comments suggested discussion content was better organised and more structured, and more focussed on relationships between concepts. In addition, students reported that group members were more active, and contributed more to the discussions. On the other hand, some students warned that mapping slowed the group down, that the scribe was sometimes too preoccupied with the map, and that some group members started to pay more attention to the digital whiteboard rather than to other group members.

Table 4: Average number of concepts and branches

	Year 1 N=96 M(SD)	Year 2 N=64 M(SD)
Number of concepts in problem analysis maps	17.6(6.4)	15.1(4.9)
Number of branches in problem analysis maps	3.5(0.6)	3.4(0.9)
Number of concepts in problem synthesis maps	66.1(19.4)	43.0(14.5)
Number of branches in problem synthesis maps	4.7(1.1)	5.5(2.0)

Table 4 gives a rough sketch of the structure of the mind maps. First year and second year students appeared to have constructed similar maps, although first year students added significantly more nodes to their maps of the synthesizing discussion ($p=0.01$). Correlations between student evaluations of the quality of mind maps made during problem synthesis and the number of branches in these maps were negative for first year students (Pearson $r = -0.20$,

p<.05) as was the correlation between satisfaction with problem synthesis and number of branches (r=-.24, p<.01). For second year students, negative correlations were found between the number of nodes and perceived quality of mind maps (r=-0.27, p<.01), and between the number of nodes and satisfaction with problem synthesis (r=-.39, p<.01). Second year students perceived clustering as being more useful, when maps contained more nodes (r=.44, p<.01) and more branches (r=.44, p<.01). They were also more comfortable with problem analysis and more satisfied with the number of ideas generated, when maps contained more branches (r=.38, p<.01, resp. r=.36, p<.01). The number of concepts did not significantly correlate with these variables. No significant results were found for first year students.
Despite student comments suggesting the use of mapping tools slowed the group down, problem analysis in experimental groups did not take significantly longer than in control groups (see table 5).

Table 5: Duration of problem analysis in minutes averaged over 8 sessions and N groups

	Year 1 M(SD),N	Year 2 M(SD),N
Duration brainstorm mapping condition	17.9(4.5),12	17.6(4.4),8
Duration clustering mapping condition	8.4(2.8),12	8.6(4.3),8
Duration brainstorm control condition	19.5(4.4),18	19.8(4.4),14
Duration clustering control condition	8.3(2.7), 18	5.9(2.5),14

Although students in the mapping condition did score marginally higher on exam questions that probed for relations between concepts, neither exam test scores, nor delayed test scores differed significantly across conditions.

Discussion

In PBL, mind maps can be used when learning activities are initiated (e.g., during idea generation and problem elaboration) or when group members synthesize and integrate newly found information. Maps organize the group's retrieval and combination of information, and mapping can enhance discussion structure and stimulate member's in-depth processing and elaboration of information (Mesmer-Magnus & DeChurch, 2009). Students in tutorial groups using mapping tools were significantly more satisfied with problem analysis and synthesis than students in control groups and would like to continue using maps, especially during problem synthesis. Meetings with tutors confirmed these impressions, and most tutors were pleased with the PBL process in the mapping condition. The results are encouraging given the fact that students' prior experience with mapping was very limited. Interestingly, spontaneous use of mind mapping tools emerged in later years. For instance, in a course module with third year students one third of whom had experience with mind mapping, half the tutorial groups spontaneously used maps during problem analysis and synthesis.

Working with digital whiteboards did not upset students. Indeed, digital whiteboards have been used extensively to facilitate mind and concept mapping in groups (e.g., Ritchhart, Turner & Hadar, 2009). However, these boards do not afford multi-user interaction. In the future, tabletops (e.g., Buisine et al., 2007) may prove to deliver better support. Multi-user interaction may also improve the role of the scribe. The role of the scribes merits closer attention, as a scribe risks losing contact with the other group members, while a map on the whiteboard demands attention. Use of maps in blended or virtual PBL environments will also be explored, although high level tasks, such as critical analysis of problems and synthesizing new information are still believed to be better supported in synchronous, face-to-face learning environments.

Differences between first and second year students may be the result of the different nature of content material covered in both course modules. Ideally, students should always find positive value in learning materials, a sense of achieving a worthwhile purpose, and they should feel confident about their ability to study or solve them. Nevertheless, the second year course may have been more challenging or covering a more remote part of the students' conceptual habitat or addressing problems that converge on specific solutions. The fact that second year students produced maps with fewer nodes than those of first year students may suggest second year students feel more comfortable with the reduction function of maps. Alternatively, it may suggest information exchange was hampered by greater informational interdependence (Mesmer-Magnus & DeChurch, 2009) or because of added coordination requirements at the group level, e.g., costs of coordinating the group product or resolving disputes or disseminating inferences (Ekeocha & Brennan, 2008; cf. Klein, Wiggins, & Dominguez, 2010). Further analysis of map contents is needed to explain the difference in map size.

Since the number of groups under investigation was rather small, significant differences between students in the mapping condition and students in the control condition did not materialize. Effects of mapping on learning outcomes may require promotion of the use of maps during individual study, while making individual activity visible and allowing room for interpersonal evaluation.

Interestingly, students appeared to value maps as a tool for supporting the elaboration and clustering of the products of a brainstorm. In regular PBL groups, this critical part of the problem analysis phase is often neglected, especially in later years. The low scores on items gauging usefulness of clustering illustrate this (cf. tables 1 and 2). Especially second year students seem to be more willing to embrace the tool as a means to deepen problem analysis, as is suggested by the duration and evaluation data above. Why students sometimes fail to commit to a thorough problem analysis deserves further study.

Students consider maps to be attractive tools for supporting problem synthesis. Although use of maps seems superior to the use of a blackboard and chalk, especially during elaboration/clustering, it appears that the search for tools to support problem analysis and idea generation should be expanded. For instance, idea browsers or creativity support tools may enrich the brainstorm (DeRosa, Smith, & Hantula, 2007). One should not confuse the problems that PBL poses for students with the hard, wicked problems for which idea browsers seem well suited. Nor should one confuse students in PBL groups with members of intense problem solving teams (cf. Rentsch et al., 2010). Nevertheless, stakes can get higher over the course of the curriculum, and at times like these students' problem analysis skills may need extra support. A pilot using a creativity support tool during brainstorming confirmed that students who used idea browsers felt they could express themselves better but considered the problems to be less interesting than students in the control group, who particpated in regular PBL brainstorm sessions. Here, the tensions between divergent perspectives and shared knowledge building (cf. Puntambekar, 2006), a possible mismatch between objective and perceived learner control, limited time resources, and the absence of creativity requirements in PBL appeared to have stood in the way of a rewarding learning experience (cf. Unsworth & Clegg, 2010). As with the use of mind maps during problem analysis, students will at all times need to believe that the question “Is undertaking this action worthwhile?” can be anwered affirmatively.

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