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# Concept Mapping with ICT

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## Introduction

When we interact with children, we are sometimes amused by their naïve ideas. For example, a boy may call any man he meets “father”. By doing that, we know the boy has not learnt the concept *father*. Sometimes we are fascinated by statements made by precocious children. I once heard a 3 year-old girl saying to another girl, “You are not loyal to me!” It makes me wonder whether the girl truly understands the meaning of *loyalty*.

Our experience tells us intuitively that we are learning many concepts in our lives. We also know that some concepts more concrete, usually those related to physical objects like a chair. Then again, with progressive enrichment of our life experiences, such concrete concepts may take on different shades of meaning. If you have seen some designer chairs, you will be amazed how these objects can be related to chairs. There are also abstract concepts like *loyalty* or *betrayal* that requires one’s life experience - often coupled with deep emotional experience - to truly appreciate their meanings. In short, concept learning forms a very important part of human life.

From an educational perspective, many psychologists believe that concept learning, which involves knowing the attributes of the concepts and how concepts are related to each other, is considered pre-requisite for learning rules, principles and for solving problems (e.g. Gagne, 1985). Strong learners usually have a clear framework of how concepts in a field are inter-related to each other. This chapter focuses on learning concepts through concept mapping assisted with ICT tools.

## Concept and concept learning

First, let us discuss what a concept is. Ironically, the concept of *concept* is rather difficult to grasp. When a boy points to a dog and says “dog”, does it mean he knows the meaning of a *dog*? What if he points to a cat and also says “dog”? Thus, knowing the label of something does not mean knowing the concept.

A simple explanation is that a concept is a mental construct, an abstraction of reality represented by symbols or labels. These symbols or labels are usually denoted by word(s) that refer to a category or class of phenomena, things, processes or the relationships between them. For example, *tool* is a concept; it represents a class of objects that can serve to improve work performances. *Gravity* is another concept; it refers to the invisible forces that attract all masses in the universe. Klaumeier (1992) further elaborated on the attributes of a concept. To Klaumeier, a concept has intrinsic attributes, functional attributes, and relational attributes. The intrinsic attributes refer to some invariant properties of the concept, for example, a *ruler* has markings on it. The functional attributes refer to how the thing works and its use (a *ruler* is used to measure length of an object). The relational attributes refer to qualities defined in relation to other things (a ruler is related to length and instrument).

Given an understanding of concept, I will proceed to explain how a concept is learnt. Following Klaumeier's suggestion, there are four progressive levels of learning a concept: Concrete level, identity level, classificatory level, and formal level. I will use the above example of a boy learning about the concept of dog to illustrate these four levels of learning. At the concrete level, the boy recognises a walking animal with a tail and has been told by his mother that it is called a dog. He forms an image of this dog and could recognise it again the next time he sees it. He could tell that a dog is very different from an ant, which is much smaller and not fury. At the identity level, he begins to be able to tell that it is a dog even when he sees it from different angles, or from a different modal representation like a picture or a video of a dog. That means some level of generalisation is achieved. At the classificatory level, the boy begins to tell an example from a non-example. He can tell that even though a cat is four-legged animal with a tail, it is not a dog; whereas a terrier and a hound are both dogs even though they look different. At the formal level, the boy can identify successfully all examples and non-examples, and he is able to name the concept.

There are a few instructional models for concept learning, one of which is Concept Attainment model, which is credited to Jerome Bruner (Bruner, Goodnow, & Austin, 1967). This instructional model uses an inductive approach by asking the students to compare and contrast examples and non-examples so that they could identify the attributes of a concept and generate a definition for the concept. The students will also generate other examples of the concept. There are many websites that give more specific examples of how concept attainment can be conducted. Concept learning is also heavily influenced by Ausubel's (1963) theory of meaningful learning. According to Ausubel, knowledge is hierarchically organised and new information is meaningful to the extent that it can be related (attached or anchored) to what is already known. He proposed the use of advance organiser, in the form of text or graphics that describes existing knowledge or framework so that a student could link new information to the framework. In a sense, it is a form of mental scaffolding for the students to learn a new concept.

The years of the references in the above paragraph suggest a long history of development of theories and strategies on concept learning, particularly among researchers and educators who subscribe to cognitivist theories of learning. In recent years, the idea of hierarchical approach of learning from simple to complex is challenged. Is it really necessary to learn facts, followed by concepts, principles and theories in sequential order? Concept learning does not seem to receive as much attention among constructivist advocates. This is because constructivist approaches, like problem-based learning, focus on learning through ill-structured complex problems. Such approaches usually require the students to experience, apply, discuss, and even debate about abstract concepts (e.g. honesty). There is an implicit understanding that concept learning occurs through solving of authentic problems. Spiro, Coulson, Feltovich, and Anderson (1988), for example, proposed the Cognitive Flexibility theory which suggests that students can benefit from multiple representations of the same phenomenon in different contexts so that they can grasp the complexity of contextualised knowledge and can better apply the knowledge in different contexts. They used the analogy of developing a deep understanding of an environment by criss-crossing the same terrain from different angles and different paths. For examples, a medical student might be able to grasp the concept of heart attack after being exposed to various cases of heart attack under different circumstances.

This chapter focuses on computer-based concept mapping, which is an activity that can be used with either cognitivist or constructivist approaches. The focus on concept learning, however, fits better with the cognitivist view of learning.

**1. What is a concept map? How does concept mapping help in learning concepts?**

A concept map is a diagrammatic representation of relationships between concepts. In a concept map, the nodes denoting the concepts are linked by lines or arrows with relationships between the nodes labelled. A pair of connected concepts, together with the relationship, forms a proposition. Each proposition is a meaningful statement. Concepts can be connected with a number of cross links that denotes its relationships across different branches in a concept map. The concepts can and at times should be organized into hierarchies to show the relationships among the concepts. The following diagram shows a concept map on *water* and its three states (Figure 1).

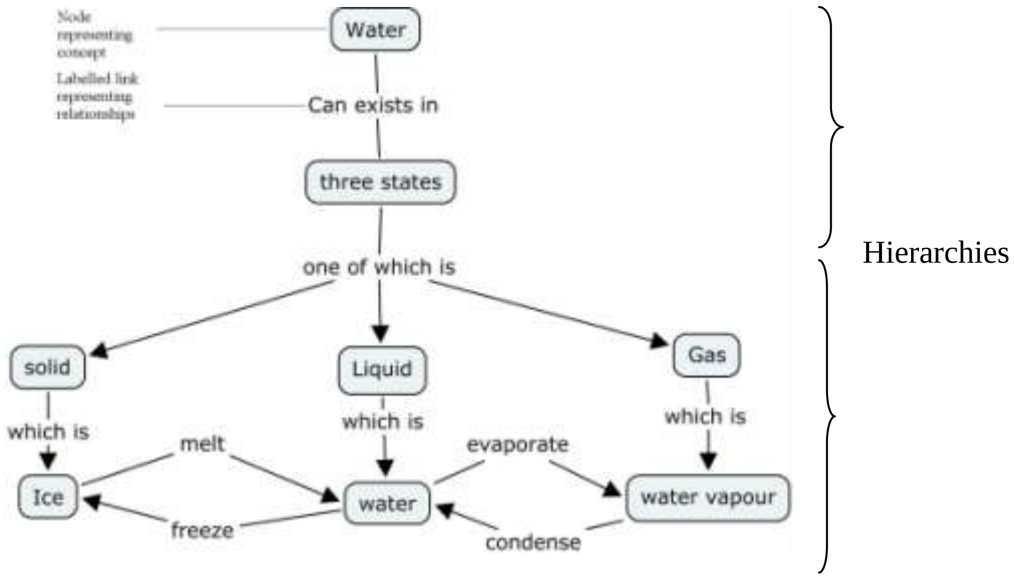


Figure 1. A concept map on states of matter

Based on Ausubel's theory, concept mapping can be regarded as an organisation tool for meaningful learning. When students construct concept maps, they have to identify the key concepts of the subject matter and connect the concepts with meaningful labels. The students are therefore engaged cognitively in analysing and processing the information. As a concept map represents interrelationships between concepts, the students must be able to make the appropriate connections and label the relationships with appropriate link words. The hierarchical structure of concept maps also allows the students to make connections between new knowledge and existing knowledge which is characteristic of meaningful learning (Novak & Godwin, 1984).

More specifically, concept mapping can be used to facilitate concept learning in the following ways:

1. As an advance organizer. A teacher could construct a concept map as an advance organizer. Before elaborating on a concept, the teacher shows to the students the concept on the map and how it is related to other concepts. After explaining the concept, the teacher revisits the map to see its relationships with other concepts again.

2. As a comparative organizer. A teacher could ask the students to construct a concept map and ask them to identify two or more similar concepts on the map. The students then proceed to identify the similarities and differences among the concepts.

3. For progressive differentiation. The students construct a concept map around a main topic. They then compare and contrast with their friends' maps before revising their own maps and state reasons for the changes. Alternatively, ask the students to construct a concept map for a topic and continue to expand on the concept maps across topics in a subject or even across subjects. As they revise concept maps, state reasons for the changes.

Jonassen (2000) advocates the inclusion of building concept maps into instructional activities because it will help students to build structural knowledge. He classifies knowledge as knowing that, knowing how and knowing why. Structural knowledge is to him the component of knowing why. He further explains that getting students to build concept maps can help to avoid passive learning which may result in the accumulation of inert knowledge among students.

**What are the roles of ICT in concept mapping? What are ICT tools for concept mapping?**

Although concept maps can be produced using the paper-and-pencil method, computer-based software can facilitate the process by acting as a Mindtool (Jonassen, 2000), which means a tool that represents the implicit knowledge structures stored in our minds. From the perspective of a Mindtool, the students are required to represent their understanding in certain knowledge representations. In the case of concept mapping, the students have to think about the key concepts in a particular topic, the relationship between the various concepts, the descriptions for the relationship, and the hierarchies of concepts. The computer relieves the students of the chores and cognitive demand of less important tasks, such as erasing or redrawing the maps which is likely to happen since good concept maps usually require a few iterations to produce. Other features that computer-based software could provide include:

- Ease of regrouping and change (relieve learners of lower level tasks like changing links)
- Ease of comparison
- Convenience of brainstorming ideas
- Allow continual build-on of concepts across lessons and across topics
- Hyperlinks to relevant sources

- Allow collaborative mapping (e.g. group brain storming or group online collaboration)

Computer-based program such as CMaps (http://cmap.ihmc.us/) has advanced over the years; it is rather user friendly and is free of charge. The institute that develops CMaps also provides free server space for users to share their maps online. Some other example of commercial software for concept mapping include

- Inspiration: http://www.inspiration.com/
- Semantic Research: http://www.semanticresearch.com/

How is a concept map different from a mindmap? After all, they are both graphics that represent what we think and the relationships among our ideas. Figure 2 shows an example of a mindmap I constructed by listing some key points about pedagogies related to computer-mediated communication as I read a research paper. A mindmap does not require students to explicate the links between the nodes which will not facilitate students in building structural knowledge. Mindmap, is however, useful for other purposes like brainstorming ideas for writing essay. An example of mindmapping software is Freemind ( http://freemind.sourceforge.net/wiki/index.php/Main_Page).

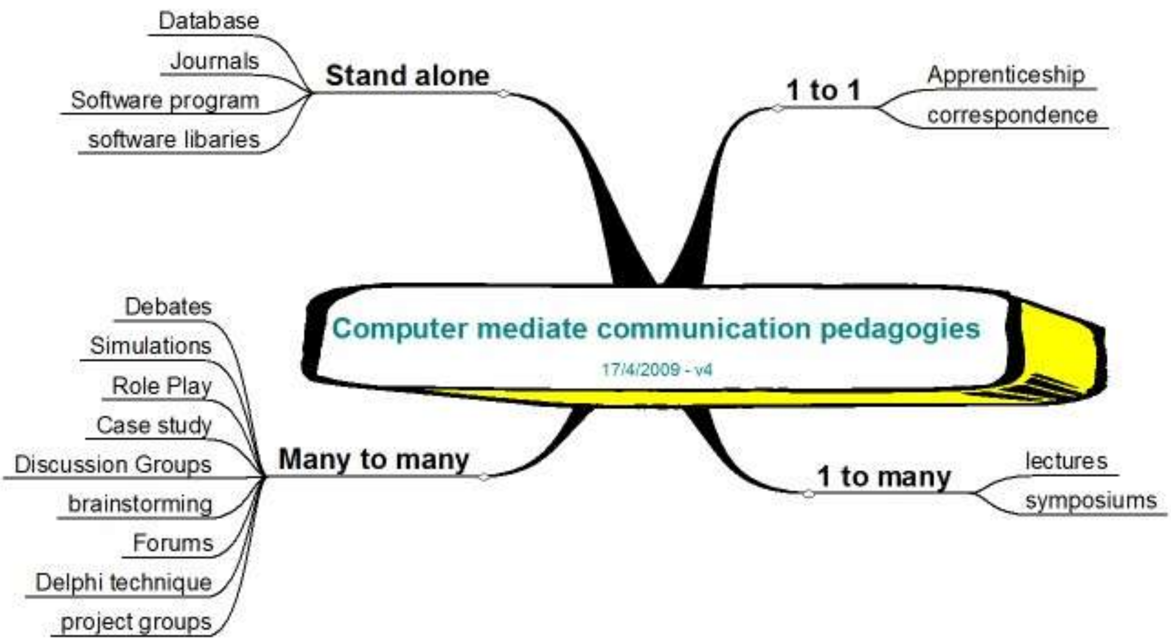


Figure 2. An example of a mindmap

Comparing a concept map (Figure 1) and a mindmap (Figure 2), the differences are quite apparent (Table 1). Not discounting the values of mind mapping, the focus of this chapter is on concept mapping. It is advisable not to use a mind mapping software for the purpose of concept mapping and teachers should be aware of the different pedagogical values of each tool.

Table 1. Comparison between concept map and mindmap

| | Concept maps | Mindmaps |
|---|---|---|
| Researchers | • Ausubel, Novak and Gowin | • Tony Buzan |
| Theoretical basis | • Cognitivism / constructivism | • Hemispheric laterization |
| Functions | • Depicts relationships between concepts (propositional) | • Record ideas and their relationships |
| Characteristics of a map | • Hierarchies of concepts<br>• Only words representing concepts are used<br>• Building from a high-level concept<br>• Every concept is represented once | • Representation diagram arranged radially around a central idea<br>• Phrases can be used<br>• One central key word/idea<br>• Ideas can be represented multiple times |
| Pedagogical values | • Knowledge explication & representation of understanding | • Mnemonic technique<br>• Systematic Brainstorming |

**Implementing concept mapping**

Concept mapping can be conducted in different ways in class. The following instructions are an example on how to organize collaborative concept mapping activities in class. This activity requires students to collaboratively construct a concept map and compare their maps. It exposes the students to multiple ways of seeing relationships among concepts and by comparison, encourages their reflection. It thus encompasses both self-directed and collaborative learning.

Instructions:

a. Divide the class into groups of 4-5.
b. As a group, identify a topic which you are familiar with. Individually, each member is to construct a concept map based on the topic.
c. Textbook or reference materials can be provided as a guide. Give sufficient time for the participants to construct the map.
d. Students within the same group will share and compare their maps. Explain any differences.
e. Discuss with the whole class their experience. Did they have very different concept maps? Is there any disagreement that was not resolved? Would they change the concept map after discussing with their peers?

For children in elementary schools, guidance may be needed in constructing a concept map. You may find that even explaining the term concept can be challenging. The following are suggested steps to construct a concept map:

a. Identify the key concept, which will be the highest level concept. For example, 'States of Matter'.
b. List other concepts related to the key concepts. For example, Solid, Liquid, and Gas. Note that a concept is usually represented by a word or a short phrase, not a sentence.
c. Specify the relationships between the key concept and each of these concepts. Delete irrelevant concepts if necessary.
d. Specify the inter-relationships (cross links) if any.
e. Repeat the process for the next level of concepts. For example, *ice* is an example of *solid*.
f. Do a self checking on the followings:
    - Include concept terms in the boxes (not sentences)
    - Label relationships between concepts
    - A clear hierarchy of concepts
    - Cross linking of concepts

Concept mapping can be used for self-directed learning. By constructing a concept map, it helps the students to reflect on their understanding of concepts and relationships and therefore some learning gaps that they need to focus on. When used in a pervasive way, the students can progressively include new information and relate them to their existing maps. The process also encourages them to review their maps continually. By examining and comparing their concept maps with others', it allows them to assess their learning and progress.

On the other hand, when students construct concept maps in groups, they share ideas and learn from one another on how the information can be succinctly organized. They also need to negotiate and discuss about the meaning of concepts and the relationship among them. As such, constructing concept maps in a group can promote collaborative learning among students. Concept mapping tools like CMap now allows computer-mediated co-construction of concept maps. Alternatively, a completed concept map can be used as an object for discussion among a group of students.

A study conducted by De Simone, Schmid, & McEwen (2001) on university students found that computer-mediated collaborative concept mapping encouraged the students to employ higher order thinking, to apply, investigate and communicate ideas. Their students found concept mapping useful for articulating what they knew and collaborative learning allowed them to elaborate on what they knew as ideas are discussed. The students indicated their preference to discuss concept maps face-to-face rather than through computers as they found asynchronous computer-mediated communication frustrating because of delays in exchange of information, lack of body language and immediate feedback, and that concept maps placed online were static.

## 2. Assessing concept maps

There are different ways of assessing a concept map, which can be broadly classified as quantitative and qualitative methods. The quantitative methods involve assigning scores to a concept map and qualitative methods involve assessing the quality of a concept map with some criteria.

When assessing students' concept maps, the following questions can be used as a guide for a quick qualitative assessment:

- Are the key concepts appropriately labelled?
- Have all the related concepts been identified? What have the students missed out?

- Are irrelevant concepts included?
- Are the hierarchical relationships among the concept appropriate?
- Are the links appropriately labelled? Do they use the same label for the same type of relationship?
- Are there opportunities to crosslinks more concepts? Are the crosslinks appropriately labelled?

One simple scoring method is by counting the number of valid components. For example, the number of concepts, hierarchical levels, and cross-links. In a way, the three scores represent the breadth, depth and connectedness of the concept map (Turns, Atman, & Adams, 2000). There is also a weighted approach, for example, Novak and Gowin (1984) suggests assigning weighted scores to various valid components of a concept map to reflect the relative importance of hierarchy and cross links.

| | | | |
|---|---|---|---|
| | 1 | x | valid Relationship |
| + | 1 | x | valid Example |
| + | 5 | x | valid Hierarchy |
| + | 10 | x | valid Crosslink |
| = Concept map score | | | |

Ruiz-Primo and Shavelson (1997) suggested computing scores based on correctness of propositions as compared to expert's concept map, for example, a concept map constructed by the teacher. First, we need to develop a proposition inventory; a proposition consists of a pair of connected concepts, together with its labelled relationship to form a meaningful statement. They used three criteria: accuracy of proposition, proportion of valid propositions out of all the propositions in the student's map, and proportion of valid propositions compared to the expert's map.

The quantitative methods receive some criticisms as they focus on scoring the students' map. Using an expert's map as a criterion also draws ire from some educators for the implication that there is a "best" concept map. Constructivists oriented educators would tend to use qualitative method of assessment, often giving the students agency to assess their own concept maps. They argue that students are inclined to link concepts in different ways and there is no single correct way of constructing a concept map on a topic. It is not uncommon to find two experts constructing radically different concept maps on the same topic. It is therefore important for teachers not to provide judgemental feedback. Thus, teachers should focus on asking students to explain the rationales behind their construction and articulate relationships among the concepts. First, the process of articulating and explaining presents an opportunity for the students to reflect on their understanding. In addition, by doing that, the teacher could understand how a student relates pairs of concept, thus revealing to a deeper extent the student's understanding of a topic. In addition, when we allow students to explore and express different ways of linking the concepts, we are developing their cognitive flexibility. A concept may be higher in hierarchy (more general) compared to another concept from one perspective but the hierarchical relationship might be reversed from another perspective. For example, under the topic "States of Matter", "water" could be an example of a liquid "state". Under the topic "Water", "water" can exist in different "states". Another example, "communication" could be a sub-skill under "scientific research skills". From the perspective of "communication skills", presenting scientific papers can be one of the communication skills. In fact, some software like Semantic Web allows users to pick any concept to be the central concept and see how other concepts relate to the central concept.

**Conclusion**

In summary, constructing concept maps can be a meaningful learning activity with a range of possible positive outcomes. The processes involve in constructing these graphical representations requires students to be active constructor of knowledge while the computer acts as intellectual partner to facilitate students in efficient organisation of knowledge. This pedagogical arrangement is congruent to the notion of using ICT as cognitive tools and thus serves as a good example of how ICT tool can be employed to facilitate higher order learning among students. Table 2 summarises the roles of students, teachers and ICT in concept mapping activity.

Table 2. Roles of students, teachers and ICT in computer-assisted concept mapping

| Roles of Students | Roles of Teachers | Roles of ICT |
|---|---|---|
| • Identify key concepts<br>• Organise and analyse | • Design concept mapping activities | • Allows students to categorise and chunk |

| | | |
|---|---|---|
| information<br>• Make connections among concepts<br>• Identify relationships among concepts<br>• Identify hierarchies among concepts<br>• Compare and contrast different concept maps | • Frame guiding questions and prompts for evaluating or comparing concept maps<br>• Guide the students in making missing links and gaps | information<br>• Presents information graphically for visualization and construction of mental schemas<br>• Relieve students of lower order activities |

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