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Review Article

Concept mapping as a Tool for Learning and Assessment in Problem-based Learning

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Abstract

The knowledge structure of medical experts and successful learners is characterized by comprehensive integrated frameworks of related concepts. The development of this knowledge structure can facilitate clinical problem solving and other higher cognitive activities. Concept mapping is a learning tool which can depict the representation of knowledge structure of learners. Concept maps are built on learning theory concepts which complement problem-based learning (PBL). Students studying in PBL programs can construct concept maps centered on PBL cases and integrating the basic sciences and community concepts related to the case they study. Furthermore, concept maps can be used in PBL tutorial sessions for enhancing discussion, identifying learning gaps, generation of learning objectives, promoting learning integration and assessment of learning. Other uses of concept mapping in PBL could be in large group sessions in Seminars or team-based learning sessions to facilitate interactions and relevance of different concepts to the PBL case. However, challenges to concept mapping use in medical education include the development of tools with reliability and validity-evidence.

Keywords: Concept mapping, Medical education, Problem-Based Learning, Knowledge structure, Student assessment

Introduction

Medical schools have a social mission to graduate physicians who are equipped with knowledge, skills and attitudes which are necessary for safe clinical practice. For achieving this mission, medical schools have to develop educational strategies and assessment methods which can help students to develop these competencies. One of the educational strategies which emerged to help medical schools in achieving their mission was Problem based learning (PBL). PBL started in the early sixties of this century as a novel educational strategy and then mushroomed gradually across the globe. The objectives of PBL are to help students to: 1) acquire a core body of integrated knowledge that is required to effectively address clinical problems, 2) develop the ability to use this knowledge effectively in the evaluation and care of patients' health problems (clinical reasoning), and 3)

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develop the ability to extend and improve knowledge to keep up to date and cope with new problems that may arise in their professional lives (self-directed learning skills)[1]. An educational tool that appeared to complement PBL in achieving its objectives is concept mapping. Concept mapping in PBL programs can help medical students to develop organized, integrated knowledge structure built on specific health problems. This knowledge structure grows by the development of expertise and can facilitate problem solving and other higher cognitive activities[2].

What is a concept map?

Concept map is a way of learning by which students link together a series of concepts related to a particular topic producing two dimensional, hierarchically-organized diagram representing their knowledge framework. Concept mapping was developed by Joseph D. Novak and his research team in the 1970 as a means of representing the knowledge structure of science students. A concept map includes nodes (or concepts), linking lines (usually with a unidirectional arrow from one concept to another), and linking phrases which describe the relationship between nodes. Linking lines with linking phrases are called labeled lines. Two nodes connected with a labeled line are called a proposition (Table 1). Moreover, concept arrangement and linking line orientation determine the structure of the map (e.g., hierarchical or nonhierarchical)[2]. A proposition acts as the building block of a concept map, supplying information about students' declarative knowledge on concept pairs.

Table 1: Components of a concept map

Component	Description
Nodes, concepts	Squares or ellipses that each represent a different concept
Cross links	Lines or arrows that connect various nodes
Linking phrases	A label for each line that describes the relationship between the linked concepts
Proposition	The combination of any two nodes and the label that connects them

Theoretical principles of concept mapping

Knowledge structure is an important component of understanding in a subject domain, especially in science. The knowledge structure of experts and successful learners is characterized by elaborate, highly integrated frameworks of related concepts, which faciltate problem solving and other cognitive activities[2]. Concept mapping is based on the constructivism theory of learning, which indicates that learning is an active process where students actively construct their knowledge[3]. By relating and integrating new knowl-edge with already existing knowledge structure, learners develop deeper and richer understanding, and better use of knowledge[4].

Concept mapping is also related to the cognitive load theory of learning. By constructing these domain-specific knowledge structures (schemata), learners reduce the large number of individual information elements (concepts) in the map to one schema. This schemata organizes knowledge in long-term memory and substantially reduces working memory load because the schema can be retrieved and processed as one information element in the working memory[5]. Three cognitive processes have been proposed to be involved in developing the knowledge structures: 1) elaboration, i.e. linking the new knowledge into what is already stored in long-term memory; 2) refinement, i.e. sorting the information to keep the relevant ones; and 3) restructuring, i.e. development of new knowledge maps which represent the basis for developing expertise[6].

Steps of constructing concept maps

In general, concept maps are constructed in three phases, namely organization, layout and linking phases. In the organization phase, learners list the concepts related to a theme, create groups and sub-groups of related concepts, and rearrange and introduce new concepts if required. In the layout phase, learners arrange interrelationships and connections among groupings use a consistent hierarchy in which the most important concepts are in the center or at the top, and connect the concepts in a simple sentence that shows the relationship between them. In the linking phase, learners use arrows to connect and show the relationship between connected concepts; write a word or short phrase by each arrow to specify the relationship (*Figure 1*).

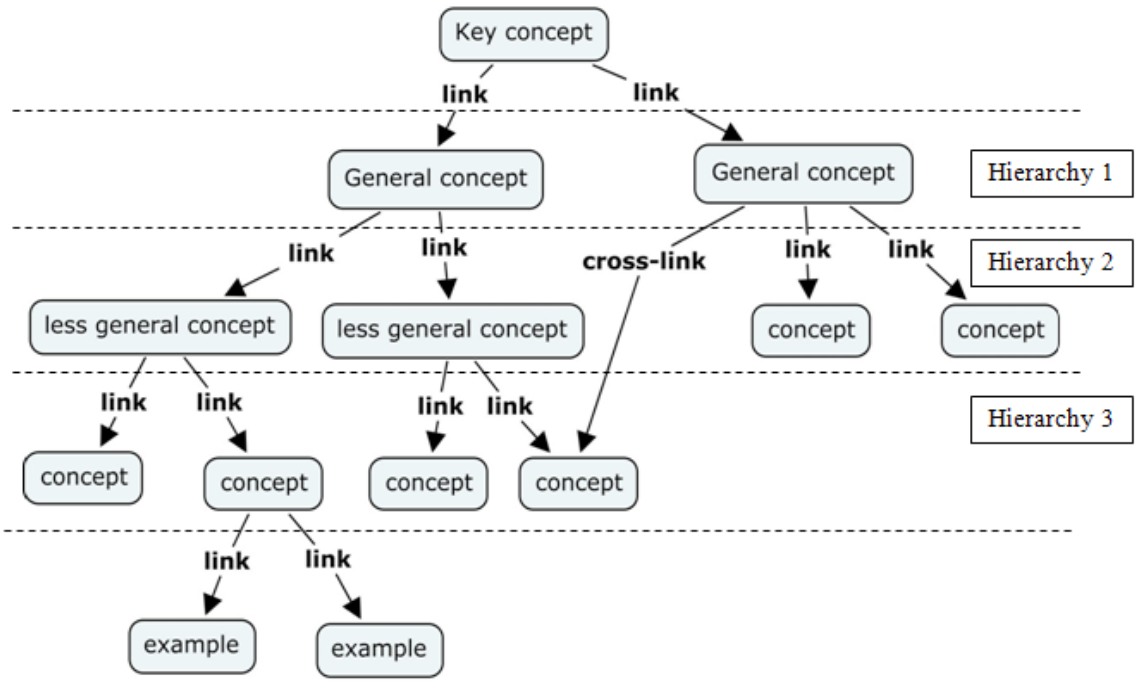

Figure 1: A concept map model (Adapted from Novak & Gowin, 1984)

Uses of concept maps in medical education

Our brain organizes the knowledge in a hierarchical framework and concept maps are one of the learning approaches that facilitate this process of organization of knowledge which lead to enhance the learning capability of learners[7]. One important strength of the use of concept mapping is its ability to expose knowledge structures in the minds of learners. Concept maps have been useful in education because of the following:

a) *Fostering meaningful learning*: One of the most important goals of concept mapping is to foster meaningful learning. The learning to be meaningful should be clear and related to learners' prior knowledge so that he/she can easily incorporate the new learning into his prior knowledge[8]. Furthermore, concept mapping promotes both conceptual and critical thinking. It can display the greater depth of student's learning because it reveals how the knowledge is organized, how the students understand the relationship of various concepts and display the creativity they used to integrate additional concepts[9].
b) *Supporting active learning:* Concept maps may have many educational purposes including improving comprehension and retention, encouraging cooperative and collaborative learning, curriculum development, and fostering problem solving[9].
c) *Integration of knowledge:* Concept mapping enables students to diagram their understanding of key ideas in a topic area and to demonstrate their conceptualization of the relationships among them[9]. This way, it can help students to integrate the clinical sci ence they had gained into the real patient's presentation.
d) *Assessment of knowledge structures:* Concept maps can measure the knowledge structure or framework in a way that other tests cannot do. This structure is the way that information is organized and then retrieved from the brain whenever it is needed.
e) *Providing feedback for learners:* A previous study indicated that 'concept maps without feedback did not significantly improve student performance, whereas concept maps with feedback produced a substantial increase in student problem solving performance and a decrease in failure rates[10]. The constructed concept maps provide the teacher with an understanding of the students' gaps in knowledge structure. This will establish a template for the teacher to provide feedback and clarify misunderstandings in both content and process for students.

Concept mapping assessment

Assessment of concept maps can be considered as a set of procedures used to measure the structure/organization of a student's declarative knowledge. A concept-map assessment is characterized by three essential aspects: a task (that invites students to demonstrate an evidence for their knowledge structure), a response format (paper-based or electronic), and a scoring system (which raters use to assess the students' knowledge structure)[11]. The concept map task can range on a spectrum of directedness from high-directed to low-directed task based on the information provided to the students. High-directed concept map

tasks provide students with the concepts, connecting lines, linking phrases, and the map structure. In contrast, in a low-directed concept map task, students are free to decide which and how many concepts they include in their maps, which concepts are related, and which words to use to explain a relationship[12]. Regarding the scoring system, concept maps can be scored using a structural system which assigns scores to the concept map's organizational structure or a quality (relational) system which measures the quality or importance of map components, with no regard to the overall structure of the map or a mixed (hybrid) system[13].

Concept maps and problem-based learning

Problem based learning (PBL) is a learning method in which learners first encounter a problem followed by a systematic, learner-centered inquiry and reflection process. It is now an established method in undergraduate medical education that aims to develop reasoning skills based on clinical problems similar to real practice, hoping that it will enhance contextual learning of basic science[14]. Both concept mapping and PBL have parallel purposes, both are based on constructivism view of learning and both can be seen as complementary to each other[15]. The main three objectives of PBL are to help students to: a) acquire a core body of integrated knowledge that is required to effectively address clinical problems, b) develop the ability to use this knowledge effectively in the evaluation and care of patients' health problems (clinical reasoning), and c) develop the ability to extend and improve knowledge to keep up to date and cope with new problems that may arise in their professional lives (self-directed learning skills). On the other hand, concept mapping in PBL programs can help medical students to develop organized, integrated knowledge structure built on specific health problems (Fig. 2). This knowledge structure grows by the development of expertise and can facilitate problem solving and other higher cognitive activities. Although concept mapping was noted from the start as a significant innovation aimed to promote meaningful learning, only few studies have examined the concept mapping in a PBL context. We have previously demonstrated the application of concept mapping in PBL and developed a new simple instrument for assessing students' knowledge structure in PBL (Table 2). The task of concept mapping in PBL medical programs does not include providing students with concepts, and construction of concept maps is guided by the learning needs generated by students in small group tutorials. In addition, concept maps are expected to depict the multidisciplinary integration of concepts in relation to the PBL case. We have also demonstrated that the interrater reliability of concept map assessment scores using this instrument ranged from 0.69 to 0.75[16]. We are currently examining the generalizability of concept mapping assessment scores of medical students in PBL across different domains and raters. Preliminary results suggested that greater improvements in dependability could be made by increasing the number of raters than by increasing the number of concept map domains (In press).

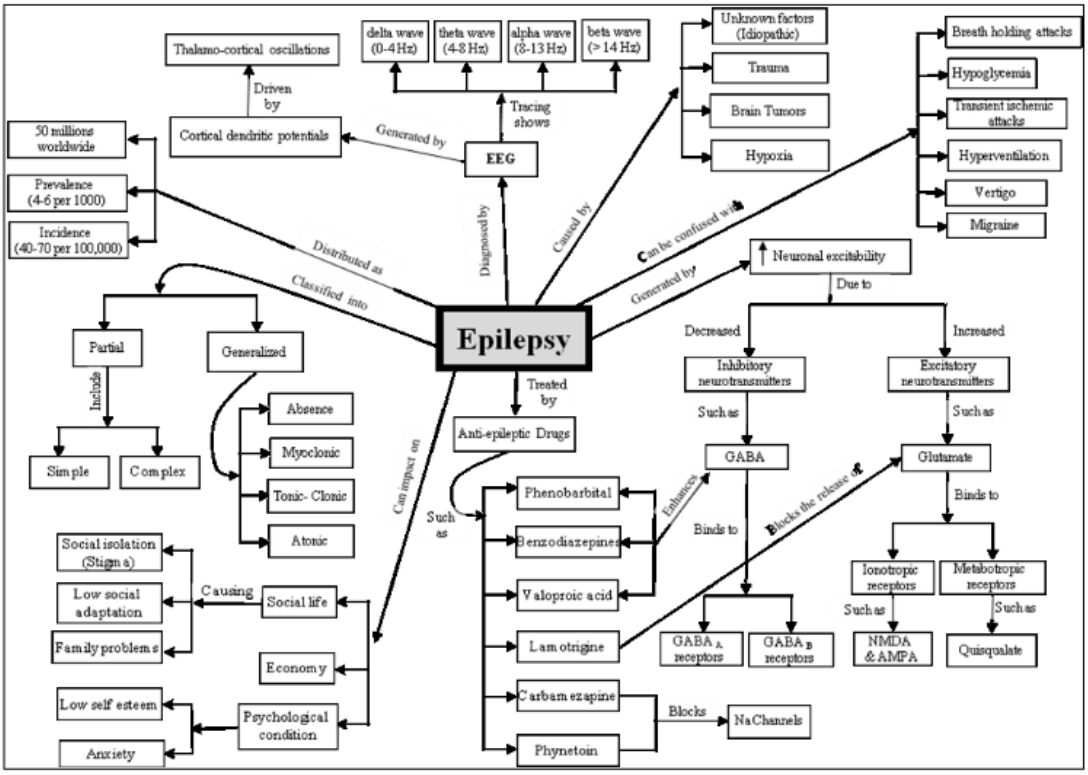

Figure 2: A concept map showing the integrated concepts related to the problem on "epilepsy" using learning objectives generated in PBL tutorials as a template[16]

Applications of concept mapping in PBL and possible challenges

Because of the complementarity with PBL, concept mapping can be used in PBL programs as follows:

1) In small group PBL tutorials: During the first tutorial session, the tutorial group can collaboratively construct a concept map related to each problem. This process can help to identify the gaps, discover preconceptions in their knowledge related to the topic, and steer the group to generate relevant learning objectives. In the second tutorial session, students can draw concept maps after the self-study and the structured learning activities of the week. This can help students determine the change in their understanding during the study week.

2) During self-study: By building the different concepts related to the problem as they proceed in self-study, students can use concept maps to construct their knowledge structure with relevance to clinical cases. This will promote the concept of integration between basic and clinical sciences in the minds of the students.

3) In large group seminars (Review sessions): Concept Maps related to the problem of the week can be projected to the students in large groups during the seminars. Each week, a student representative from one of the tutorial groups presents a constructed map to the students in the seminar. Tutorial groups can take turns every week in presenting their concept maps. Peer

feedback on maps, challenges students to critically rethink the concepts and connections on the map, to determine if they want to change the maps or if they find that the map truly represents the way they understand the material[17]. This will help to provide students with multiple ways to see the same information. Despite the strong theoretical evidence supporting the usefulness of concept mapping in medical education, there are challenges which surround this method may hinder its applicability in many medical schools. First: Concept mapping as a learning tool does not match the learning styles of many students. This can create resistance among the students to apply this method, and could affect the education administrators to continue in applying this learning tool in their institutions. Second: the evidence of validity and reliability of concept mapping assessment scores, using different types of tasks or scoring systems, is still in infancy. This concern becomes clear when a decision is taken for using concept mapping scores for summative assessment.

Table 2: The structured tool for assessment of concept maps in a PBL curriculum (Adapted from Kassab and Hussain, 2010)

Evaluation criteria	1	2	3	4	5
	Poor	Fair	Good	V. good	Excellent
Valid selection of concepts					
Hierarchical arrangement of concepts					
Integration between concepts					
Relationship to context of the problem					
Degree of student creativity					

***** The total mark is the sum of the five sub-scores (out of 25)

Explanations: (for raters)

- *Valid selection of concepts:* whether meaningful and valid concepts have been selected from the PBL problem.
- *Hierarchical arrangement of concepts:* the degree of arrangement of concepts with more general concepts at the top and more specific below or extending outward.
- *Integration between concepts:* how the student shows meaningful interconnections between basic and clinical sciences concepts in the map.
- *Relationship to the context of the PBL problem:* how the concepts are directly related and linked to the context of the problem.
- *Degree of student creativity:* the degree to which the student demonstrates unusual elements that aid communication or stimulate interest without being distracting.

Conclusions

This review aimed to introduce concept mapping as a tool for learning and assessment of medical students. Specifically, concept mapping can complement PBL in supporting student learning. Concept mapping in PBL programs can help medical students to develop organized, integrated knowledge structure built on specific health problems. In PBL medical programs, concept maps can be used in different activities including small group tutori-

als, large group seminars or during self-study. Teachers can also use prototype concept maps to assess the knowledge structure of medical students in PBL. However, the reliability and validity-evidence of concept map assessment scores still requires more research.

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