

Rx for Medical Educators – a Good Dose of Concept Mapping

1. Introduction

Research on concept mapping has been on-going for about 35 years. Concept maps were developed in 1972 by Joseph Novak and colleagues at Cornell University. They are based on Ausubel's Assimilation Theory and Novak's Theory of Learning (J. D. Novak 2003). Concept maps are graphical representations of knowledge that are comprised of concepts and the relationships between them. Concept maps contain content in context.

There are three major challenges for educators:

1. How do I get my students to understand what I teach?
2. How can I encourage my students to learn meaningfully?
3. How can I evaluate how well they have learned?

This workshop shows you how to use concept mapping for teaching, learning and evaluation.

By the end of this workshop, participants will appreciate how concept maps can be used for teaching, learning and assessment, and be able to construct their own concept maps using CmapTools.

1.1 Contents of the CD

- CmapTools program – Windows, Linux and Mac.
- Selected PDFs on concept mapping.
- CmapTools help file.
- This document.

1.2 Websites

- Institute for Human and Machine Cognition: <http://cmap.ihmc.us>. Contains resources relating to CmapTools.
- Medicine's Postgraduate Portal: <http://sumed.sun.ac.za>. Has many examples of medical concept maps.

2 Some Theory

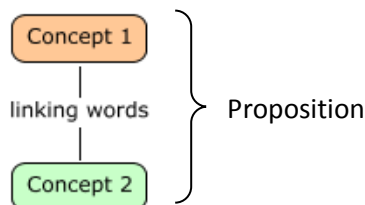
Concept maps are graphical representations of a knowledge domain (J. Novak n.d.). They consist of concepts contained within nodes. The nodes are connected by linking phrases to form propositions. Concept maps have strong psychological and theoretical foundations, based on Ausubel's Assimilation Theory and Novak's Theory of Learning (J. D. Novak & Cañas 2008). Concept mapping is primarily used to facilitate meaningful learning. The program used in this workshop (CmapTools) is easy enough for primary school children to use and powerful enough for NASA to capture the knowledge of their retiring rocket scientists. CmapTools is a free concept mapping tool that installs on your desktop PC. It connects to the internet as well as concept maps hosted on thousands of computers across the globe.

- Concept maps are graphical tools for organizing and representing knowledge.

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- A concept is unit of meaning and is described by a word or phrase. Concepts consist of labels (enclosed in circles or boxes) and relationships (a connecting line) linking two concepts.
- The text on the line (linking words or phrases) describes the relationship between the two concepts.
- A proposition consists of two or more concepts connected using linking words or phrases to form a meaningful statement (semantic unit).

Figure 1 - A proposition, the basic unit of memory



Concept maps were developed in 1972 in the course of Joseph Novak's research program at Cornell University.

Concept maps have a strong psychological and theoretical foundation, based on Ausubel's Assimilation Theory and Novak's Theory of Learning. We learn new things by using our current knowledge and, to a greater or lesser degree, integrating new knowledge with what we already know. A concept map is a graphical representation of these relationships between concepts in our cognitive structure.

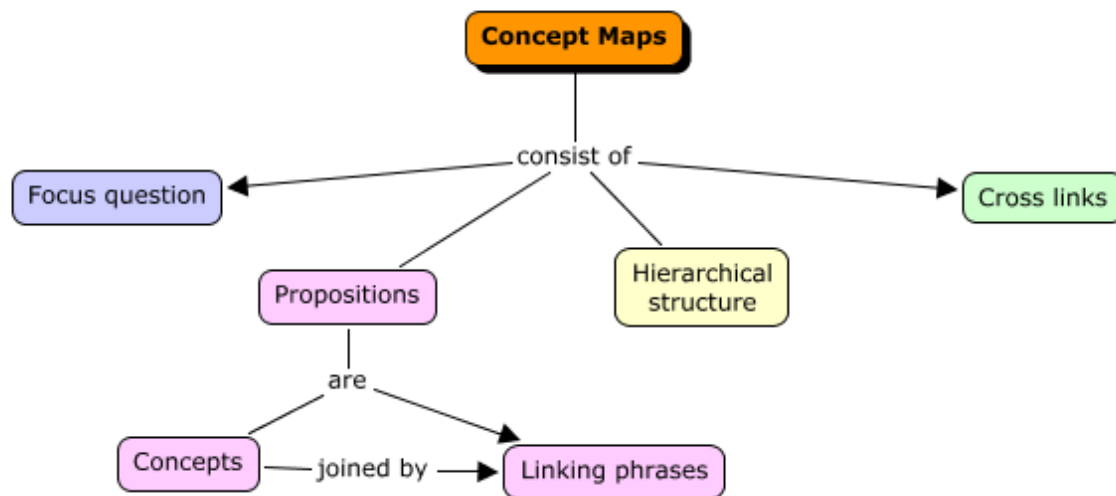
Research showed that constructing concept maps is useful to represent knowledge and promote understanding (J. D. Novak & Cañas 2008).

2.1 Characteristics of concept maps

- **Focus question** - clearly specifies the problem or issue the concept map should help to resolve.
- **Propositions** - a concept map consists of a graphical representation of a set of propositions about a topic.
- **Hierarchical structure** - the most general concepts are at the top of the map and the more specific, less general concepts are arranged hierarchically below. Because of this, concept maps tend to be read from the top, progressing down towards the bottom. This is not a rule; it could be cyclic as long as there is logical order (e.g. using arrows or numbers). Also there can be more than one root.
- **Cross-Links** - relationships or links between concepts in different segments or domains of the concept map. Cross-links often represent new insights on the part of the knowledge producer.

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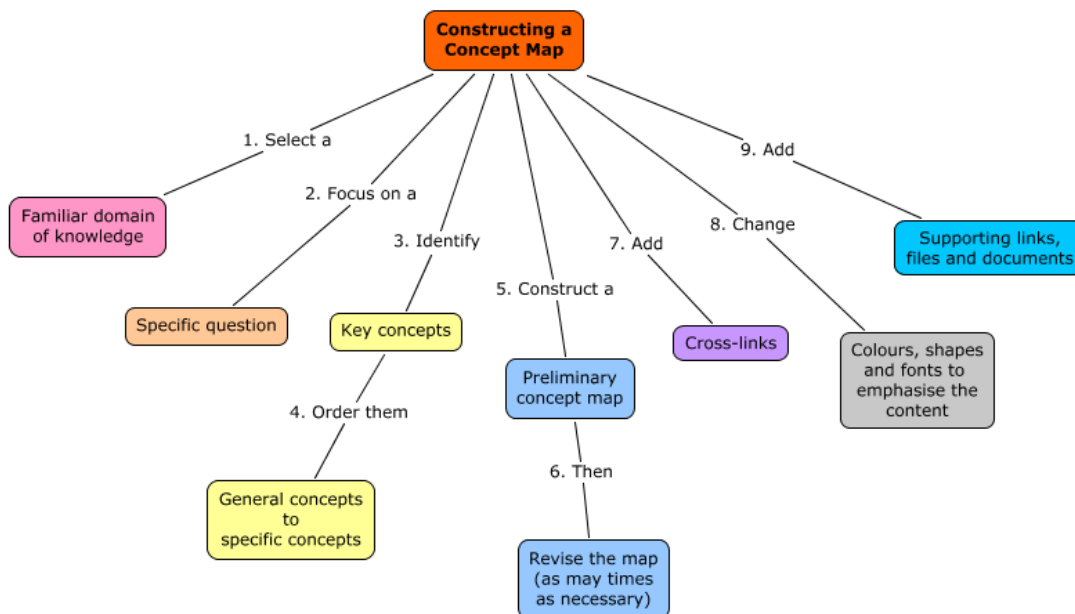
Figure 2 - Components of concept maps



2.2 Constructing a Concept Map

There is no simple recipe or set of steps for constructing a concept map, everyone has their own style. Some start by listing a set of concepts, others go directly to placing a root concept and start linking other concepts from it. Here is a suggested sequence:

Figure 3 - Steps for constructing concept maps



2.3 Decide on the Focus Question

A focus question is a question that clearly specifies the problem or issue the concept map should help to resolve. Every concept map responds to a focus question, and a good focus question can lead to a much richer concept map. The first step to learning about something is to ask the right questions.

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2.4 Identify Key Concepts

List each concept using the smallest number of words (you can write these down or enter them directly on the concept map).

2.5 Structure the Hierarchy

Arrange the concepts in a loose hierarchy (general topics at the top and specific examples below).

2.6 Link Concepts

Connect concepts using linking words, to create propositions. Linking words usually consist of, or include, a verb. As the concept map is created, concepts are moved around, added, removed, and redefined.

The process of constructing the concept map continues by linking the rest of the concepts, revisiting the linking words, adding other concepts, etc. Care must be given to making sure that every two concepts with their corresponding linking phrases form a proposition that makes sense, that it is a unit of meaning, and that long sentences are not included in the concept map spanning through several concepts and linking phrases.

After a preliminary map is constructed, it is always necessary to revise this map. Good maps usually result from three to many revisions.

2.7 Create Cross-links

Once the preliminary map is built, cross-links should be sought. These are links between concepts in different segments or domains of knowledge on the map that help to illustrate how these domains are related to one another. Cross-links are important in order to show that the learner understands the relationships between the sub-domains in the map.

It is important to recognize that all concepts are in some way related to one another. Therefore, it is necessary to be selective in identifying cross-links, and to be as precise as possible in selecting the linking words that connect concepts. In addition, one should avoid "sentences in the boxes", that is, full sentences used as concepts, since this usually indicate that a whole subsection of the map could be constructed from the statement in the box.

A concept map is seldom "finished". There are always more concepts that could be added and refinements that could be made.

2.8 Finishing Touches

Finally, the map should be revised, concepts re-positioned in ways that lend to clarity and better over-all structure, and a "final" map prepared. Change the size and font style, and add colors to "dress up" the concept map.

The difficult part is creating the linking phrases. Once you find good linking words, and identify cross-links, you can see that every concept can potentially be related to every other concept. Choose to construct the most prominent and most useful cross-links. This process involves what Bloom (1956) identified as high levels of cognitive performance, namely evaluation and synthesis of knowledge. Concept mapping is an easy way to encourage very high levels of cognitive performance.

Concept maps are not only a powerful tool for capturing, representing, and archiving knowledge of individuals, but also a powerful tool to encourage meaningful learning and to create new knowledge.

3 Using Concept Maps for Teaching

Knowledge transfer whether in the form of a lecture, slideshow, video or other medium, usually has four distinct stages (Kinchin & Cabot 2007), (González et al. 2008), (Alvarez & Montoya n.d.):

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- Preparation of the topic
- Structuring of the content
- Design of the presentation
- The Delivery

Usually far more time goes into the first three stages than in delivering the content. Concept mapping can be used in all four stages.

3.1 Preparation

Concept maps can help the presenter prepare. Defining the focus question helps to set the boundaries of the content. Relevant concepts can be identified and entered in no particular order.

3.2 Structuring

Organizing the concepts into a hierarchy and adding links and connecting phrases provides a logical structure for your presentation.

3.3 Design

In the design phase, background graphics can be added to the entire map or for any element of the concept map including: concepts, links and linking phrases. Similar concepts can be associated by colouring them the same. There are no animations in CmapTools. Animations can sometimes be distracting. A wide variety of supporting resources can be attached to concepts or linking phrases such as: graphics, audio, video, PDFs, docs, spread sheets, PowerPoint slideshows, links to websites and other concept maps. Constructing a concept map can often be far quicker than creating a PowerPoint slide show.

3.4 Delivery

To facilitate delivery of the presentation, there is a slideshow feature built into CmapTools which provides for selective revealing and emphasis of the content.

4 Learning with Concept Maps

One of our most fundamental goals as educators is to promote meaningful learning in our students. Ausubel made the very important distinction between rote learning and meaningful learning, and stated that meaningful learning requires three conditions:

1. The material to be learned must be conceptually clear and presented with language and examples relatable to the learner's prior knowledge. Concept maps can be helpful to meet this condition, both by identifying general concepts prior to instruction in more specific concepts, and by assisting in the sequencing of learning tasks through progressively more explicit knowledge that can be anchored into developing conceptual frameworks.
2. The learner must possess relevant prior knowledge. This condition can be met after age 3 for virtually any domain of subject matter, but it is necessary to be careful and explicit in building concept frameworks if one hopes to present detailed specific knowledge in any field in subsequent lessons. We see, therefore, that conditions (1) and (2) are interrelated and both are important.

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3. The learner must choose to learn meaningfully. The one condition over which the teacher or mentor has only indirect control is the motivation of students to choose to learn by attempting to incorporate new meanings into their prior knowledge, rather than simply memorizing concept definitions or propositional statements or computational procedures. The creation of concept maps supports the incorporation of new meanings into prior knowledge.

When concept mapping is compared with other sorts of activities, such as outlining or defining concepts, that also can induce the learner to take a thoughtful, systematic approach to engaging subject matter, the positive benefit of concept mapping often diminishes (a finding noted also in the review by Horton, 1993). However, even in these situations, it appears that concept mapping is especially good, in comparison to other interventions, for the learning of relationships among concepts.

From several of the studies reviewed, there is indication that concept mapping may be particularly beneficial for lower ability learners, partly because it does induce the active, inquiring, orderly approach to learning that is likely a more natural part of the higher ability student's approach to learning. On the other hand, when learners are not yet familiar with constructing concept maps, there is some indication that the cognitive load of creating maps from scratch may hinder learning. When students are novice mappers, other "scaffold" ways of interacting with concept maps, for example, filling in the blank content nodes of a concept map already containing the labelled relationships of a completed concept map, may be beneficial.

5 Assessment Using Concept Maps

Another very powerful use of concept maps is as an evaluation tool, thus encouraging students to use meaningful-mode learning patterns. Concept maps are also effective in identifying both valid and invalid ideas held by students. They can be as effective as more time-consuming clinical interviews for identifying the relevant knowledge a learner possesses before (i.e. prior knowledge determination) or after instruction (Rye & Rubba 2002).

There are numerous methods of scoring concept maps. Scoring systems focused on concepts more closely correlate with traditional testing scores. Using all the elements of the concept map for scoring often produces a different outcome from traditional testing methods and promotes meaningful learning (West et al. 2002).

I am not going to go into details regarding the reliability and validity of the different scoring systems except to say that the inter-rater reliability of scoring concept maps depends on the scoring system used and that construct validity comparing concept maps to traditional assessments has a correlation of around $r=0.5$. Concept maps measure something related to traditional exams and should probably be used as a complimentary method of assessment.

5.1 Fill-in-the-blanks (Complete or Partial)

This can be done a number of ways (Figure 4):

- Entirely paper-based. Students write the concepts number into the box. Relatively easy to mark.

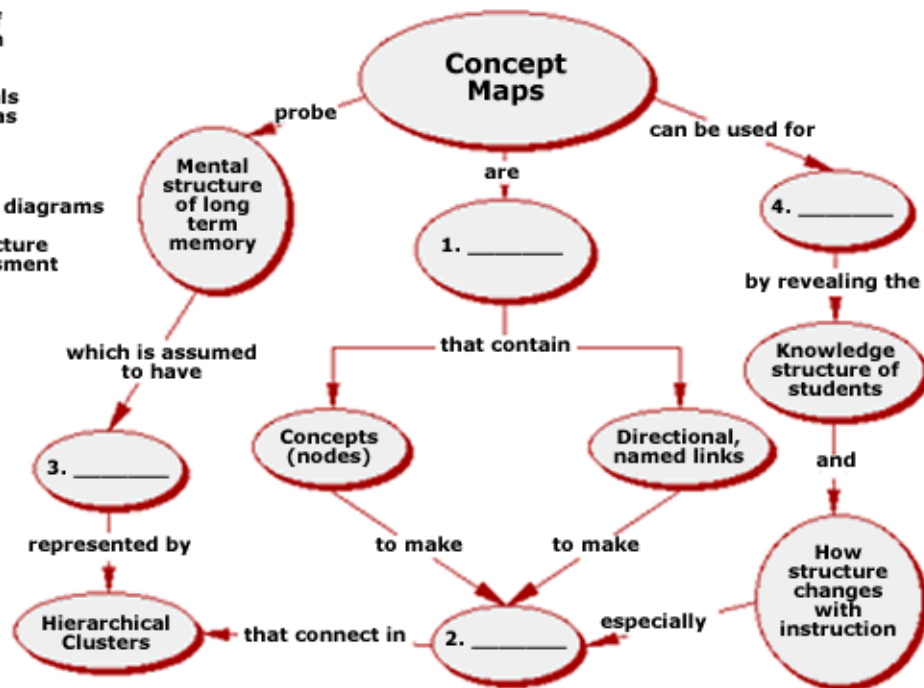
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- Concepts on paper or screen and empty map on a computer. Students type the correct concept into the box. Can be marked by computer.
- Entirely computer-based. Concepts placed on the screen next to the empty map. Students copy the concepts and paste them into the boxes. Can be marked by computer.
- Variations:
 - Instead of just concepts, provide a list of concepts and linking phrases (Figure 5 and 6).
 - Partially complete the map – e.g. fill in the easy bits and let the student complete the rest.

Figure 4 - Fill-in-the-blank concepts

Please fill in each of the blank ovals with an answer from the list below. Notice that each of the ovals contains a number as well as a space for your answer.

- A. Two-dimensional diagrams
- B. Propositions
- C. Relatedness structure
- D. Classroom assessment



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Figure 5 - Fill-in-the-blank linking phrases (before completion)

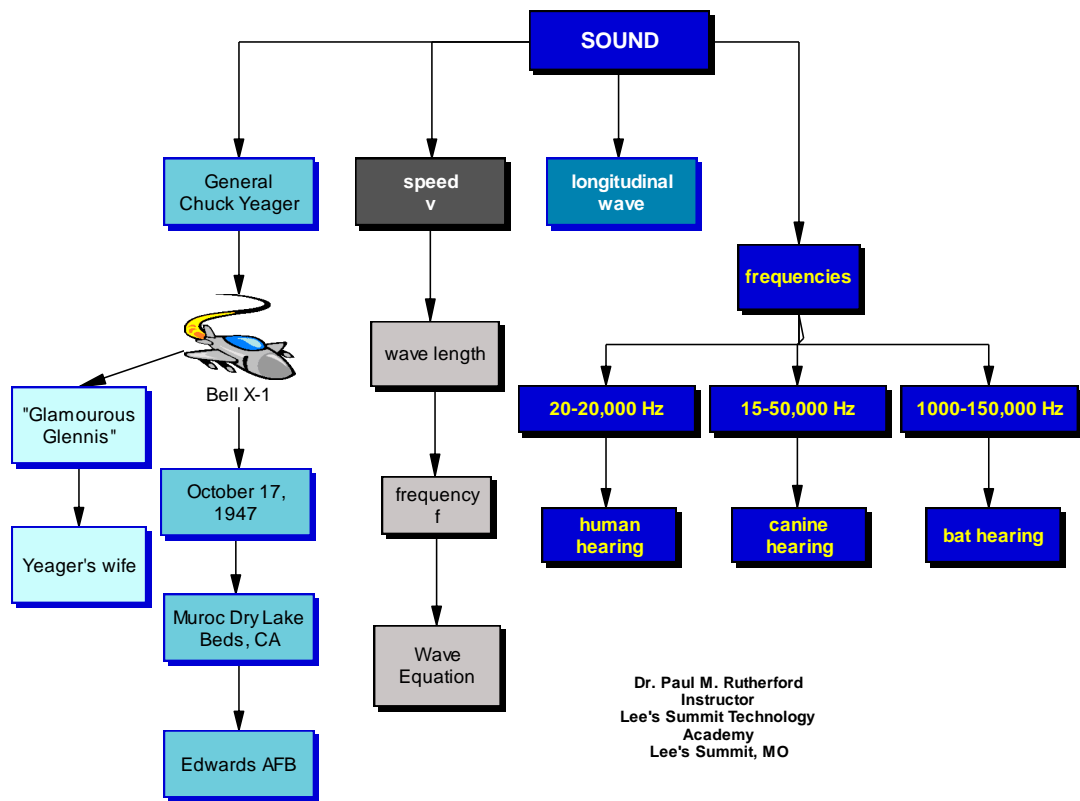
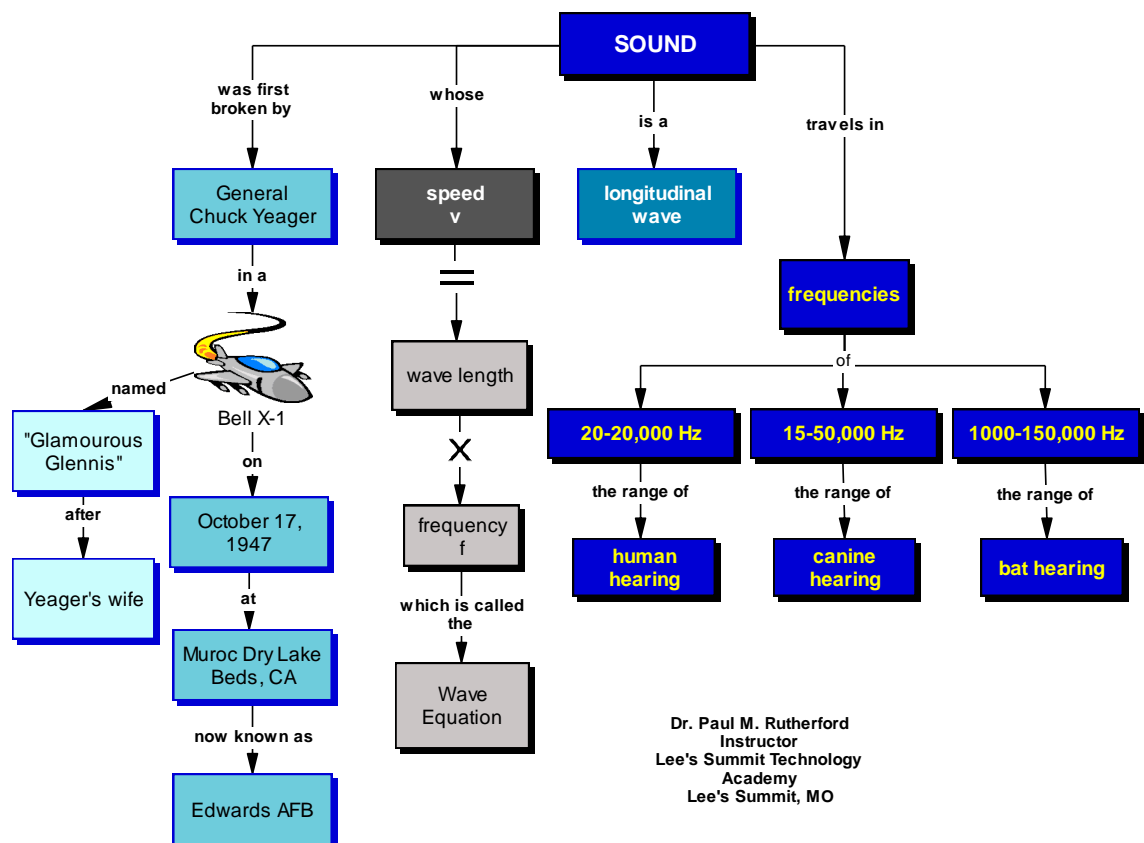


Figure 6 - Fill-in-the-blank linking phrases (after completion)

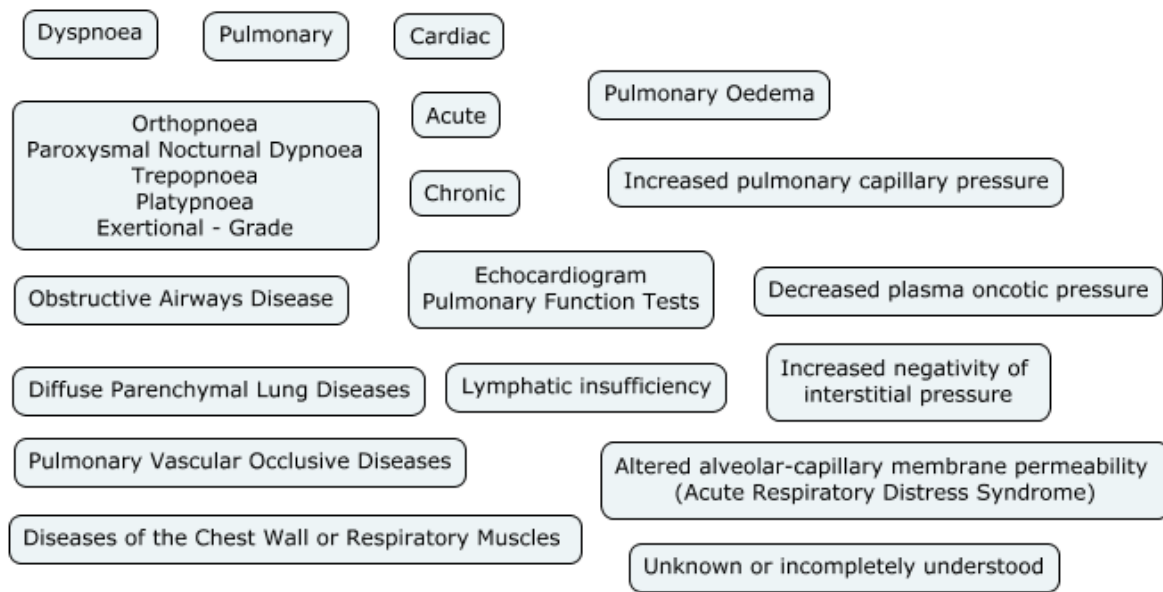


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5.2 Mapping Pre-selected Terms (Parking Lot)

Supply students with a list of concepts (Figure 7) and/or linking phrases and instruct them to create their own concept maps using the pre-determined concepts and linking phrases. This can be evaluated by the program.

Figure 7 - Parking lot



5.3 Micro-mapping or Seeded Term Mapping

Provide students with a list of starter or seed terms on a concept map. Students need to build on this foundation using their own knowledge of the topic. You could specify the minimum number of concepts and relate them to the number of marks allocated.

5.4 Collaborative Mapping

Students can work on the same concept map – either synchronously or asynchronously. I have not used the asynchronous collaboration feature as it raises communication issues between the students that are difficult to overcome. Probably the easiest collaborative method is to give a group the task of completing a particular concept map and giving them a group mark.

5.5 Unguided Mapping

Students are free to create concept maps entirely on their own. This could be on a given topic, chapter or article or left up to their discretion. There are numerous ways to allocate marks to the various parts of their concept maps. You could set a minimal score for them to achieve. An objective method that I have used (and given to the students beforehand) is:

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Table 1 - Objective schema for marking concept maps

| Item | Score |
|----------------------------------|-------------------------------|
| Propositions | 1 point per valid proposition |
| Links (In and Out) from Concepts | 1 point per valid link |
| Hierarchy | 5 points per level |
| Cross Links | 10 points per link |
| Focus question | 10 points or zero |
| Resources | 1 point per resource link |

5.6 Rubric

An example:

Table 2 - Rubric for marking concept maps

| | Superior (7 to 9) | Satisfactory (5 or 6) | Marginal (4) | Unsatisfactory (1 to 3) |
|-------------------------------|---|---|--------------------------------------|------------------------------------|
| Focus question | Focus question present Focus question relevant Focus question not too broad | Focus question present Focus question partially relevant Focus question too broad | No focus question | No focus question |
| List of concepts | Covers the entire domain | Covers just the important topics | Does not adequately cover the domain | Misses major topics |
| Linking phrases | All linking phrases correct and relevant | Linking phrases could be improved | Linking phrases are inaccurate | Missing linking phrases |
| Hierarchical structure | Strict hierarchy present Five or more levels | Strict hierarchy present Fewer than 5 levels | Some evidence of hierarchy | No hierarchy |
| Cross links | More than 5 cross links | Two to four cross links | Only one cross link | No cross links |
| Resources | More than five attachments | Two to four attachments | Only one attachment | No attachments |

6 Concept Mapping for Personal Learning Environments

Besides facilitating meaningful learning, CmapTools can form the backbone of a Personal Learning Environment. It can function as a desktop or web-based application or both. It has security features that allow you to specify who can view and change your concept map. It can link to any electronic resource on your PC or on the internet. It can launch videos or PowerPoint slideshows and display pictures. Most of all, it is easy to use and update.

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Most of us involved in medical education have had some experience of e-learning using Moodle or some other Learning Management System for lessons, videos, assignments and MCQs. But two factors are transforming this familiar landscape: the availability of the Internet and computing power virtually everywhere. Being able to connect to the internet anytime and anywhere using on almost any device has bred a new generation of learners called the “Net Generation”. These learners now tend to:

- Absorb information quickly from multiple sources
- Expect immediate response and feedback, and
- Prefer on-demand access to media

Over the next few years growing internet use and relatively cheap computing will influence our own learners. They are likely to expect their learning to be delivered quickly on demand and using a variety of rich media.

6.1 Personal Learning Environments

Instead of centralised, instructor-controlled learning, a Personal Learning Environment (PLE) enables each learner to take control of their own learning. A PLE could be a single desktop program or a selection of software tools to integrate information on their personal computer with web resources. Just as each student’s approach to learning differs, so their set of tools will differ. PLEs place the emphasis on the learner and not the teacher.

The driving forces behind the adoption of PLEs are the realisation that:

- Each learner has a unique learning style
- Learning is a lifelong experience
- Learning takes place in different contexts
- Many institutions will contribute to learning along the way
- e-Learning will play an increasingly prominent role.

There are two broad approaches to PLEs: institutional and individual. I will focus on individual PLEs.

6.1.1 Individual PLEs

Using the individual approach to PLEs, the teacher’s responsibility becomes one of knowing what tools are available and exposing our learners to them. In seeking to leading by example, educators need to develop their own PLE and be familiar with a wide range of tools such as: blogs, instant messaging, file sharing, feed aggregators, podcasts and social networks.

Besides facilitating meaningful learning, CmapTools can form the backbone of a PLE. It can function as a desktop or web-based application or both. It has security features that allow you to specify who can view and change your concept map. It can link to any electronic resource on your PC or on the internet. It can launch videos or PowerPoint slideshows and display pictures. Most of all, it is easy to use and update. Students can also collaborate on constructing the same concept map simultaneously from different sites. There is a feature built into CmapTools that will analyse your concept map and suggest topics you might not have thought about.

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7 Conclusion

Medical education will increasingly be nudged in the direction of e-learning.

“The curious thing about technology is the way it resolves complexity into simplicity” Kevin Kelly

Tutors and students both need to master new skills and tools in order to be effective life-long learners. Whether you are a teacher or student, having a program like CmapTools as part of your personal learning environment can enhance both your effectiveness as a teacher and your ability to learn.

8 References

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