The Role of Concept Maps in the Medical Education

O Papel dos Mapas Conceituais na Educação Médica

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KEYWORDS:
- Learning
- Concept Maps
- Medical Education.

ABSTRACT
As part of the medical education, due to the compelling changes required to produce a professional who learns how to learn, the meaningful learning construct proposed by David Ausubel provides a true contextualization of the knowledge needed for medical practice, allowing in this way a more effective learning and allowing it to be used in an interdisciplinary and complex context. Accordingly, this manuscript aims to present the role of concept maps in medical education.

PALAVRAS-CHAVE:
- Aprendizagem
- Mapas Conceituais
- Educação Médica.

RESUMO
No âmbito da educação médica, diante das imperiosas mudanças necessárias para a formação de um profissional que aprenda a aprender, a aprendizagem significativa de David Ausubel permite uma genuína contextualização dos conhecimentos necessários à prática médica, facilitando, portanto, um aprendizado mais efetivo e permitindo a atuação em um contexto complexo e interdisciplinar. Em conformidade com o exposto, o presente manuscrito objetiva apresentar o papel dos mapas conceituais na educação médica.

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INTRODUCTION

Health professionals face new challenges every day. The medical profession has suffered changes not only in the quantity of knowledges needed to be learned, but also in how this material is incorporated by the student. As such, the traditional teaching model used in medical education has been questioned. Recognizing that knowledge grows in a spiral and that it is shaped by the society to which it belongs, preserving a disciplinary perspective – one that is dissociated from practice and with teaching objectives focused primarily on the disease and not on patient healthcare – is not the most appropriate proposal for success. Taking these aspects into account, pedagogical changes have been proposed – which begin to configure a new paradigm in the medical teaching aimed to transform the student into a critical, reflexive individual who is able in his practice to fully learn how to learn. Supported by this point of view, this article broaches the concept of concept maps (CM), aiming to open the discussion of this tool as an instrument to be applied effectively to contribute to the realization of forming an effective physician. Aiming to provide learning in an individual way through the known meaningful learning theory, a concept proposed by psychologist David Ausubel, in which knowledge is better spread when it’s built in an idiosyncratic way, the needs and limitations of the apprentice are respected, exposing one to situations where learning is based on previous knowledge, which is carried in one’s own cognitive net. By doing so, an interaction between the individual and the concept occurs, resulting in learning. In this situation, concept maps are tools used to expose the learner to previous knowledge and to make it easier to visualize the existing links in the process of the construction of knowledge.

1. CM: What are they? Where do they come from?

The concept map was developed as a tool to organize knowledge and as a way to represent it to oneself and for others. Joseph Novak and collaborators developed this tool from David Ausubel’s theory – the meaningful learning theory –, which proposes that knowledge cannot be properly constructed in an arbitrary manner and based exclusively on memorization, but rather should be (1) understood, (2) significantly relevant and (3) well-integrated. This is made possible by the assimilation of the new proposals through pre-existing cognitive structures, as reasoned by Ausubel. Although the maps have not been mentioned in the meaningful learning theory, they represent an important tool for preparing previous organizers.

Concept maps are also based on constructivist theories such as Jean Piaget’s Genetic Epistemology theory, which postulated that previous knowledge is used as a net to understand and learn new information. From his studies with children, the biologist conceived that psychological development started at birth and ended in adulthood. For Piaget, this development was considered a progressive balance. These references bring a significant contribution to the discussion, since they suggest evolution and conflict as driving forces in the search for balance, characterizing moral and cognitive abilities not as completely inherent, but as a result of complex interactions between the individual and his environment. The teaching-learning process is complex, dynamic, and doesn’t happen in linear form as an addition of subjects to those previously established or learned. Therefore, teaching requires respect for the autonomy and the dignity of each individual – especially in the core of a progressive approach, foundation for an education that takes into account the individual as a being who builds his own history – as are the aims at the core of adult education. To educate is mainly to build and as such, the role of the educator and educational institutions is certainly not only to inform or simply transform the educational experience into pure technical training. Rather than simply depositing inert subjects into the student’s mind, the teacher should also learn alongside the student. To achieve this, all available technology must be employed, including concept maps.

2. What is their importance?

Concept maps hold great potential for the student, both to help in the formulation of new concepts as well to evaluate the student in relation to learning, mainly in the student-focused curriculum – for example, based on active teaching-learning methodologies – but also in the traditional educational curriculum.

One of the main utilities of the CM in medical education courses is the possibility of integrating various concepts, which are frequently fragmented in many cognitive compartments – CMs may help evidence the existing connections between these concepts, allowing establishment of probable means for integration. In a further analysis, the distinct concepts are not static, representing a web that is joined by the relations between the concepts that evolve in the cognitive structure of the student, supported by the existing concepts that, handled in an articulated way and respecting its own abstraction levels, provides a solid base to be used daily. The establishment of a well-elaborated net of knowledge is a fundamental step in the construction of any given subject. Accordingly, the use of concept maps prioritizes a meaningful learning experience and this learning will promote creative production in real life.

The health sciences area – mainly when we think about the education of physicians – has significantly benefited from...
the use of this tool\textsuperscript{21}. In fact, medical practice requires the development of critical thinking for problem solving and decision making, which contribute in a positive way to communication, diagnosis, and treatment of patients. Critical thinking is an active process, considering that it evaluates and reflects on all the evidence presented, prior to deciding what action will be taken. This ability can be practiced, and most of all, stimulated with the use of concept maps\textsuperscript{22}. In fact, in a practice clinical situation, the student needs to assess the patient’s history in order to properly develop the diagnosis and therapeutic conduct, which is very difficult when the knowledge is simply memorized\textsuperscript{23}. In this situation, concept maps may help students in the establishment of a net of connections between theoretical knowledge and real life\textsuperscript{24}.

3. How is a concept map organized?
Concept maps can be organized in different ways, depending mostly on the person that constructs them. The layout can be organized\textsuperscript{25}:

1. as a web, in which the main subject-matter is placed in the middle of the map;
2. in a hierarchical fashion: showing the information on a descending scale of importance;
3. as a flowchart: organizing the information in a linear way similar to a book’s structure;
4. in a conceptual way: organizing the information in a format similar to that of a flowchart, but with the possibility of inserting and excluding new concepts;
5. in a landscape structure: to be used in situations that are required to display information in panoramic contexts;
6. the multidirectional structure (3-D): uses depth to represent relationships that cannot be shown with 2-dimensional maps;
7. the “mandais”: presents the information in geometric forms, in which the telescopic characteristic allows a visual effect focusing on ways to represent the user’s thought process\textsuperscript{26}.

A concept map must show how one piece of information is related to another, why it is included, and what is its importance. This aspect must be visually clear in the map, in its hierarchical structure and also in the connections made between the concepts inside the map through short sentences like, “need of…”, “leads to…”, “cause…”, “inhibits…”, and many other possibilities\textsuperscript{27,28}. This is an essential part of the map and cannot be underestimated; other people’s comprehension of this part of the map and the correct interpretation of these small links is essential; this way, it is possible to be sure that the ideas displayed in the concept map won’t be changed or misunderstood\textsuperscript{29}.

It is important to note that the concept maps’ structures are not rigid, even having been the product of logical thought. Actually, the maps are very flexible and are in constant change as new knowledge is acquired\textsuperscript{30}. When new information is obtained – especially if it diverges from the concepts shown in the map – the student should place this new concept, changing part of the map and its structure, in a manner that the harmony between the concepts is preserved when the whole map is viewed. This type of change requires, in a way, a solid foundation – in the context of meaningful learning – to be performed correctly\textsuperscript{31}.

Early on, the elaboration of the maps depends on the person’s know-how to make them and on one’s knowledge to identify the relevant concepts and existing relations between them. However, the ability acquired from working with the maps will results in greater efficiency in their elaboration – therefore, with continued exercise, one tends to develop a higher competence to establish knowledge relationships. Figure 1 demonstrates an example of a web with little complexity and another, more complex and well-established web is displayed in figure 2\textsuperscript{32}.

4. How is a concept map built?
Although there are no strict rules for building a concept map, usually the diagrammatic representation of concept maps are created using arrows, but must not be confused with charts or flow diagrams, as they do not have a sequence, temporality or directionality, nor are they organized as or possess a power hierarchy. What is really important is that the map serves an instrument, able to evidence meanings given to concepts and the relations between them in the context of a given body of knowledge.

Nowadays there are softwares that facilitate the construction of maps, like the Cmap Tools developed and available free of charge by IHMC – University of West Florida (http://cmap.ihmc.us/\textsuperscript{33,27,29}).

To make a concept map under the view of an apprentice/student, the following steps should be considered as a guide: 1) Brainstorming; 2) Organize the ideas; 3) Organize the concepts on the maps; 4) Relate the concepts; 5) Review the ideas, concepts and the organization, making changes if necessary. When under the view of a professor/master/organizer/teacher: 1) Identify the structure according to the teaching subject context; 2) Identify advanced organizers needed to reach the meaningful learning of the subject; 3) Identify pre-existing meanings in the apprentice/student cognitive structure; 4) Se-
FIGURA 1:
Mapa conceitual construído por estudantes do curso de graduação em Medicina.

FIGURA 2:
Mapa conceitual construído por médico com experiência em doenças infecciosas e parasitárias. Observar a maior riqueza de conexões.
quentially organize the subject and select the curricular tools, using progressive differentiation and integrative reconciliation as programmatic principles; 5) Teach using previous organizers, to build links between the concepts that the student already has and the ones that are required to learn, as well as for the establishment of explicit relations between the new and the preexisting knowledge that are able to give significance to the new learning material.

Based on these considerations, construction of the CM should address the aspects described in Table 1.

**Table 1**

<table>
<thead>
<tr>
<th>How to make a concept map</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify the key concepts of the subject that will be mapped and list them. Limitation between 6 and 10 (number of concepts).</td>
</tr>
<tr>
<td>2. Order the concepts, placing the more general, more inclusive ones at the top of the map and, gradually the others until the diagram is complete according to the principle of progressive differentiation.</td>
</tr>
<tr>
<td>3. Connect the concepts with lines and name these lines with one or more keywords that make explicit the relationship between the concepts, the concepts and the keywords must suggest a proposition that expresses the meaning of the relation. Avoid words that point only to simple relationships between the concepts. Search for horizontal and crossed relations.</td>
</tr>
<tr>
<td>4. Include examples to the map, optionally, below the corresponding concepts; the examples are placed at the lower part of the map.</td>
</tr>
<tr>
<td>5. Review the CM thinking about another way to make it, other ways to categorize the concepts. Remember there is no one way to draw a concept map. As the understanding about the relationships between the concepts changes, or as you learn, your map also changes. A concept map is a great and dynamic tool, reflecting the understanding of the maker at the moment when it is built.</td>
</tr>
<tr>
<td>6. Share your concept map with friends and take time to examine their maps. Ask what the relations mean, question the location of some concepts, the inclusion of some that don’t seem important to you, the omission of some that you consider essential. The concept map is a good instrument to share, trade and negotiate significances.</td>
</tr>
</tbody>
</table>

**Notes:**

1 – If for example, the map concerns a paragraph of text, the number of concepts is limited by the paragraph. If the map also incorporates your knowledge about the subject, beyond the content of the text, more specific concepts can be included in the map.

2 – Avoid the use of words that indicate trivial relations between the concepts. Look for horizontal and crossed relations.

3 – Usually, the first draft of the map has poor symmetry and some concepts or groups of concepts are misplaced in relation to others that are better related. The review is important to improve these aspects.

5. What are the benefits of concept mapping?

The benefits obtained with the application of concept maps are many. Difficult concepts are approached in steps, improving learning and making them easier to understand. The information on the map can be shown in a long way or in a short way, with no loss of information, complexity or significance. Concept maps can also be a great studying tool when reviewing ideas, as they facilitate the organization of information for the student, since they can use concept maps to integrate, reconcile and differentiate concepts. The maps facilitate learning a subject because the students use logic to reach their own conclusions. They also take into account the students’ previous knowledge, recognizing it as essential to the acquisition of new concepts and theories.

Furthermore, the maps have the benefit of visually displaying the information acquired, which helps students who have a visual memory and who “learn by seeing.” Equally important, the maps help the students to have interdisciplinary and multidisciplinary learning. Often times otherwise excellent students have difficulties associating concepts from different disciplines, they may see things more clearly with concept maps. Students may become more independent and responsible for their learning, developing self-confidence, and attaining a more significant and personalized learning. As the study process becomes more autonomous, students with greater difficulties have more chances of obtaining help from the teachers. Nothing prevents that other students help the ones with difficulties, since in this situation no one is the sole holder of knowledge.

As an instrument of evaluation of learning, concept maps can be used to obtain visualization of the concept organization that the apprentice gives to certain knowledge. Additionally, concept maps have been shown to be an effective tool in associating practice and theory, extinguishing the distance between them and allowing a dynamization of subjects while facilitating contextualization. Another point to be emphasized is the association the various concept maps, which provides for the creation of more complex and comprehensive structures, and can even assess the understand and learning in a study module within a course. This design also allows, depending on the timing of the CM, for verification of the content in the student’s memory, both immediately after study and later over the course of his education.

6. Which are the challenges?

Some studies show limits with the use of concept maps, which are mainly related to the lack of ability in dealing with this instrument or even to inexperience with the method. These
limitations decrease as the students get grow accustomed to the method and its applications.

Marangos e Alley\textsuperscript{32} demonstrated that despite the fact that students pointed out the maps as useful tools in the process of test preparation and subject summaries, few of them used the maps effectively. In this case, the students used the concept maps mainly for test preparation\textsuperscript{32}.

Another difficulty concerns to the application of the CM, in a fast and practical way for the performance of some activities, such as an outline of an essay to be written\textsuperscript{33}. There are also obstacles for the capacitation of individuals in the access and use of the software, which allows for the construction of maps in a fast and effective way\textsuperscript{33}. In this context some knowledge and ability to work with computers is required, which may limit its use in areas with poor technological structure and low digital inclusion.

7. What are the applications of concept maps?

In the area of medical education, concept maps can be used to\textsuperscript{15,17,15,34}: (1) organize and analyze a curriculum into a logical sequence of concepts, (2) facilitate refinement and improvement of concepts in the cognitive structure as a didactic technique, (3) present the knowledge through its hierarchical structures, (4) allow the student to internalize its concepts, building his own conceptual map, (5) lead the student to meaningful learning and (6) as an assessment tool. About this last topic, the first step for the use of concept maps in the evaluation of a student is to identify and formulate the assessment criteria. Accordingly, grading is based on the organization and quality of each component of the map\textsuperscript{14}. The number of connections and overall integration of the exposed ideas can also be analyzed. West et al. propose that concept maps and traditional tests measure distinct cognitive domains, therefore they may complete each other\textsuperscript{28}.

Another application of the concept map is in the facilitation of learning a second language, through a positive impact on the process of planning and organization of the study or even in preparation for the execution of tasks and in preparation for testing, which can be also be useful in the health area (for example, in relation to the Spanish language)\textsuperscript{33}. There are many well-structured studies in the area of medical education – and also in health education area – about the application of the CM in the process of teaching-learning\textsuperscript{15,33}. For example, França et al.\textsuperscript{30} used concept maps to explore the existing knowledge of obese patients in order to determine how best to educate them\textsuperscript{35}. The results with concept maps showed some differences between the patients: those who underestimated their caloric intake, for example, expressed more feelings on the maps and the ones who gave correct estimates of their caloric intake showed more knowledge about the restriction of food intake when on a diet.

IN CONCLUSION...

The cognitive processes implicated in teaching-learning are widely varied, and based on this diversity, it is important to use varied tools to enhance the construction of knowledge. Considering medical education specifically, more and more it seems that the use of an isolated method, whether traditional or expositive classes or problem-based learning, brings limitations, depending on the peculiarities of each student. Supported by this premise, the discussion about the increase in learning from the use of new techniques, new methods, and new tools – a genuine methodological plurality – must always be present and conscious. The use of the concept map can represent another strategy for medical education.

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AUTHORS’ CONTRIBUTIONS
Andréia Patrícia Gomes conceived the research project. All the authors participated in the development and final version of the article.

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The authors had no conflicts of interest.

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