Concept maps in medical education: an analytical literature review
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OBJECTIVES As the medical profession continues to change, so do the educational methods by which medical students are taught. Various authors have acknowledged the need for alternative teaching and learning strategies that will enable medical students to retain vast amounts of information, integrate critical thinking skills and solve a range of complex clinical problems. Previous research has indicated that concept maps may be one such teaching and learning strategy. This article aims to: (i) review the current research on concept maps as a potential pedagogical approach to medical student learning, and (ii) discuss implications for medical student teaching and learning, as well as directions for future research.

METHODS The literature included in this review was obtained by searching library databases including ACADEMIC SEARCH, ERIC, EBSCOHost, PsychINFO, PsychARTICLES, PubMed/MEDLINE, CINAHL and EMBASE. This literature review is a summary of both conceptual and empirically published literature on the uses of concept mapping in medical education.

RESULTS The 35 studies reviewed here indicate that concept maps function in four main ways: (i) by promoting meaningful learning; (ii) by providing an additional resource for learning; (iii) by enabling instructors to provide feedback to students, and (iv) by conducting assessment of learning and performance.

CONCLUSIONS This review provides ideas for medical school faculty staff on the use of concept maps in teaching and learning. Strategies such as fostering critical thinking and clinical reasoning, incorporating concept mapping within problem-based learning, and using concept mapping in group and collaborative learning are identified. New developments in medical education include the use of serial concept maps, concept maps as a methodology to assist learners with lower cognitive competence, and the combination of group concept maps with structured feedback.
INTRODUCTION

According to Shulman,1 ‘the signature pedagogies of the professions are not eternal and unchanging. Even though they seem remarkably stable at any one point in time, they are always subject to change as conditions in the practice of the profession itself and in the institutions that provide professional service or care undergo larger societal change.’ Thus, changes in the practice of medical education lead to many questions. Is medical education preparing future practitioners for the inevitable changes in health care delivery? Are medical students learning in ways that will facilitate their future clinical practice? Are there more effective educational strategies that can be used in the development of medical practitioners? The rapid changes in the science of medicine and the need for future practitioners to remain competent as the medical environment evolves mean that today’s medical students must learn in meaningful and integrated ways. Meaningful learning, the ability to understand and relate relevant medical concepts by linking them to prior knowledge, is of great formative value to medical students. Furthermore, critical thinking, clinical reasoning and clinical problem solving are of significant importance in the education of future doctors. Despite attempts to foster new ways of learning, mainly in graduate medical education,2 the creation of new teaching tools has been limited by difficulties in developing, delivering and assessing such strategies in undergraduate medical curricula. With that in mind, this article will review the current research on concept maps as a potential pedagogical approach to medical student learning. Implications for medical student teaching and learning are outlined, along with directions for future research in medical education.

CONCEPT MAPS: WHAT ARE THEY?

Before proceeding to the analysis of literature on concept maps, it is helpful to review the definition of concept maps, the theoretical framework supporting their use, the steps needed to create them and some of the challenges involved in using maps.

Definitions

The concept map, a graphic tool for organising and representing knowledge, was developed by Novak and Gowin3 and is based on Ausubel’s4,5 assimilation theory of learning. Novak and Gowin3 describe a concept map as ‘a schematic device for representing a set of concept meanings embedded in a framework of propositions’. In this view, we think and learn with concepts by linking new concepts to what we already know.6 In addition, concepts are stored hierarchically and differentiated as learning grows. Learning with concept maps means that the learner is making an intentional effort to link, differentiate and relate concepts to one another.3,7

Theoretical framework

Ausubel and his co-authors believe that during the process of thinking and learning with concepts, an individual uses three processes: subsumption, progressive differentiation and integrative reconciliation.5,8 In subsumption, lower-order concepts are subsumed under higher-order concepts.9 In progressive differentiation, concepts are broken down into finer and finer components. In this way, progressive differentiation is similar to the process of analysis. Finally, integrative reconciliation occurs when the learner attempts to reconcile and link concepts on the left side of the map with those on the right.10,11 This is similar to the process of synthesis.

Figure 1, a concept map of a concept map, depicts these three processes. It shows how lower-order concepts are subsumed under higher-order concepts, how concepts are differentiated, and how concepts are horizontally reconciled.

Creating concept maps

To create a concept map, the learner engages in an active process that includes the following steps. Firstly, the learner identifies the most general concepts and places them at the top of the map. Secondly, the learner identifies more specific concepts that relate to the general concepts in some way. Thirdly, the learner ties together the general and specific concepts with linking words that make sense to him or her. Finally, the learner actively looks for cross-linkages that tie concepts from one side of the map to concepts on the other. Concept maps can be created by hand with paper and pencil, or they can be created using one of many computer-based software programs, for example CMap Tools (see http://cmap.ihmc.us/conceptmap.html).

Challenges in using concept maps

Concept maps are often considered a new way of learning by both students and faculty staff, and as such it takes time for both to understand and incorporate mapping as a learning strategy. Student
resistance is sometimes seen during the initial stages of incorporating concept mapping into the medical school curriculum. This resistance is usually related to the time it takes to create maps. It may also be related to the students’ inability to understand how constructing maps and learning meaningfully will assist them in scoring well on standardised tests.2,3

Another challenge in using maps involves helping faculty understand that maps are designed to implement the concept of meaningful learning. This means that the faculty member’s focus shifts from teaching content to helping the student create and understand the meaning of the concepts within the context of his or her medical practice. As students develop an understanding of meaning, their maps will incorporate not only the content of the curriculum, but also their experiences in clinical practice. This implies that as the students’ learning grows, the maps they create will change over time. Teaching staff may see this as ‘unreliability’ in the maps, when in reality the idiosyncratic nature of the maps demonstrates how the students’ learning has grown and changed over time. This is analogous to the process that takes place in the development of expertise. As doctors develop their level of expertise, their understanding of particular topics grows and deepens. If one asks two experts to develop maps on the same topic, it is likely that these maps will look different because they reflect the cognitive structures of different people, as well as the varied clinical experiences of those experts. As such, concept mapping is a learning strategy that requires adjustment on the part of both students and teaching staff.

METHODS

In this study, we chose to investigate concept maps over other learning strategies for two reasons. Firstly, there is a growing body of literature in this area and, secondly, the maps may be a learning strategy to assist medical students in learning clinical reasoning, critical thinking and clinical decision making. The literature included in this review was obtained by searching a variety of library databases for the years 1989–2009. The databases included ACADEMIC SEARCH, ERIC, EBSCOHost, PsychINFO, PsychARTICLES, PubMed/MEDLINE, CINAHL and EMBASE. The key terms used in the search were ‘concept mapping’, ‘meaningful learning’, ‘education’, ‘medical education’, ‘assessment’ and ‘learning outcomes’. The references of all retrieved articles were scanned to identify additional articles. Over 350 articles were found in this search.

Because the purpose of this literature review was to inform medical education, articles and studies were included if they were perspective articles that described the use of concept maps in medical or health professions education curricula, courses or programmes, or if they were research articles in which the participants were medical or health professions students. Health professions students included undergraduate and graduate nursing students, undergraduate science students, dentistry students and veterinary students. In addition, both quantitative and qualitative studies were included, as well as studies in either basic or clinical sciences. Before any research
article was included in this review, its study design, sample and methodology were assessed. Reliable and valid studies were included as these articles were identified as providing insight into the effectiveness and applicability of concept mapping in medical education. Articles about the use of concept maps in patient education and understanding patient knowledge structures were excluded from this review.

Table S1 briefly describes the purpose and findings of the 35 articles selected for this review. Of the studies and articles included here, 19 refer to the medical profession, two of which relate to basic sciences, 13 refer to the nursing profession, two to the veterinary profession, and one to the dental profession. To analyse these articles, researchers reviewed each manuscript to identify the themes discussed and the findings presented. Following this review, researchers were able to reduce the initial themes to four categories in which concept maps were used in medical education.

RESULTS

The studies reviewed here indicate that concept maps function in four main ways within medical education:

1. by promoting meaningful learning;
2. by providing an additional resource for learning;
3. by enabling instructors to provide feedback to students, and

Each of these functions is explained in further detail.

Promoting meaningful learning

Concept maps have been successfully used in education for over 25 years and a growing body of literature indicates that their use in medical education is increasing. The vast majority of articles in this review indicate that concept maps foster the development of meaningful learning, critical thinking and problem solving in the learner. As indicated in these studies, meaningful learning occurs when the student links new knowledge with previous knowledge, thereby creating more integrated cognitive knowledge structures. The studies indicate that through the use of concept maps, students were able to integrate basic and clinical science information, move from linear thinking patterns to more integrated holistic patterns, and demonstrate critical thinking abilities within their disciplines. Ertmer and Nouri indicate that this type of meaningful learning was also achieved using concept maps online. As indicated in Table S1, these studies have established the effectiveness of concept mapping in promoting learning and yet the vast majority of them are limited by, for instance, their use of small samples of convenience, descriptions of single educational programmes and their limited generalisability.

Despite these limitations a number of interesting findings are apparent in this review. Firstly, concept maps are being integrated into the delivery of problem-based learning (PBL) approaches in medical and health professions education. Hsu reports the successful use of concept maps within the discussion component of PBL. Her results indicate that the ‘experimental group had significantly higher proposition and hierarchy scores for their concept maps compared with the control group’. Rendas et al. describe similar findings and report that their results ‘appear to indicate the use of concept maps stimulated meaningful learning within a PBL course’. They go on to state: ‘PBL and concept mapping proved to be complementary 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 visualised in the concept maps.’

Secondly, concept maps are being used in medical and health professions education to foster the development of group and collaborative learning. For example, Kinchin and Hay performed a qualitative study that identified three major patterns or structures when analysing students’ concept maps. These patterns or structures (spoke, chain and net) were identified as indicators of different developmental understanding. Kinchin and Hay went on to expand this work and study concept mapping in collaborative learning. They placed students in groups of three and asked them to produce a consensus concept map on the topic of pathogenic microbes. Findings indicated that students who were in triads of individuals with very different knowledge structures showed greater improvements in their learning than students who were in groups with more similar knowledge structures. These findings are similar to those of Boxtel et al., who found significant learning gains when concept mapping was used as a group task.

Thirdly, recent research has examined if and how students with specific learning styles benefit from the use of concept maps. Studies by both Kostovich
et al.,29 and Laight30 indicate that learning style does not play a role in ability to perform well on concept maps. These researchers indicate that concept maps can function well across groups of learners with multiple and varied learning styles.

Finally, two studies have raised interesting and new issues within the field of medical education that will need additional research and exploration. In one of the studies, All and Huycke14 used serial concept maps in graduate education to demonstrate the evolution of a student’s thinking over time. All and Huycke14 define a serial concept map as ‘a series of evolving maps created about a single concept over a specified time period’. Serial concept maps have provided a way to intermittently monitor student progress, to clarify faulty conceptual relationships, and to foster the connections between theoretical information and clinical practice. In addition, new work by González et al.,21 provides interesting information on the use of concept maps in medical education. These authors divided their students into two groups: a control group, which attended a traditional course in physiology, and an intervention group, which constructed concept maps ‘related to cardiovascular physiology and used them to solve problems related to this subject’.21 Both groups of students were tested using two types of examination: a problem-solving examination and a multiple-choice examination. Findings indicate that the group using concept maps performed significantly better on the problem-solving examination. Their performance on the multiple-choice examination was similar to that of the traditional group. These findings by González et al.,21 seem to uphold those of Roberts,36 who found no significant change in concept map scores over time but did find significant correlations between map scores and practical assignment scores. They also appear to corroborate those of West et al.,2 who indicate that assessments with concept maps may be measuring different cognitive domains from assessments with more standard tests. Even more interesting in the González et al.,21 study is the finding that using concept maps in problem solving had the most impact on students who came into the study with the lowest cognitive competence. This finding will need additional research, but it is important nonetheless as it may indicate that concept mapping represents a method by which teaching staff can assist medical students who are struggling to learn and perform.

Providing a resource for learning

The literature in this review reports that concept maps function as a resource for student learning within a curriculum and as a resource for knowledge elicitation and curriculum development. However, there is still a great need for additional research as the vast majority of articles in this area tend to be descriptive in nature.

As a resource for learning, concept maps allow students to demonstrate their mastery of the concepts associated with a particular body of knowledge. Concept mapping is a creative activity that fosters reflection on one’s own understanding.6 According to Pinto and Zeitz,9 concept maps can facilitate students’ understanding of the organisation and integration of important concepts. Torre et al.40 note that students reported: ‘...the concept maps allowed for creativity by developing a system of thinking that included pattern recognition, the ability to think broadly on topics, and finally, allowed for knowledge integration.’

Laight30 designed a study to explore students’ attitudes towards concept maps as an additional learning resource. Pre-prepared concept maps were integrated into traditional instructional methods. Questionnaires asked whether the concept maps were useful and allowed for other comments. A significant majority of students reported that pre-prepared concept maps were useful to their learning. Students reported being motivated to think more deeply and noted that they gained in understanding of conceptual inter-relationships. Therefore, according to Laight30, pre-prepared concept maps may offer alternative and innovative learning and teaching opportunities and methods in large classes.

Patrick et al.,36 and Weiss and Levison41 both describe concept maps as a resource for learning and curriculum development. Patrick et al.,36 explain how concept maps can assist in the development of curriculum databases in medical schools, specifically to support the development of PBL curricula. Weiss and Levison,41 by contrast, describe using concept maps as a blueprint for the development of curricular goals and objectives. Weiss and Levison also indicate that the maps can serve to assist with the integration of curricular themes across and among departments and disciplines, and describe how the maps assisted in the development of a women’s health medical education collaboration.41

One of the most innovative ways in which concept maps function as a resource for learning is articulated by Castro et al.,15 and Willemsen et al.43 These authors indicate that concept maps can function in the development of knowledge models. Castro et al.,15 describe how they used concept maps to begin
building a knowledge ontology within the nutrigenomics community. Willemsen et al. observe that, within clinical genomics research, ‘one of the main challenges is the acquisition and integration of data, information, and expert knowledge for specific biomedical domains and diseases’. They created 155 concept maps linked together in a knowledge model that allows for the visualisation of vast amounts of information. These ontologies and knowledge models have the potential to provide highly integrated and organised knowledge frameworks that can be applied to medical student learning and clinical performance.

Providing feedback

In relation to feedback, concept mapping can assist students in clarifying a topic, and teachers can use maps to provide feedback and identify student misunderstandings. According to Kinchin and Hay, concept maps are seen as a tool for communication between student and teacher which reveals the student’s constructions of connections.

Edmondson and Smith performed a qualitative study that analysed students’ responses to the integration of concept maps as a teaching and learning tool. Almost one-half of the students agreed that creating a concept map was an effective learning device. As a teaching method, the concept map provided the teacher with an understanding of the students’ errors, thereby allowing the teacher to provide feedback and clarify both content and performance.

Morse and Jutras provide us with an ever-greater understanding of the role that feedback can play in teaching and learning with concept maps. In their study, students in a cell biology course were divided into three groups. The control group did not construct concept maps; the second group constructed maps individually, and the third group created maps individually and then discussed them in teams that provided both peer and instructor feedback. Results from this study indicate that ‘concept maps without feedback had no significant effect on student performance, whereas concept maps with feedback produced a measurable increase in student problem solving performance and a decrease in failure rates’. This finding is important because it confirms one of the theoretical premises of concept mapping. Novak and Gowin believe that a major purpose of concept mapping is to foster the development of shared meaning between the instructor and the student. As instructors and students discuss, think about and revise concept maps, their learning and shared meaning-making processes deepen. This study demonstrates how the discussion of concept maps in a group, combined with feedback on the maps provided by the instructor, fosters students’ learning and performance.

Assessment of learning and performance

Concept maps have been used in a variety of studies as an assessment tool to identify student clinical performance, understand student thinking and reasoning processes, and compare student maps with expert maps. Williams notes that concept maps can be used to assess learning rather than just as an end process of learning. However, according to Roberts, because maps can vary greatly in style, a scoring method which suits the particular type of map must be chosen. The studies in this literature review indicate researchers are working on methods by which assessment activities and scores can be linked to the development of concept maps.

Daley et al. used concept maps as both a learning and an assessment strategy. Over the course of a semester in a clinical setting, 54 students created ‘three concept maps depicting relationships among the clients, pathophysiologic factors, pharmacologic factors, and therapeutic nursing interventions. These maps were used in post-conferences as discussion tools to foster links between theoretical course material and clients for which the students were providing care’. Results indicate a statistically significant change between the first and last concept map scores of the semester. Hicks-Moore and Pastirik also conducted a study to assess the level of critical thinking with concept maps. Their results indicate that critical thinking, as measured by the Holistic Critical Thinking Scoring Rubric, was enhanced by developing maps in the clinical setting.

Concept mapping was also used in a pre-test/post-test study carried out by West et al. West et al. found that concept mapping assessment (CMA) scores improved after course instruction; however, CMA scores did not correlate with final course or standardised test scores. According to West et al., ‘the absence of a positive correlation suggests that CMA measures a different knowledge characteristic than do multiple-choice examinations’; therefore, CMA has the potential to evaluate how students or residents organise and use knowledge in a way that traditional tests cannot. West et al. expanded on this work by studying both a structural scoring method and a relational scoring method. Structural scoring is based on the map’s organisation of hierarchical structure,
concept links and cross-links. Structural scoring assigns points for each valid component in four categories. Relational scoring is based on the quality or importance of each component, with no regard to the overall structure of the map. West et al.\(^{10}\) found that structural scores increased significantly, particularly with more experienced residents, yet relational scores were not significantly different.

McGaghie et al.\(^{32}\) conducted a quantitative study that used Pathfinder scaling to evaluate concept maps for internal consistency, student-instructor similarity, and correlational relationships to final examination results. Although descriptive analysis did not show a correlation between student-instructor concept map similarity scores and scores on examinations, student scores were internally consistent and the similarity of student maps with instructor maps increased significantly following instruction. McGaghie et al. also report on three additional studies that attempted to compare concept maps developed by faculty experts with maps prepared by medical students. Findings indicate that after a 3-week unit in pulmonary physiology, student and expert maps were more similar.\(^{35}\) However, as a side note, McGaghie et al. report a wide variety in the maps of experts.\(^{33}\)

Most recently, the understanding of CMAs has moved to the development of rubrics and multiple scoring systems. For example, Moni and Moni\(^{34}\) developed an assessment rubric for concept maps in a dentistry programme. The rubric was based on the content, logic and presentation of the maps. Students reported that they viewed the rubric positively, but, more importantly, the researchers were able to identify two distinct patterns in the ways students used the rubric to facilitate map construction and learning.\(^{34}\) D’Antoni et al.\(^{16}\) adapted the CMA scoring system developed by West et al.\(^{2}\) and found that the depth of the map can be assessed based on concept links, cross-links, hierarchies, examples, pictures and colours. Finally, Srinivasan et al.\(^{39}\) developed a study to test the reliability of CMAs. They created four scoring systems and found that the scoring systems that focused on the quality of the map, on the quality and importance of concepts, and a hybrid system had similar reliability and were overall more reliable than the scoring system that focused on the structure of the map alone.

**Implications for Medical Education and Future Research**

Based on this literature review, it appears that the concept map has a potential role to play in medical education as a teaching, learning and assessment strategy. Despite the limitations of each individual research article cited here, there is a growing body of evidence on the effectiveness of mapping as a method to promote meaningful learning, as a resource for learning, as a methodology for providing student feedback, and as an assessment strategy in medical education. The research cited in this review demonstrates that concept maps can assist in medical student learning. The reviewers could find no studies that indicate detrimental effects of using this strategy in medical education. Additionally, for teaching staff in medical schools, this review provides ideas on how to use concept maps to foster critical thinking and clinical reasoning in medical students, how to incorporate concept mapping within PBL approaches, and how to use concept mapping in group and collaborative learning. New developments in medical and health professions education include the use of serial concept maps, concept maps as a methodology to assist learners with lower cognitive competence, and enhancing the use of concept maps in group settings by providing specific feedback to students.

Nonetheless, specific research on the validity of mapping within the medical school curriculum remains necessary. This review includes a preliminary analysis of the different ways in which maps can be used in assessments and a number of proposed scoring formulas for concept maps, both quantitative and qualitative. However, for maps to be used widely within medical education, the area of assessment and scoring needs to be developed much further. How can we use concept maps to assess and document learning and change in meaning and understanding for learners? Can a simplified scoring method that clearly documents learning outcomes be developed? Further research is also needed into how concept mapping as an assessment tool correlates with standardised assessments within medical education. Validity and reliability testing of concept mapping compared with other measures of learning is also needed.

Additionally, longitudinal studies on the use of concept mapping in medical education are virtually non-existent. Longitudinal research is needed to determine if concept maps can play a role in assisting medical students as they make the transition to practising doctors. This type of research would need to focus on how thinking and learning patterns develop and change over the course of a doctor’s career. It is this type of longitudinal work that may have implications for understanding how concept maps can assist in developing clinical reasoning processes in doctors.
Finally, as Nesbit and Adesope state: ‘...investigators should examine the processes by which students learn with concept maps and their effects on higher-level learning goals such as problem-solving transfer, application, and analysis; conceptual change and the development of learning skills.’ We believe that further research into the relationships between concept mapping and clinical reasoning, medical problem solving and diagnostic errors in clinical practice is also needed in medical education. As Novak and Cañas state: ‘While at first glance concept maps may appear to be just another graphic representation of information, understanding the foundations for this tool and its proper use will lead the user to see that this is truly a profound and powerful tool. It may at first look like a simple arrangement of words into a hierarchy, but when care is used in organising the concepts represented by the words, and the propositions or ideas are formed with well-chosen linking words, one begins to see that a good concept map is at once simple, but also elegantly complex with profound meanings.’

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REFERENCES


SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

**Table S1.** Articles related to concept mapping in medical education.

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