Toward meaningful learning in undergraduate medical education using concept maps in a PBL pathophysiology course

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Rendas, António B., Marta Fonseca, and Patrícia Rosado Pinto. Toward meaningful learning in undergraduate medical education using concept maps in a PBL pathophysiology course. Adv Physiol Educ 30: 23–29, 2006; doi:10.1152/ajpgi.00036.2005.—Problem-based learning (PBL) is now an established method in undergraduate medical education that aims to develop reasoning skills based on clinical problems. More recently, the use of concept mapping in medical education aims to improve meaningful learning. At the New University of Lisbon, we have been using PBL as a major educational method in a pathophysiology course. In 2003–2004, we started to use Inspiration, a computer-based concept mapping tool, with a single tutorial PBL group. A total of 36 maps were constructed related to short cases, already used in the PBL course, in which a certain number of key nodes were hidden to allow the students to fill in the gaps. The results obtained appear to indicate that the use of concept maps stimulated meaningful learning within a PBL course.

medical reasoning; reasoning skills; teaching; “Inspiration”; concept mapping; problem-based learning

MEDICAL SCHOOLS have been changing their educational programs and teaching strategies, at national and international levels, to ensure that students have active responsibility for their learning process and are prepared for life-long, self-directed learning (19).

The effort toward developing active learning was based on the concern, expressed by experienced medical educators, that students memorized facts (“rote learning”) instead of understanding and applying concepts (“meaningful learning”). According to Michael (11), meaningful learning involves the acquisition of “useful” knowledge because 1) it is stored in such a way that it can be accessed from different starting points, 2) it is well integrated with previous knowledge, and 3) it is accompanied by the building of multiple representations (mental models) connected to other models for many other phenomena.

Problem-based learning (PBL) is now an established method in undergraduate medical education that, despite well-known disparities in application throughout the world, aims to develop reasoning skills based on clinical problems similar to real practice, hoping that it will enhance contextual learning of basic sciences (12).

At the New University of Lisbon, we have been using PBL as a major educational method in the pathophysiology course (16). This course is placed in the third year of a six-year traditional medical curriculum; recently, we (15) have developed a computer simulation that produces a detailed record of the student’s learning procedures including the identified learning issues and resources. On the basis of this experience, we consider that PBL allowed our students to acquire relevant pathophysiological knowledge (1), but, because we have developed our strategies more toward educational interaction, we still lack evidence about students’ understanding of the concepts during the learning process.

The use of concept mapping in medical education aims to respond to the need for meaningful learning. As stated in one of the early studies (14), mapping helps students to organize and integrate information, assess existing knowledge, gain insights into new and existing knowledge, and relate basic sciences concepts to clinical presentation of the patient. The founder of concept mapping, Joseph Novak, recently reviewed his work (13), which was started in the 1960s, and emphasized the contribution of the method to meaningful learning from primary schools to universities. The process involves identifying concepts, selecting them by importance, and finding hierarchical relations between them. The concept map can be viewed as a picture of the cognitive analysis of the problem by displaying the concepts and links between them.

Although concept mapping was noted from the start as a significant innovation aimed to promote meaningful learning (17), few studies have been reported in medical education, and even fewer have been related to PBL. One example is the early study already mentioned (14), which relates the development of specific concept maps to cases analyzed during tutorial sessions. In another study (3), in the setting of veterinary medicine, concept maps were used by faculty to write PBL cases and made available to students to reinforce major concept themes. The process of case development as part of a PBL program is described in another study (18), in which medical students used concept maps to provide a framework for their learning issues.

Concept mapping has also been recently used in depth in physiology education to improve students’ understanding of pulmonary concepts and to compare their understanding with that of teachers and medical experts (6–10). This innovative approach involved the use of Pathfinder, a scaling algorithm that represents cognitive structures of concepts and allows for a comparison between individuals and groups. This quantitative approach is more directed toward the understanding of the structure of medical reasoning, but it raises another important issue related to the use of technological resources to design and analyze concept maps. A recent review (2) addressed the importance of computer-based concept mapping tools, such as Inspiration and Semnet, which allow the construction of con-
cept maps in a simple fashion, thus removing the "drudgery and mess of revising paper-based concept maps."

We started to use paper-based concept maps in the PBL pathophysiology curriculum in the academic year of 2002–2003, in a single tutorial group, but the method proved very time consuming. Nevertheless, the students considered it very useful for the understanding of pathophysiological concepts and particularly for self-study, and this evaluation encouraged further use of concept maps in the educational program.

In the academic year of 2003–2004, we started to use Inspiration to construct concept maps in the PBL pathophysiology course, still in a single tutorial group. The purpose of this article is to present our experience together with the description of an educational program already being applied to the whole class of students in 2004–2005.

METHODS

The present study occurred in the academic year of 2003–2004 and included a single tutorial group of 14 students from a whole class of 199 who took the PBL pathophysiology course as previously described (15, 16) and, in addition, also used concept maps in the manner described below. The group was supervised by one faculty member and a senior medical student. The course was divided in six blocks covering the following body systems: digestive, cardiovascular, blood, respiratory, renal, and endocrine. In each block, the students were faced with a complete clinical simulation, adapted for PBL, and six short cases, addressing relevant concepts not covered by the complete case. For example, if in the cardiovascular block the long case placed more emphasis on coronary syndromes, the short cases covered hypertension, heart failure, or shock. Each block lasted for 3 wk, with two weekly sessions lasting for 2 h. The students received the timetable at the beginning of each block with their assigned duties concerning the analysis of the complete case or the short ones (Fig. 1). The students were divided in six groups of two to three each to work on the long case (PBL computer simulation) and reunited for the tutorial session. The same division of work applied to the short cases, as described in detail below. The relevant data in each case was registered as patient information, working hypothesis, and learning issues on a Panaboard with an integral printer. The printed record of the data obtained in every session was given to the students as an aid to prepare the following session.

The concept maps were based on the short cases, which are paper cases given beforehand to the students. The senior medical student designed the maps using Inspiration, aiming to give a broad picture of the pathophysiological mechanisms involved. For example, if the case described a patient with renal hypertension, the map addressed the overall pathophysiology of hypertension with the patient information included. The tutor reviewed the maps with the senior student, and both decided about a certain number of key nodes, which were hidden to allow the students to fill the gaps (Fig. 2). A total of 36 maps were constructed related to the short cases.

The short cases were studied as follows. After a brief discussion of the clinical information and registration of the relevant data on the Panaboard, the students assigned to the task received an incomplete map related to the case and were asked to bring the map with the gaps filled for the next session. This work was presented at the beginning of the session during an overall group discussion of the concepts included in the map. The discussion of the sixth short case occurred in the beginning of the first session of the following block (Fig. 1).

The dynamics of the PBL tutorial sessions have already been described, but, in addition, in the last session of each block, the pathophysiological features of the long case were discussed, and the student(s) assigned to that task presented a concept map constructed using Inspiration, with the assistance of the senior student.

At the end of each block, a questionnaire (Fig. 3) was distributed to the students to collect their opinions about the usefulness of concept maps and about the learning objectives related to the process. The design of the questionnaire was based on the “Instructional guide given to workshop participants on constructing a concept map” (14). Students were asked to evaluate the relevance for the learning process of the use of concept maps with regard to five items: identification of main concepts, establishment of an order for the concepts, establishment of the relationship between individual concepts using key words, establishment of horizontal links between concepts, and evaluation of the structure (organization and

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<thead>
<tr>
<th>1st session</th>
<th>2nd session</th>
<th>3rd session</th>
<th>4th session</th>
<th>5th session</th>
<th>6th session</th>
<th>1st session (next block)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBL - Phase 1: Patient encounter</td>
<td>Short Case 1: Conceptual map resolution</td>
<td>Short Case 2: Conceptual map resolution</td>
<td>Short Case 3: Conceptual map resolution</td>
<td>Short Case 4: Conceptual map resolution</td>
<td>Short Case 5: Conceptual map resolution</td>
<td>Short Case 6: Conceptual map resolution</td>
</tr>
<tr>
<td>PBL - Phase 2: Present illness</td>
<td>PBL - Phase 3: Review of body systems</td>
<td>PBL - Phase 4: Personal, familial and social background</td>
<td>PBL - Phase 5: Physical examination</td>
<td>PBL - Phase 6: Laboratory findings and other diagnostic procedures</td>
<td>Final debate</td>
<td>PBL - Phase 1: Patient encounter</td>
</tr>
<tr>
<td>Short Case 1: Reading and comment</td>
<td>Short Case 2: Reading and comment</td>
<td>Short Case 3: Reading and comment</td>
<td>Short Case 4: Reading and comment</td>
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<td>Short Case 6: Reading and comment</td>
<td>Short Case 1: Reading and comment</td>
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Fig. 1. Standard timetable of the sessions covering one block (each session lasted 2 h and occurred twice a week). PBL, problem-based learning.
A 35-year-old man presents to the clinic for routine medical care. He is well, with no complaints. His past medical history is remarkable for long-standing uncontrolled hypertension. On physical examination, his blood pressure in the right arm is 170/80 mmHg and in the left arm is 165/85 mmHg. The femoral pulses are diminished.

hierarchy) of the whole map. Their opinions were measured on a Likert five-point scale (strongly agree, agree, neutral, disagree, and strongly disagree). In an attempt to evaluate how the students felt about changes in their learning experience over time, a comparison was performed between the answers given to the five items of the questionnaire at the end of the first and sixth block.

This evaluation tool also served to gather suggestions from the students to improve the pedagogical process because the last question of the questionnaire was an open one.

Fig. 2. Section of a concept map of hypertension.
The findings of the questionnaire were discussed with the students at the end of the teaching program. During an interview, conducted by one of the authors, the respondents were asked to clarify and elaborate on the answers provided by the questionnaire as well as to suggest improvements to the following year.

This project was undertaken within the range of the activities supervised by the Pedagogical Council of our medical school, where students and faculty are represented.

RESULTS

In most cases, the groups of students were able to fill the gaps in the short case maps with key concepts and improve the maps with additional concepts and relations among them.

As for the long cases, the students were able to design a concept map at the end of each block, progressively integrating in it the new information acquired in each session to develop a complex map related to a complete clinical case.

The increasing complexity of the maps showed, throughout the sessions, how the students successfully coped with the integration of new information. It also showed how the acquired knowledge was included and interrelated by increasing the number of horizontal and vertical links (Fig. 4, A and B).

The questionnaires, designed to characterize the students’ degree of satisfaction, were applied at the end of each block, and all students completed them. The pattern of the answers was very similar throughout the blocks and is summarized in Fig. 5. Only one item (the maps helped the students to establish horizontal relationships between concepts) received 22.2% of “no opinion” answers. Concerning all the other items, 100% of the students “agreed” or “totally agreed” that the use of concept maps had enhanced their capacity to identify key concepts, organize them in hierarchies, and establish relationships among them. Furthermore, and as an attempt to evaluate the students’ perceptions of their own performance over time, we found that the number of students who totally agreed with item 2 (“es-
establish an order for the concepts”), item 3 (“establish the relationship between individual concepts using key words”), item 4 (“establish horizontal links between concepts”), and item 5 (“evaluate the structure—organization and hierarchy—of your map”) increased between cases 1 and 6 (from 7% to 25% in item 2, from 42% to 75% in item 3, from 17% to 50% in item 4, and from 8% to 33% in item 5). However, due to the small size of the group, these differences can only be considered as a trend. No other measurement of performance was applied to this group because, as other studies have shown, no correlation
has been found between performance in multiple-choice tests and the efficacy of concept maps (9, 19).

The students’ responses to the open question were grouped in themes and listed along with the number of comments for each theme. All the students claimed that the concept maps had been very useful for the study of pathophysiology. The main reasons reported were that concept maps:

- Provided a useful visualization of the concepts,
- Were a good tool to study and revise the content of each block,
- Promoted meaningful learning instead of rote learning,
- Could be progressively produced (from simple concepts and linear relationships to a more complicated knowledge framework), and
- Could be used in group work.

During the interview, the students confirmed the responses of the questionnaires and explained how they had used concept maps to study the content during the year and also how they were using the maps to revise contents for the final exams.

Although they considered concept maps an indispensable study tool, they also said that this strategy had been rather time consuming.

Additionally, it was said that the completion of the maps provided an excellent opportunity to discuss the reference sources used for each theme (“it was a good opportunity to discuss the most important reference sources for each block”).

**DISCUSSION**

The objective of this study was to introduce concept maps in a PBL pathophysiology course to promote meaningful learning. Furthermore, it was expected that this experience, derived from a single tutorial group, could support a curricular proposal to apply this approach to a full class of students taking the same course in the future.

To our knowledge, such an approach using Inspiration, a computer-based concept mapping tool, has not yet been published in medical education literature. The work (3, 14, 18) previously reported was more concerned with introducing concept mapping skills, both to students and tutors, and only gave examples of the use of maps not addressing the issue of its application in curricular development. Even fewer studies described the use of concept maps in a PBL setting; nevertheless, one recent study (4) presented a technique called “mechanistic case diagramming,” involving the stepwise representation of the pathophysiological mechanisms of a case, from causes to symptoms, which, despite being handmade, appeared to critically reflect on students learning. The other advantage of this approach relates to the inclusion of the clinical information from the case, obtained with a PBL methodology, in a map with the overall pathophysiological mechanisms in what is called the “case-specific model” (14) of concept mapping.

The results obtained from our study appear to indicate that the use of concept maps within a PBL course stimulated meaningful learning and promoted the development of students’ learning strategies both individually and as a group. Concerning the students’ degree of satisfaction, the responses were highly favorable, with a decrease when they were asked about understanding relations between horizontal concepts. This may reflect some difficulty faced by the students in moving from declarative (knowing that something is the case and represented by propositions) and procedural knowledge (knowing how to do something and represented by production
sequences or contingency statements) to structural knowledge (knowing why something is the case and represented by concept maps), as stated in a recent review (2). This issue is going to be one of our concerns in planning future tutorial sessions.

The other difficulty expressed by the students was the considerable time taken to construct a concept map at the end of each block, based on the PBL case, showing that the acquisition of concept mapping skills by the students was slow to develop. In contrast, the students stated that the discussion of the incomplete maps developed by the tutors, based on the short cases, was considered very useful to promote meaningful learning and less time consuming. In our setting, it was probably more useful to expose the students to a broad range of incomplete maps, and we have always encouraged them to correct and complete the maps used in the tutorial sessions. In addition, most students stated that they developed their own maps for individual study and found them a very useful study tool. This competence was probably developed during the design of the maps related with the long cases.

Because of the small number of students, we felt that it was not possible to study the effects of cognitive and noncognitive influences on the use of concept maps, namely, learning styles. This issue was addressed in a recent work (5) that showed that the use of preprepared concept maps was not influenced by the students’ learning styles, suggesting its application in large classes favoring motivation and engagement.

This work did not address the issue of grading concept maps; however, the detailed work developed by the only group using a quantitative approach to concept mapping in medical education expressed concern about the use of expert’s concepts as a “gold standard” for students performance (8). In our case, the search for such standards was even more difficult because we were dealing with pathophysiological concepts more difficult to operationalize than those related with pulmonary physiology. For this reason, it was decided, in preparation for the proposal for the curriculum to be applied to the whole class, to ask the other tutors not involved in the method to review and improve the maps already in use to check if the objectives of the blocks were covered. All the tutors are medical doctors with considerable experience as teaching staff of the pathophysiology course. Each tutor reviewed the maps related with their field of specialization, but the overall editing of the revised maps was the responsibility of the senior student and the tutor who developed them. The comments of the teaching staff were very favorable toward the use of concept maps in the PBL pathophysiology course. It was also decided to apply the same questionnaire in the evaluation of student’s opinions throughout the course.

At this stage, we feel that, based on a preliminary study with limited objectives and a small number of students, we were able to consolidate the strengths of two complementary approaches, PBL and concept mapping, as a means to promote meaningful learning. Further studies, already in progress, with a large population will allow us to address new areas of research such as differences between the ways how students represent and understand knowledge at different stages of the course.

What Did We Learn with the Project?

- Inspiration proved to be an excellent computer software for the drawing of the concept maps.
- The “case-specific model” of concept map used proved to be appropriate because it managed to include relevant clinical information of the case together with the pathophysiological mechanisms involved.
- Exposure of the students to a broad range of incomplete maps allowed for the analysis of core pathophysiological concepts in a way that promoted meaningful learning.
- PBL and concept mapping proved to be complimentary tools because the method of information gathering, hypothesis generation, and identification of learning issues allowed for the exposure of a broad range of knowledge needs that were visualized in the concept maps, which, after discussion, could be considered as cognitive frameworks of the meaningful learning occurring in each case and for the whole course.

REFERENCES