

# Concept Mapping, Mind Mapping and Argument Mapping: What are the Differences and Do They Matter?

W. Martin Davies  
The University of Melbourne, Australia  
wmdavies@unimelb.edu.au

**Abstract:** *In recent years, academics and educators have begun to use software mapping tools for a number of education-related purposes. Typically, the tools are used to help impart critical and analytical skills to students, to enable students to see relationships between concepts, and also as a method of assessment. The common feature of all these tools is the use of diagrammatic relationships of various kinds in preference to written or verbal descriptions. Pictures and structured diagrams are thought to be more comprehensible than just words, and a clearer way to illustrate understanding of complex topics. Variants of these tools are available under different names: “concept mapping”, “mind mapping” and “argument mapping”. Sometimes these terms are used synonymously. However, as this paper will demonstrate, there are clear differences in each of these mapping tools. This paper offers an outline of the various types of tool available and their advantages and disadvantages. It argues that the choice of mapping tool largely depends on the purpose or aim for which the tool is used and that the tools may well be converging to offer educators as yet unrealised and potentially complementary functions.*

**Keywords:** *Concept mapping, mind mapping, computer-aided argument mapping, critical thinking, argument, inference-making, knowledge mapping.*

## 1. INTRODUCTION

The era of computer-aided mapping tools is well and truly here. In the past five to ten years, a variety of software packages have been developed that enable the visual display of information, concepts and relations between ideas. These mapping tools take a variety of names including: “concept mapping”, “mind mapping” or “argument mapping”. The potential of these tools for educational purposes is only now starting to be realised.

The idea of displaying complex information visually is, of course, quite old. Flow charts, for example, were developed in 1972 (Nassi & Shneiderman, 1973) pie charts and other visual formats go back much earlier (Tufte, 1983). More recently, visual displays have been used to simplify complex philosophical issues (Horn, 1998). Formal ways of “mapping” complex information—as opposed to the earth’s surface, countries, cities and other destinations—began at least thirty years ago.

More recently, the use of information and computer technology has enabled information mapping to be achieved with far greater ease. A plethora of software tools has been developed to meet various information mapping needs. What do these tools do? What are their similarities and differences? What are their advantages and disadvantages? How precisely do they enhance teaching and learning? This paper considers these questions and reviews three most commonly used mapping devices. The paper claims that the type of information mapping tool to be used is largely a function of the purpose for which it is intended. A clear understanding of the nature and distinctiveness of

these tools may offer educators as yet unrealised and potentially complementary functions to aid student learning.

## 2. THE PURPOSE AND JUSTIFICATION FOR MAPPING TOOLS

The over-riding aim of all mapping tools is similar. If students can represent or manipulate a complex set of relationships in a diagram, they are more likely to understand those relationships, remember them, and be able to analyse their component parts. This, in turn, promotes “deep” and not “surface” approaches to learning (Biggs, 1987; Entwistle, 1981; Marton & Saljo, 1976a, 1976b; Ramsden, 1992). Secondly, maps are also much easier to follow than verbal or written descriptions (Larkin & Simon, 1987; Mayer & Gallini, 1990). Thirdly, maps utilise the often under-utilised parts of the brain associated with visual imagery. This enables more processing power to be used, hence leads to a greater capacity for learning. Finally, the work involved in map-making requires more active engagement on the part of the learner, and this too leads to greater learning (Twardy, 2004).

There is empirical support for the use of mapping tools in enhancing, retaining and improving knowledge. Evidence from the cognitive sciences shows that visual displays do enhance learning (Vekiri, 2002; Winn, 1991). Maps allow the separate encoding of information in memory in visual and well as propositional form, a phenomenon called “conjoint retention” or “dual coding” (Kulhavy, Lee, & Caterino, 1985; Paivio, 1971, 1983; Schwartz, 1988). In the former hypothesis, representations are encoded as separate intact units; in the latter, visual representations are synchronously organised and processed simultaneously and verbal representations are hierarchically organised and serially processed (Vekiri, 2002). In a later section, I will return to the educational justification of mapping tools and why they work in more detail.

While the overriding objectives of mapping tools are similar, there are stark differences in their application. The next section of this paper outlines each of the broad categories and reviews their advantages and disadvantages.

## 3. THE MAPPING TOOLS

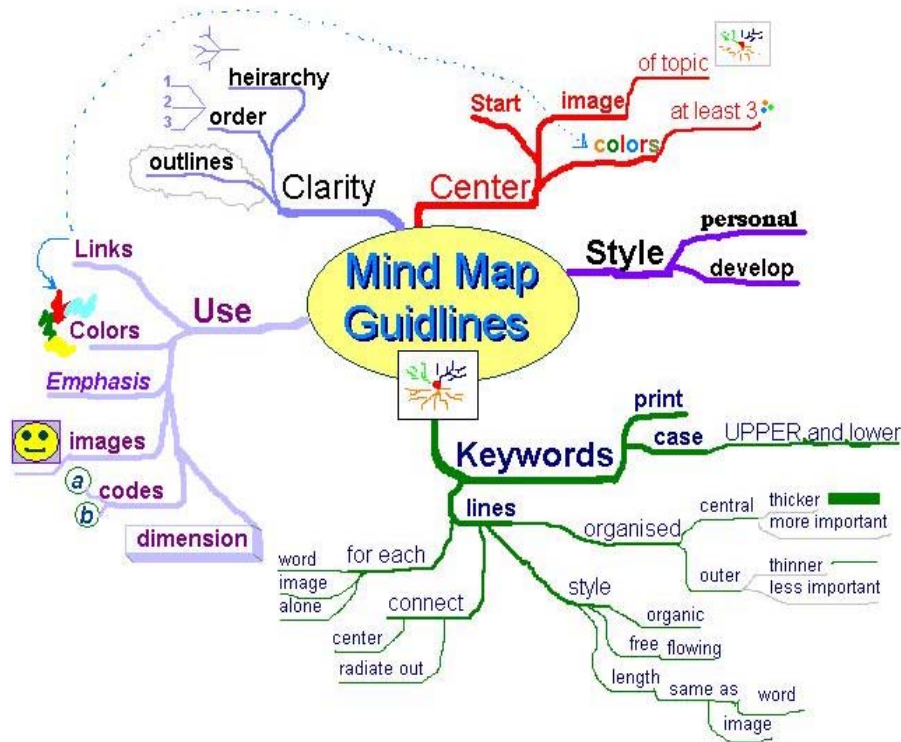
### 3.1 Mind Mapping

Mind mapping (or “idea” mapping) has been defined as ‘visual, *non-linear* representations of ideas and their relationships’ (Biktimirov & Nilson, 2006). Mind maps comprise a network of connected and related concepts. However, in mind mapping, any idea can be connected to any other. Free-form, spontaneous thinking is required when creating a mind map, and the aim of mind mapping is to find creative associations between ideas. Thus, mind maps are principally *association* maps. Formal mind mapping techniques arguably began with Buzan (Buzan, 1974; Buzan & Buzan, 2000). These techniques involved using line thicknesses, colours, pictures and diagrams to aid knowledge recollection. Buzan makes the following recommendations when mind mapping (Buzan & Buzan, 2000).

1. Place an image or topic in the centre using at least 3 colours
2. Use images, symbols, codes, and dimensions throughout your Mind Map.
3. Select key words and print using upper or lower case letters.
4. Each word/image is alone and sitting on its own line.
5. Connect the lines starting from the central image. The central lines are thicker, organic and flowing, becoming thinner as they radiate out from the centre.
6. Make the lines the same length as the word/image.
7. Use colours—your own code—throughout the Mind Map.

8. Develop your own personal style of Mind Mapping.
9. Use emphasis and show associations in your Mind Map.
10. Keep the Mind Map clear by using *radial hierarchy*, numerical order or outlines to embrace your branches.

Concept maps, as we shall see, do not use such design flourishes. An example of a mind map on the topic of *mind mapping guidelines* is given below ("Mind Map," 2007).



**Diagram 1:** A Mind Map

The main use of mind mapping is to create an association of ideas. However, another use is for memory retention—even if the advantages in the case of mind mapping might be marginal (P. Farrand, F. Hussain, & E. Hennessy, 2002). It is easier to remember a diagram than to remember a description. However, there have been suggestions that content is more central to learning than format (Pressley, Van Etten, Yokoi, Freebern, & VanMeter, 1998)

Mind mapping has been used in a variety of disciplines, including Finance (Biktimirov & Nilson, 2006), Economics (Nettleship, 1992), Marketing (Eriksson & Hauer, 2004), Executive Education (Mento, Martinelli, & Jones, 1999), Optometry (McClain, 1987) and Medicine (P. Farrand, F. Hussain, & E. Hennessy, 2002). It is also widely used in professions such as Fine Art and Design, Advertising and Public Relations.<sup>1</sup>

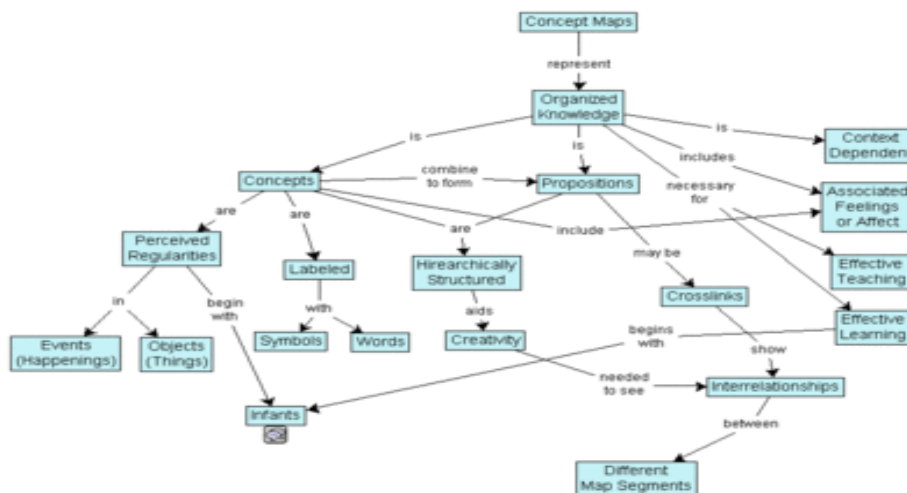
The advantages of mind mapping include its “free-form” and unconstrained structure. There are no limits on the number of ideas and links that can be made, and there is no necessity to retain an ideal structure or format. Mind mapping thus promotes creative thinking, and encourages “brainstorming”. A disadvantage of mind mapping is that the types of links being made may be limited to simple associations. Absence of clear links between ideas is also a constraint. Mind

<sup>1</sup> A list of mind mapping software is available ("List of Mind Mapping Software," 2008) and ("Software for Mind mapping and Information Storage," 2008).

mapping is limited in dealing with more complex relationships. For example, mind mapping might be useful to brainstorm the things that need to be packed prior to a holiday, or the major issues a company needs to focus on in the forthcoming financial year, however, it is hard to see it being as useful for something more complex, e.g., the causes and effects of the Asian currency crisis. More complex topics require more than an associational tool, they require relational analysis. The tool of concept mapping has been developed to address these limitations of mind mapping.

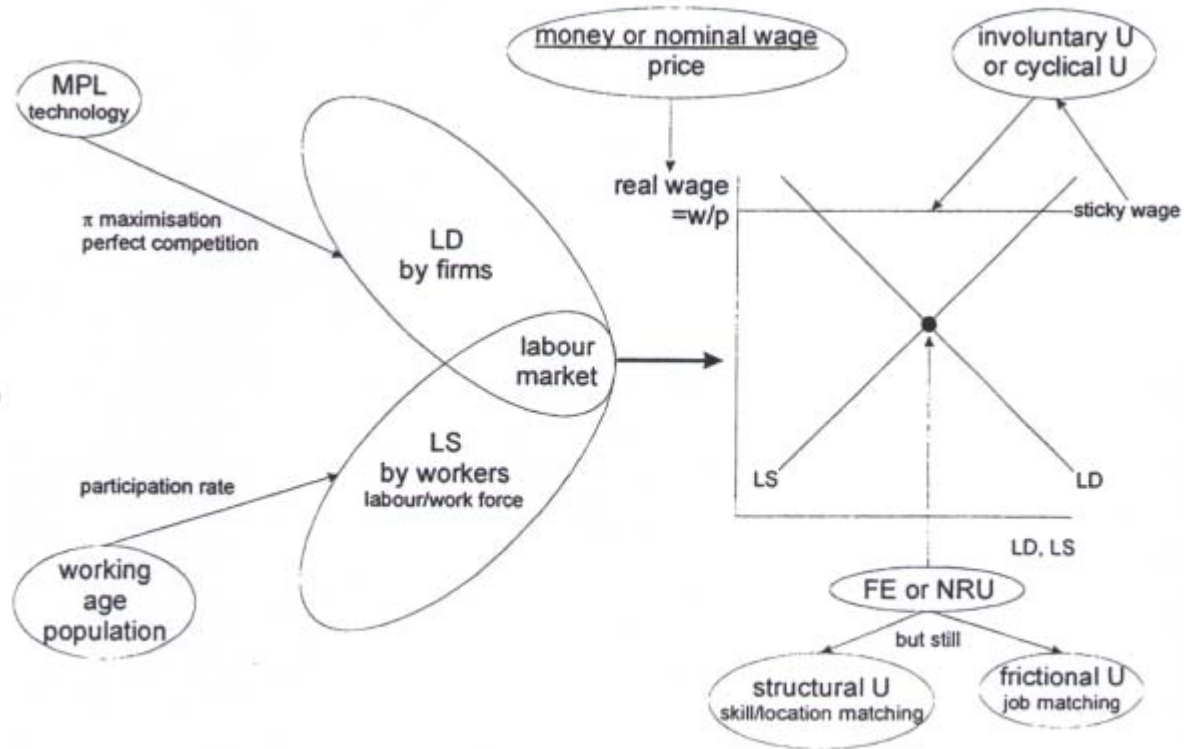
### 3.2 Concept Mapping

Concept mapping is often confused with mind mapping (Ahlberg, 1993, 2004; Slotte & Lonka, 1999). However, unlike mind mapping, concept mapping is more structured, and less pictorial in nature. The aim of concept mapping is not to generate spontaneous associative elements but to outline relationships between ideas. Thus, concept mapping is a *relational device*. A concept map has a hierarchical “tree” structure with super-ordinate and subordinate parts (primary, secondary and tertiary ideas). The map normally begins with a word or concept or phrase which represents a *focus question* that requires an answer (Novak & Canas, 2006). *Cross-links* are used to show relationships between concepts represented. Examples are added to terminal concepts as instances but these are not enclosed in boxes or circles as they are not concepts but represent instances of a concept. An example of a concept map is given below on the focus question: *What is the purpose of concept mapping?* ("Concept Map ", 2007).



**Diagram 2:** Novakian Concept map using the software *CMap* (<http://cmap.ihmc.us/conceptmap.html>)

The difference between mind mapping and concept mapping is also at the level of precision and formality. Mind maps are less formal and structured. Concept maps are formal and tightly structured. Mind maps emphasise diagrams and pictures to aid recall of associations; concept maps use hierarchical structure and relational phrases to aid understanding of relationships. A somewhat different, and less hierarchical, style of concept map on the influence of labour market on the economy is given below:



**Diagram 3:** Non-linear concept map on labour market economics

The development of concept mapping has been attributed to the work of Novak as early as 1972 and his work on children’s developing knowledge of science concepts (Novak & Canas, 2006). This work, in turn, was inspired by the work of learning psychologist Ausubel (Ausubel, 1963). The mapping technique was refined further (Novak, 1981) and then extended to the educational context (Novak & Gowin, 1984). The resulting diagrams are sometimes known as “Novakian maps” in honour of their founder.

Recent additions to the Novakian format include attempts to capture “cyclical” relationships representing complex natural and social systems (Safayeni, Derbentseva, & Canas, 2005). Technology has aided the popularity of concept mapping by means of dedicated software tools such as CMap Tools (Canas, Hill, Carff, Suri, Lott, & Eskridge, 2004) and Compendium.<sup>2</sup> Such is the interest in concept mapping, an annual international conference began in 2005.

Similar to mind mapping, there are several stages in developing a Novakian concept map. However, the stages are very different:

1. Develop a declarative-type focus question (e.g., “What is inflation?”)
2. Devise a “parking lot” of concepts and ideas that are related to the concept of inflation, and the question to be answered. The purpose of this stage is brainstorming. The resulting

<sup>2</sup> Cmap Tools is available free from the Institute of Human and Machine Cognition (<http://www.ihmc.us>). Compendium is available from the Open University (<http://www.labspace.open.ac.uk>). A list of concept mapping software is available here (“List of Concept Mapping Software,” 2008).

- concepts may or may not be used in the final map (Novak & Canas, 2006). The concepts are placed in circles or boxes to designate them as concepts.
3. Put concepts in hierarchical order of importance in a provisional map. An “expert skeleton map” can be started by an instructor in a class to scaffold the learning process, aid student participation and give students confidence. Students can complete the map themselves with the focus question and concepts provided.
  4. Link lines are then provided between the hierarchical concepts from top to bottom. The conventions for this have changed over the decades since the inception of concept mapping. Arrows were originally only used when it is necessary to link a lower concept with a higher concept. However, this convention has recently been revised by concept mappers to allow for arrows for all directions on a concept map (Ahlberg, 2004)
  5. Devise suitable cross-links for key concepts in the map. Verbs and prepositions/prepositional phrases are used most frequently, for example: “requires”, “to work with”, “will lead to”, “involves”, “during”, “of”, “through”, and so on. The aim is to show the relationship between the key concepts and their subordinate or super-ordinate elements.
  6. Add examples to the terminal points of a map representing the concepts. These are not enclosed in boxes or circles to delineate them as instances of a concept.

Since its inception as a formal technique, concept mapping has been widely used in academic disciplines, for example, Accounting (Chei-Chang, 2008; Irvine, Cooper, & Jones, 2005; Leaby & Brazina, 1998; Maas & Leaby, 2005; Simon, 2007; van der Laan & Dean, 2007 forthcoming), Finance (Biktimirov & Nilson, 2003), Engineering (Walker & King, 2002), Statistics (Schau & Mattern, 1997), Reading Comprehension (Mealy & Nist, 1989), Biology (Kinchin, 2000), Nursing (Baugh & Mellott, 1998; King & Shell, 2002; Schuster, 2000; Wilkes, Cooper, Lewin, & Batts, 1999), Medicine (Hoffman, Trott, & Neely, 2002; McGaghie, McCrimmon, Mitchell, Thompson, & Ravitch, 2000; West, Pomeroy, & Park, 2000) and Veterinary Science (Edmonson, 1993)

Research has also been done on concept mapping as an assessment tool (Gouveia & Valadares, 2004; Jonassen, Reeves, Hong, Harvey, & Peters, 1997; van der Laan & Dean, 2007 forthcoming) and as a way to assist academics in course design (Amundsen, Weston, & McAlpine, 2008). Several empirical studies have ascertained the validity of the use of concept maps (Markham, Mintzes, & Jones, 1994; Ruiz-Primo & Shavelson, 1996).

The main advantage of concept mapping is precisely its relational aim. As outlined above, concept maps enable relational links to be made between relevant concepts. In the educational context, it is claimed that meaningful learning best takes place by linking new concepts to existing knowledge (Craik & Lockhart, 1972; Maas & Leaby, 2005). Concept maps enable ‘the elements of [learning] to relate to how cognitive knowledge is developed structurally by the learner’ (Maas & Leaby, 2005, p. 77). In this way, representations are stored longer in memory.

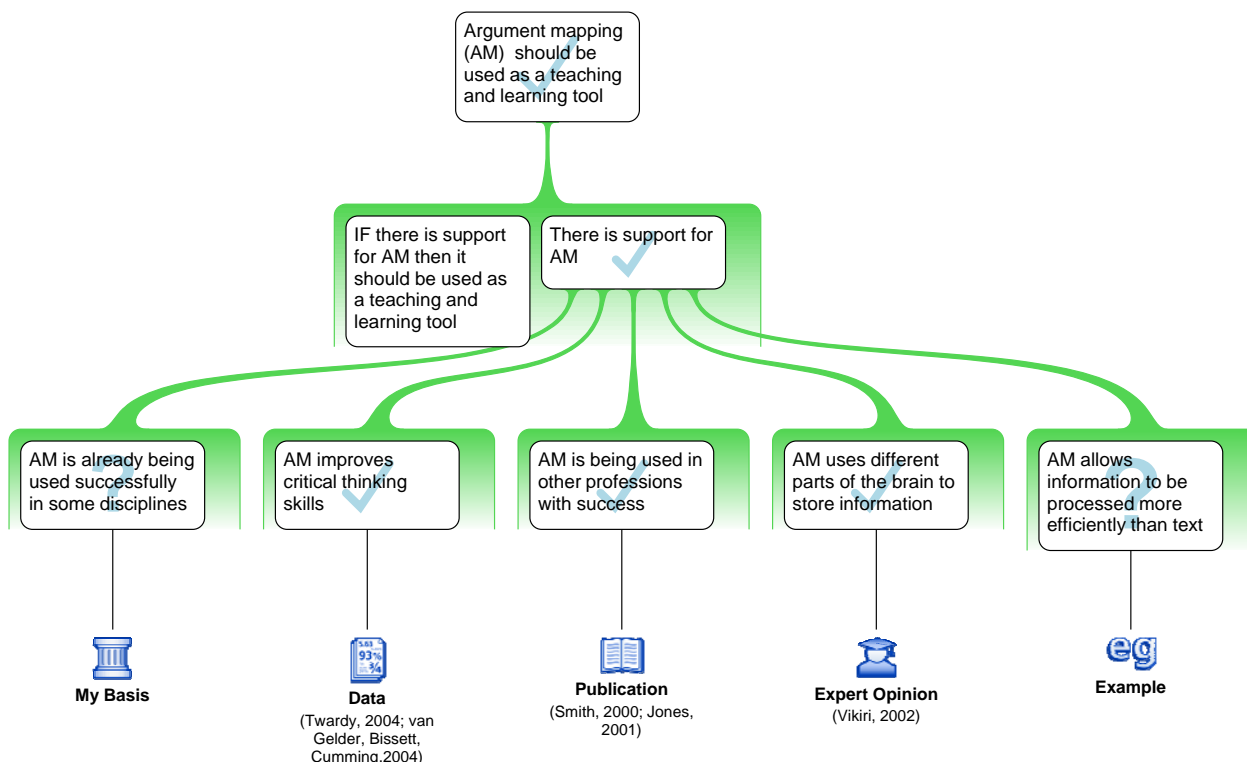
It is quite easy to imagine developing a concept map that canvasses the causes and effects of the Asian currency crisis. In a complex issue such as this, multiple causes can be linked to effects by means of relational arrows. A major disadvantage of concept mapping, however, is that it is limited to relations between concepts. Many issues require more than an identification of relationships between concepts; they require arguments to be made for positions that need to be defended, and objections to those positions to be clear. For example, it is difficult to imagine how a concept map could represent an argument for the claim that: “*The US should have intervened in the Asian currency crisis*”. This kind of relationship is not, strictly speaking, relational. This is, of course, not the fault of the concept mapping format. Concept mapping is a tool that was designed for a different

purpose. This is a limitation of concept mapping and it has led to the development of a new kind of tool; a tool for mapping arguments.

### 3.3 Argument Mapping

A relatively recent innovation, developed since 2000, is computer-aided argument mapping (CAAM). Available in a wide-range of software formats,<sup>3</sup> argument mapping has a different purpose entirely from mind maps and concept maps. Argument mapping is concerned with explicating the *inferential* structure of arguments. Where images and topics are the main feature of associative connections, and concepts are the main feature of relationships, inferences are the key feature of arguments.

“Arguments” are understood in the philosopher’s sense of statements (“premises”) joined together to result in claims (“conclusions”). An example of an argument map defending the claim that *argument maps should be used as a teaching and learning tool* is given below. At the first (top) level of the argument there is the *contention*. This is followed in this example by **co-premises**, one of which is supported by a number of **claims**. These terminal claims are, in turn, supported by **basis boxes** which provide defence for the claims.



**Diagram 3:** Argument map using the software *Rationale* (<http://www.austhink.com>)

The map above is incomplete. **Objections** and **rebuttals to objections** can be added at any point in the map (in different colours for easier visual identification). The “basis” boxes at the terminal points of the argument also require evidence in place of the brackets provided. Some of the evidence has been provided (“data”, “expert opinion”) and some have been left blank to show the software default. Also evident in the example is the **evaluation** option for both claims in the

<sup>3</sup> Harrell provides a comprehensive list of argument mapping software (Harrell, 2008).



argument and for the argument overall. Separate claims can be assessed as either “true” (the tick); uncertain/unassessed (the question mark), or false (the cross). This is used to determine whether the main contention is supported by the reasons given.

Unlike mind mapping and concept mapping, argument mapping is interested in the *inferential* basis for a claim being defended and not the causal or other associative relationships between the main claim and other claims. The software allows for an automatically-generated description of the argument in text-form. An example of this is given below. In some template argument formats—provided with the software—the mapping program also constructs a prose version of the argument complete with a limited display of linking words. However, this function is presently underdeveloped, and is a caricature of what would be needed in university-style assignment.

### **Argument mapping (AM) should be used as a teaching and learning tool -- *Accepted***

#### **1. Supported by:**

a. IF there is support for AM then it should be used as a teaching and learning tool

b. There is support for AM -- *Accepted*

#### **1. Supported by:**

a. AM is already being used successfully in some disciplines -- *No stand*

#### **1. My Basis:**

#### **2. Supported by:**

a. AM improves critical thinking skills -- *Accepted*

**1. Data:** (Twardy, 2004; van Gelder, Bissett, Cumming, 2004)

#### **3. Supported by:**

a. AM is being used in other professions with success -- *Accepted*

**1. Publication:** (Smith, 2000; Jones, 2001)

#### **4. Supported by:**

a. AM uses different parts of the brain to store information -- *Accepted*

**1. Expert Opinion:** (Vikiri, 2002)

#### **5. Supported by:**

a. AM allows information to be processed more efficiently than text -- *No stand*

#### **1. Example:**

**Table 1:** Automatically generated text of an argument map.

As noted, CAAM is still fairly new. Nonetheless, there have been several papers published demonstrating its impact on student learning, especially improvements in critical thinking (Twardy, 2004; van Gelder, 2001; van Gelder, Bissett, & Cumming, 2004). Twardy demonstrated an improvement in critical thinking skills as measured by a standard instrument in pre- and post-test by a 0.72 gain of standard deviations. Van Gelder, Bissett and Cumming demonstrated an even higher gain of 0.8 standard deviations in their study.

The main advantage argument mapping may have over other forms of mapping tools is that it focuses on a certain sub-class of relationships (i.e., logical inferences). It also puts limitations around the items being mapped. There is a clear sense in which arguments—and not relationships and associations—have “boundaries”. Eventually, all reasons have to be grounded. These grounds are presented as terminal “basis” boxes for assumptions. These are then evaluated for plausibility as shown. With mind mapping and concept mapping, connections can potentially go on “forever”.

A weakness of argument mapping is also its strength; argument mapping does not capture looser, more tangential relationships, e.g., cause and effect. This makes it a tool with a very precise



purpose. However, as we shall see in the final section, there is no reason why the advantages of argument maps cannot be supplemented with the advantages of other available tools, and with additional refinements that do not exist at present.

Another disadvantage of argument mapping that it can assume too much. In the educational context, argument mapping exercises can assume that students have a sufficiently clear understanding of a topic or issue and the precise nature of the task at hand. This understanding may often be absent. Students themselves may need to *define* the scope of the issue to be addressed and the exact parameters of the task. For example, faced with an essay topic as:

- *The changing roles of men and women have been good for society. Discuss.*

students may initially create a series of arguments which *implicitly* focus on changes in their society, the society in which they are presently living, or perhaps developed Western countries generally. They may never actually articulate what the changes might be, or in what respects (or for whom) they might be considered “good” (nor might they define what “good” means). They may not consider whether or not to confine themselves to particular changes that have taken place over a particular time period in a particular culture. Assignment topics are often deliberately ambiguous to allow students to demonstrate their abilities in deconstructing the meaning of the topic itself.

*Working out what needs to do in an essay and why* is a preparatory, and a critically important step, to being able to map an argument successfully. Students will have to do a considerable amount of initial reading and thinking, and they will have to struggle with key concepts before coming to an understanding of the exact task they need to complete. It is only after this process that the student can map an argument. Argument mapping software offers no help with these preparatory steps. However this is precisely where a further development in mapping technologies might be able to help (see **Section 4**).

The following table summarises the differences between the three forms of mapping discussed in this paper.

	<b>Purpose</b>	<b>Structure</b>	<b>Level of Abstraction</b>	<b>Nodes</b>	<b>Linking devices</b>	<b>Linking words</b>
<b>Mind Maps</b>	Associations between ideas, topics or things	Non-linear, organic, radial	High generality	Pictures, words, diagrams	Lines, line thicknesses, colours, shading	Associative words (“Use” and “colours” and “links”)
<b>Concept Maps</b>	Relations between concepts	Hierarchical, tree-like	Medium generality	Boxes	Arrows	Relational phrases (“in relation to”, “is composed of”, etc)
<b>Argument Maps</b>	Inferences between claims (conclusions) and support (premises)	Hierarchical, tree-like	Low generality	Boxes and lines	Lines, colours, shading	Inferential linking words (“because”, “not”, “however”)

**Diagram 4:** Summary of the differences between knowledge-mapping software

Notice here that argument mapping shares the hierarchical form with concept mapping, and—in some variants at least—argument mapping shares the design principles of colours, shading, and line thicknesses with mind mapping. Note too the increasing level of sophistication in the tools. Where mind maps have a high degree of generality in their application, concept maps are more specific (focussing on relational factors) and argument mapping is the least general (more specific) in application of all. This indicates, in one sense, some degree of perhaps unintended evolutionary

sophistication in the development of these tools. In the final section of this paper, some suggestions will be made on the new directions that this evolution might take.

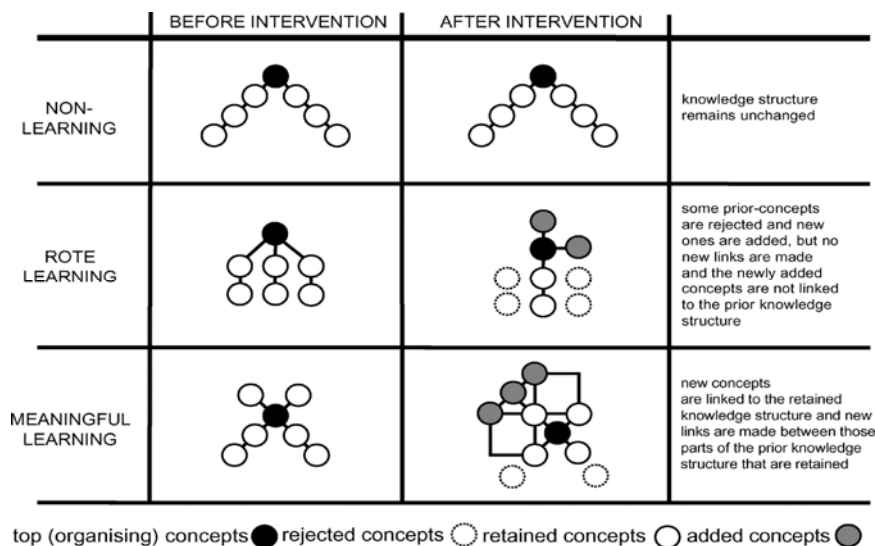
#### 4. WHY MAPPING TOOLS WORK

The most important reason for the widespread use of mapping tools is that they are claimed to benefit student learning. The educational justification for mapping tools was outlined briefly in **Section 2**. However, specific details which might explain why mapping tools work were not discussed.

##### 1. Knowledge mapping allows meaningful learning to occur.

Hay, et., al., usefully distinguish between “non-learning”, “rote learning” and “meaningful learning” (Hay, Kinchin, & Lygo-Baker, 2008). Using the pedagogical views of Kolb and Jarvis (Jarvis, 1992; Kolb & Fry, 1975) along with an application of concept mapping tools, they track changes in knowledge that results from the presentation of learning material to university students (Hay, Wells, & Kinchin, Forthcoming). They find that measurable improvements in meaningful learning occur using concept mapping under test conditions with control groups.

They find that *non-learning* occurs when no detectable change in knowledge occurs before and after the presentation of new material. *Rote learning* occurs when new information is added (or rejected) in a students’ knowledge store, but there is no new integration made between the new or substituted information. Students accept and reject information but do not think about it or relate it to other knowledge they may possess. *Meaningful learning*, by contrast, occurs when new perspectives are integrated into the knowledge structure and prior concepts of the student. The diagram below explains these differences. Hay, et. al., find that concept mapping can ‘significantly add to the quality of university teaching’ as it promotes meaningful learning (Hay et al., 2008, p. 308).



(Hay et al., 2008, p. 299)

**Diagram 5:** Different kinds of learning in an intervention student using concept mapping under test conditions.

2. *Mapping allows the presentation of new material in a way which can build on the existing knowledge base that a student already possesses.*

Having a rich source of prior knowledge that is well-structured and retrievable allows students to “scaffold” new learning. This enables meaningful learning to occur. Structured diagrams incorporating prose—such as the mapping devices mentioned in the paper—are able to represent new information better than traditional discursive prose on its own (van Gelder, 2007). This, in turn, allows efficient learning and integration with information stored in memory. There are two reasons why this occurs: map-making improves the *usability* of information and also *complements* what the brain can do imperfectly. Both improve student learning. Let’s take each of these points in turn.

*Usability:* Maps make new information more usable. Usable information can be more easily processed. This is why we draw maps in preference to providing long and detailed verbal directions. Usability has, of course, been a driving force for improvements in other areas. A fountain pen, and a ball-point pen, both aid in the skill of writing; so does a word processor. The word processor improves on earlier writing tools by being more usable. A beginner’s windsurfing board provides a more usable way of improving windsurfing skills (by being larger and more stable) than an “expert” board. A “training” bicycle—with three wheels—is similarly important. The traditional manner of presenting and understanding information is, of course, in prose (either spoken in a lecture or written in textbooks). Mapping devices, it is claimed, are now more usable than prose, and this can result in improvements in teaching and learning.

More usable information is better in improving skill development than less usable information. As noted by Hay, et. al., the basic methodology of university teaching has remained unchanged for centuries, despite dramatic transformations in other areas of the tertiary sector in the past few decades. Learning simply by reading textbooks, or listening to a presentation (incorporating linear-structured Powerpoint slides) is far more likely to result in non-learning or rote learning (Hay et al., 2008). However, if students are asked to study, draw or manipulate a map of what they have learned, this may yield improved learning because it is more usable (the *activity* of making a map is also important, as discussed below). This is because maps aid in linking new information with what they already know.

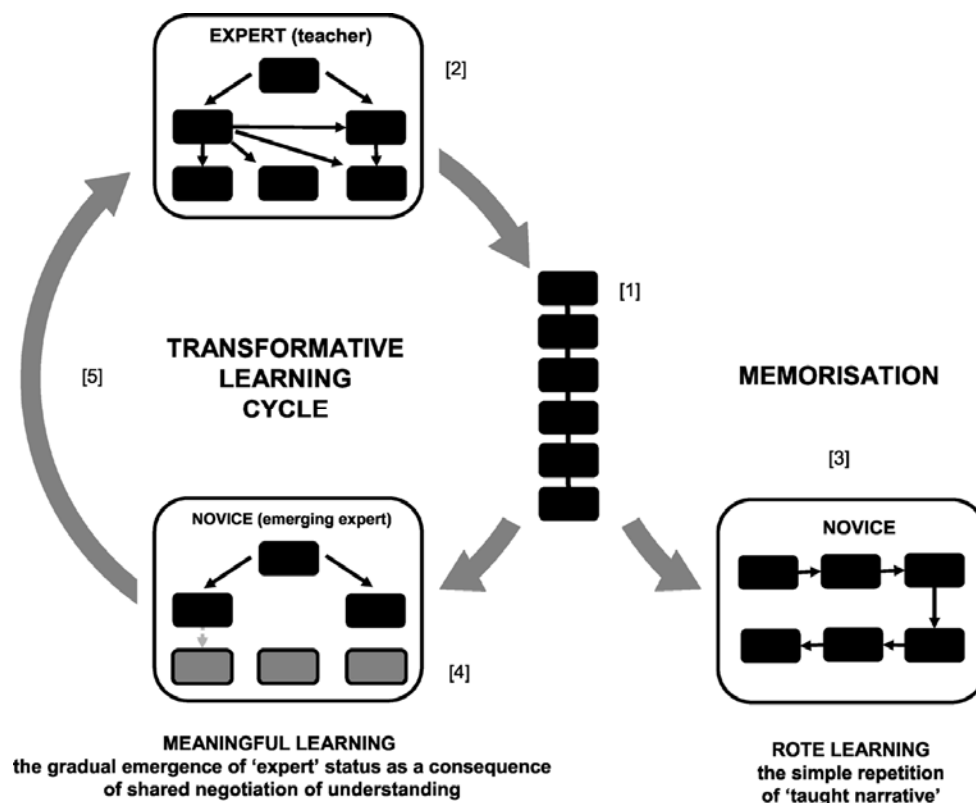
*Complementation:* Mapping also augments the brain’s ability to understand, retrieve and process information. It does this by complementing what the human brain can already do (albeit imperfectly). In the cognitive science literature, this is known as complementation. Our memory stores are seriously limited—some suggest as limited as holding only four pieces of information at a time (Cowan, 2000). Similarly, our ability to “chunk” complex pieces of relevant information and sift them from irrelevant information is limited. Mapping allows this to be done efficiently because diagrams are more easily stored in memory than other kinds of representational formats (Larkin & Simon, 1987). In Section 2, a reason was given for this. Maps allow the separate encoding of information in memory in visual and well as propositional form, a phenomenon called “conjoint retention” or “dual coding”.

3. *Mapping allows students to build new and meaningful knowledge links by means of active engagement.*

The educational literature suggests that *meaningful engagement* is a critical factor in promoting deeper learning. When students are meaningfully engaged, they form longer-lasting knowledge representations in memory ( Craik & Lockhart, 1972). The educational focus recently has moved from what the student *is*, and how to teach them (i.e., student-centred learning), to what the *teacher* does and how to improve it (i.e., teacher-centred learning), to a focus now on what the *student does* (i.e., how they engage in taught material) (Biggs, 1999). Increasingly, good teaching and learning is focussed on how best to use engagement activities, such as problem-based learning, to teach the

information required in a way that will engage students in learning and which will narrow the gap between more academically self-engaged students and those less inclined.

By contrast, Hay, et. al., note that conventional teaching formats in the university environment involve simple “narrative chains” delivered in a “linear” manner typically on Powerpoint slides. This material is designed to be accessible to students, but it often conceals deep and complex networks of tacit scholarly information. The way information that is taught to students was originally understood and constructed by academics themselves is rarely explained. Constrained by the time-scheduling required in any given academic year, well-intentioned teachers try to circumvent the process of learning for their students. This paradoxically usually results in less meaningful learning, not more. It results in ‘linearity rather than connectivity out of which genuine understanding arises’ (Hay et al., 2008, p. 306). It also fosters a lack of engagement critical to the development of meaningful understanding. To meet assessment demands, students begin to rely on memorisation techniques and cramming, not meaningful activities to ensure engagement and learning, and ultimately—via a transformative learning cycle—expertise. This failure to allow opportunities for engagement leads naturally to non-learning or simple rote learning (see diagram below).



**Diagram 6:** The narrative sequence involves an expert [2] giving a linear presentation [1]. Students may either adopt meaningful learning [4] or memorisation [3] (from Hay et al., 2008). Meaningful learning is possible only if engagement with the material is allowed enabling the construction of knowledge in meaningful patterns drawing upon prior knowledge. This process can continue indefinitely until expertise is attained.

By contrast, Hay et. al., recommends that teachers take the time to construct knowledge maps and explain their understanding of any given topic. They are less specific about the various forms that this mapping might take. They are only concerned in their paper with the promulgation of concept maps as a teaching and learning tool. However, as we have seen in this paper, knowledge or information mapping is available in a number of discrete forms. All of the forms of mapping have

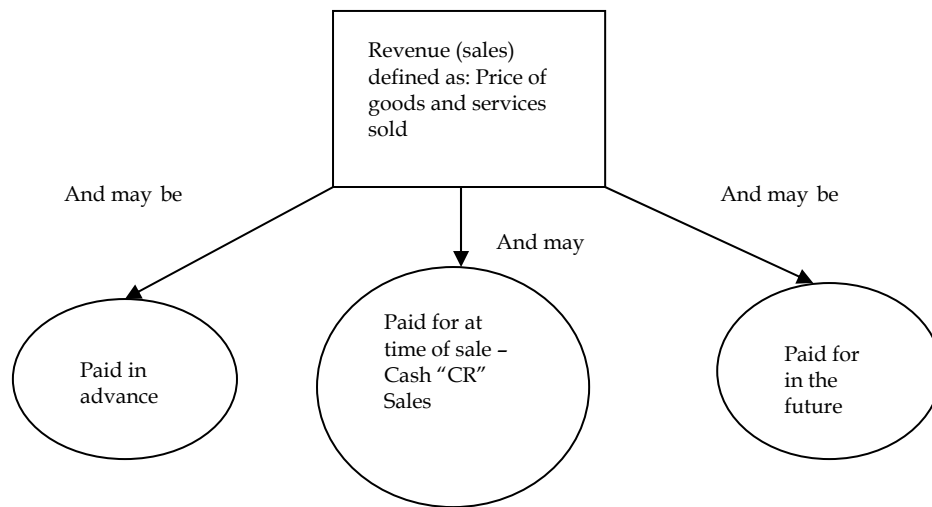
their place in the context of teaching and learning. Maps of associations, causes and effects (relations) and maps of reasoning should all be presented in lectures in preference to linear narrative chains. This would enable teachers to show the often tacit connections that exist between related academic areas. This would have a secondary benefit of allowing students to check their own understanding. Requiring students to devise maps of their learning for assessment, and encouraging them to compare and contrast those maps with fellow students is an additional activity that can promote and encourage meaningful learning.

## 5. A CONVERGENCE OF MAPPING TOOLS?

This paper has suggested that the various mapping tools have complementary functions. Mind mapping is an associational mapping tool; concept mapping provides a way of mapping relationships; argument mapping focuses on maps of inferential structures and logical connections. However, the technology is already available to enable a convergence of these mapping tools. All the mapping tools function to improve student learning in the ways just mentioned. All of them require the pedagogical advantages of map-making to supplement and drive student learning. What might be needed is a way of combining these advantages in an educational tool that provides more flexibility and power than the separate tools that exist at present.

What would a convergent form of mapping tool look like? Work has already been done on linking concept mapping software to libraries of resources—such as Global Services Library Network (<https://glsn.com/>)—so that various “nodes” in a map might allow downloading of supporting evidence that was used in making the map (van der Laan & Dean, 2007 forthcoming). This has a number of advantages. Using this functionality, students can demonstrate their understanding of an assessment topic in several independent ways: firstly they can demonstrate, at minimum, that they know, i.e., can list key concepts (a form of surface learning); second, that they understand the relationships between key concepts (a deeper form of learning requiring analytical skills); and thirdly, they can provide links to relevant external material (or indeed, material they have written themselves) supporting nodes in the map. This third form of learning requires considerable research and analytical skills. Each of these forms of learning can, of course, be independently assessed. They can provide an indication to teaching staff of the level of competence of students in a given subject area. Work has also been done on providing argument maps as assessment tasks for students in preference to written assignments in subjects such as Economics (Davies, 2008, forthcoming). Much work has been done on all the knowledge-mapping tools in isolation as outlined previously. What has not been done is work on how the different tools can be integrated.

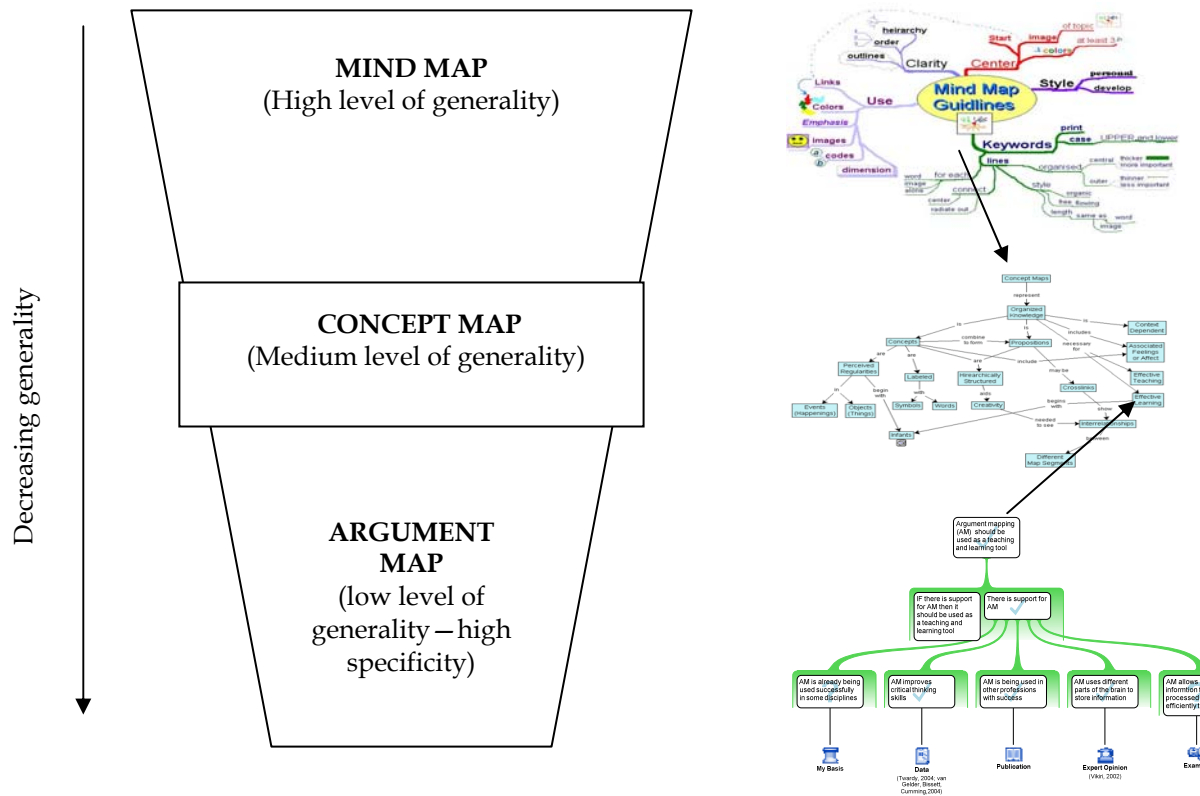
An excerpt from a concept map on an inventory for financial accounting showing the relationship between revenues and cash flows is provided below. While incomplete, we can see that as a concept map it meets the requirement of providing relationships between key concepts. However, in the map, there is little evidence that a student understands the *argument* for why revenue, for example, may be “paid in advance”. Indeed, the student may be able to draw a concept map of this kind *without* understanding the reasoning behind any of the financial practices themselves. The required information may indeed be “rote learned”. We cannot tell from the map provided whether surface or deep learning has been achieved. This knowledge may need to be assessed by means of other assessment modalities such as essays or exams, or tutorial participation.



**Diagram 7:** A partial concept map on the relationship between revenues and cash flows

Alternatively, students may be required to link argument maps at strategic points in their concept map to nodes in the map that require argumentative justification. This would demonstrate a greater level of understanding. The argument map may lie behind the nodes in the concept map and be accessible by hyperlinks. Lecturers could assess both maps simultaneously or separately.

This way of checking understanding might also proceed in another direction altogether. At a greater level of generality, mind maps may also be used providing evidence of a different kind of learning. For example, at the top most level of the concept map above, “Revenue” is stated formally as a definition. However, it is not clear whether the student has considered other associated features of the definition. The student may have been merely rote learned or copied this definition from a lecturer’s Powerpoint slide. Providing a link to a mind map showing all the associated definitional features of “revenue” would ensure that the student understood the concept well and was familiar with its various facets and associated concepts, and could demonstrate this familiarity in an assessment task. A schematic plan of how the comparative functions of each of the tools might be integrated is presented below.



**Diagram 8:** Proposed convergence of knowledge mapping technologies into a single integrated platform. The central concept map may be devised initially to demonstrate familiarity with the relationship between key concepts in a topic. At given points, or “nodes”, certain concepts may be further elaborated in terms of associative structures (mind maps), and inferential or logical arguments (argument maps). NB: Maps provided are illustrative only.

A convergence of mapping tools might proceed in other ways. As noted earlier (**Section 3.3**), to assist students in writing assignments, mapping tools also need to help with the preparatory stages involved. Earlier, we looked before at a sample essay topic:

- *The changing roles of men and women have been good for a society. Discuss.*

The point was made that mapping tools provide little assistance with tasks such as these, which require a clear understanding of task requirements. A fully-converged mapping tool should be able to assist students in developing this understanding. If this understanding can be sequenced as a series of manageable stages, this should be able to be integrated into the computational routines of a software package and form part of a converged mapping platform.

Understanding how to approach an assignment or essay topic typically involves a number of steps (although the steps may not be formally identified as such). These stages have been discussed elsewhere in detail (Davies, 2008):

- *The deconstruction phase.* This involves being able to select key noun phrases in a given essay topic provided by a lecturer and being able to define them (e.g., “roles”, “good”, “society”). It also involves knowing the meaning of the *direction words* provided by the instructor (e.g., “Discuss”, “Analyse”, “Trace”, “Compare”, etc).
- *The representation phase.* This involves being able map out the main parts of the body of the proposed essay, i.e., what topics will be discussed in each part. This is quite different from a mind map, concept map or an argument map. It is equivalent to “brainstorming” the



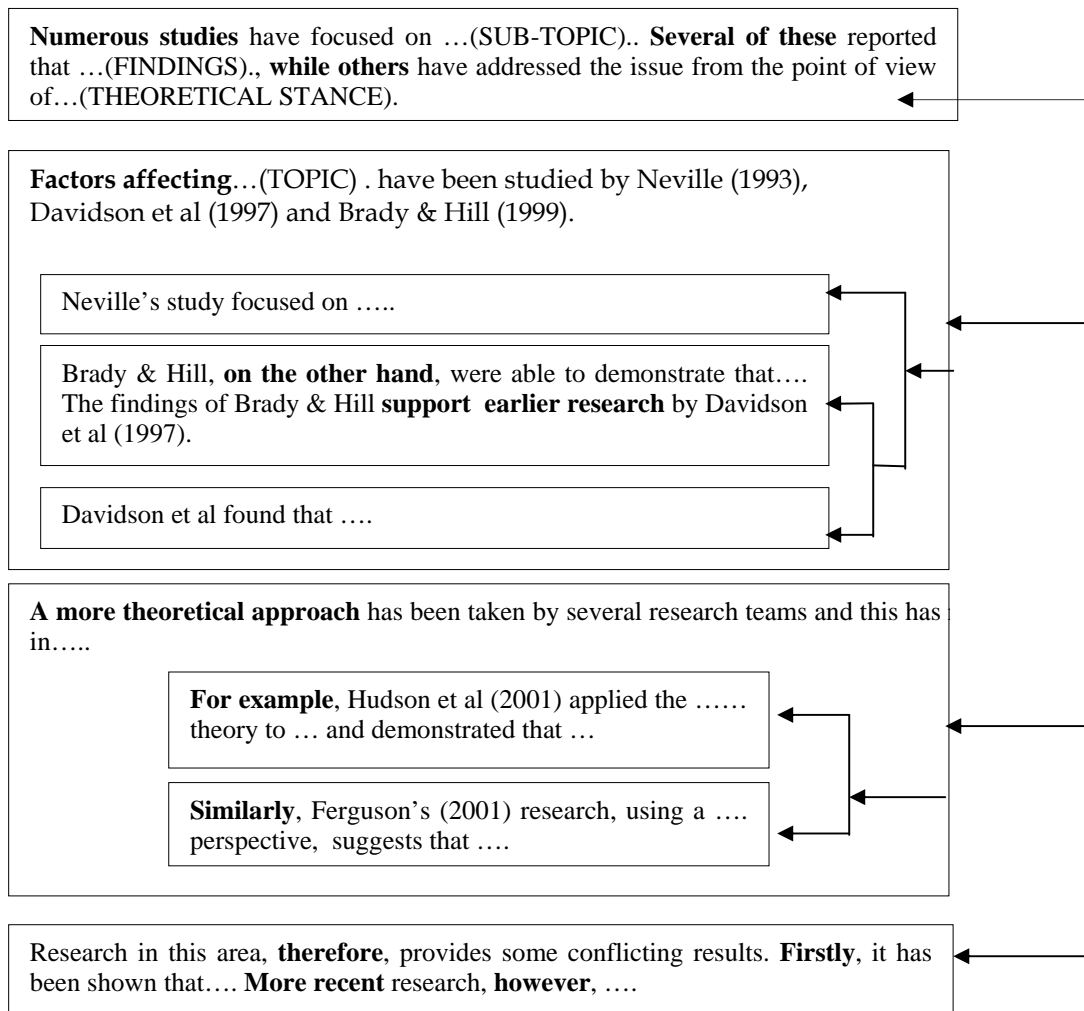
form or structure that the essay will take. An essay plan, as opposed to a knowledge map requires an overview of which issues and arguments should be presented, and the order of their presentation (i.e., from weak to strong or vice-versa). Typically, the essay structure that will be formed will mirror the parts of the assignment topic given by a lecturer, but thought will need to be given to arrangement of ideas within each section as well.

- *The issues phase.* This involves further clarity on the main issues that are relevant to each of the key terms in an essay topic (e.g., what does it mean for changing gender roles to be “good” for society?” In what sense?) This also requires some idea of the evidential support that is needed in the context of the essay. This part of the preparation would benefit from concept mapping and mind mapping techniques.
- *The research phase.* This involves knowing where and how to find academic support for the points made in an essay (e.g., the construction of search statements to be used in databases).
- *The argument phase.* This involves being able construct a clear argument with a point of view drawn from wide reading. Argument mapping may be used for this stage.
- *The writing phase.* Written assessment at university level takes the form of various genres: essays, empirical reports, annotated bibliographies, literature reviews, summaries and critiques, case studies, and so on. Each genre involves the ability to write—in clear and flowing prose—the point or issue being defended. But the style of writing and the structural requirements are very different. There are, of course, commonalities among the genres. At postgraduate-level, for example, an introduction typically involves an “funnel” structure that moves from the general topic, to the specific issue under consideration, to the gap in the research (using embedded citations as support), to the thesis statement and then an outline of the essay to follow. “Methodology” and “Discussion” sections in report writing have unique and predictable writing genres as well. In general, good academic writing of all genres from the “general” to the “specific”, and uses an arrangement of part-whole relationships between major ideas and support for those ideas (e.g., support from academic literature).

An integrated mapping software should assist students in some or all of these areas. This might be possible in further developments of mapping tools. Suggestions for how this might happen are provided below:

- **Assignment topics** could be entered by students into an integrated mapping software. Key parameters of a topic, such as important concepts, discipline-specific definitions of terms, etc. could also be added by lecturers via a separate interface accessed by means of a common course or subject code.
- **Key noun phrases** might be highlighted in the assignment topic that automatically trigger mind maps of associated key terms and synonyms. **Direction words** might be explained with an in-built glossary of academic terms which could be tailored to discipline areas.
- **Templates** for developing “block” and “chain” style essay structures might be made available. (A “block” essay presents all the points “for”/ “advantages” or “against”/ “disadvantages” for a topic first, then all the points for the opposing position; a “chain” essay presents one point, then a point against, then a second point, second point against, and so on).
- **Issues** for students to consider might be automatically generated based upon clusters of key terms entered and ranked in order of relevance.
- **Search statements** of key terms, e.g., (Man OR Male) AND (Woman OR Female) AND (Gender role OR Sex role) AND (Good OR Beneficial OR Advantageous), etc., might be automatically constructed from submitted material to be used in databases. These databases might also be linked to the software.
- **Writing templates** for different sections of assignments (essays, empirical-style reports, case-style reports, etc.) might be made available which are suited to the needs of students

and which follows the accepted academic structure commonly used in universities. Attempts have been made to articulate **design taxonomies** for graduate student writing that use predictable structures of nested part-whole relationships between ideas and support for ideas using commonly-used linking phrases (Rochecouste, 2005). These taxonomies could be incorporated into a converged mapping tool. An example of this follows:



**Diagram 9:** A template for a writing taxonomy (Rochecouste, 2005).

Beyond defining key topic and task words and constructing writing templates, students might also be assisted by an integrated mapping tool in turning essay statements into questions. Questions are always easier for students to begin addressing than statements. For example, the example provided previously can be more easily approached if the topic is transformed into: *Have the changing roles of men and women been good for society?* A student can then be directed to a template with the following terms listed: “YES” (the changing roles have been good), “YES but” (the changing roles have generally been good with minor exceptions to this view), “yes BUT” (the changing roles have generally been good, however there are major exceptions to this view), and “NO” (the changing roles have not been good) ( for an elaboration of this technique, see Davies, 2008). This might naturally translate into an argument map proforma which could then be modified and made more detailed.

Ideas for improvements are easy to state. Implementation is, of course, much harder. However, at present, none of the mapping tools discussed in this paper help students with the remedial requirements that are often needed. Perhaps an integrated knowledge mapping tool could do more

in future to help students recognise the writing *process* and the conventions of the essay genre and the logic behind these conventions.

## **6. CONCLUSION**

This paper has argued that there are sound reasons to consider knowledge-mapping in its various forms as a supplement to other teaching and learning activities in the university context. The paper has outlined the differences between the main forms of map-making: mind maps, concept maps and argument maps, and has provided an educational justification for their use. The paper claims that the choice of a given mapping tool largely depends of the purpose or aim to which the tool is used. However, the paper also suggests that these tools may well be converging to offer educators as yet unrealised and potentially complementary functions. While the idea of using knowledge maps is decades old, it is only in the early twenty-first century that this kind of map-making has come of age. This development provides new teaching and learning tools and techniques for both students and teachers that will enrich and provide new directions in education in the future.

## Reference List

- Ahlberg, M. (1993). *Concept Maps, Vee Diagrams, and Rhetorical Argumentation (RA) Analysis: Three Educational Theory-Based Tools to Facilitate Meaningful Learning*. Paper presented at the Third International Seminar on Misconceptions in Science and Mathematics, Cornell University.
- Ahlberg, M. (2004). *Varieties of Concept Mapping*. Paper presented at the First International Conference on Concept Mapping, Pamplona, Spain.
- Amundsen, C., Weston, C., & McAlpine, L. (2008). Concept Mapping to Support University Academics' Analysis of Course Content. *Studies in Higher Education, 33*(6), 633-652.
- Ausubel, D. P. (1963). *The Psychology of Meaningful Verbal Learning*. New York: Grune and Stratton.
- Baugh, N. G., & Mellott, K. G. (1998). Clinical Concept Mapping as Preparation for Student Nurses' Clinical Experiences. *Journal of Nursing Education, 37*(6), 253-256.
- Biggs, J. (1987). *Student Approaches to Learning and Studying* Hawthorn, Vic: Australian Council for Educational Research (ACER).
- Biggs, J. (1999). What the Student Does: Teaching for Enhanced Learning. *Higher Education Research and Development, 18*(1), 57-75.
- Biktimirov, E. N., & Nilson, L. B. (2003). Mapping Your Course: Designing a Graphic Syllabus for Introductory Finance. *Journal of Education for Business, 78*(July//August), 308-312.
- Biktimirov, E. N., & Nilson, L. B. (2006). Show Them the Money: Using Mind Mapping in the Introductory Finance Course. *Journal of Financial Education, 32*(Fall), 72-86.
- Buzan, T. (1974). *Using Both Sides of Your Brain*. New York: E. P. Dutton.
- Buzan, T., & Buzan, B. (2000). *The Mind Map Book*. London: BBC Books.
- Canas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., & Eskridge, T. (2004). CMap Tools: A Knowledge Modelling and Sharing Environment. In A. J. Canas, J. D. Novak & F. M. Gonzalez (Eds.), *Concept Maps Theory, Methodology, Technology: First International Conference on Concept Mapping* (Vol. 1, pp. 125-133). Pamplona, Spain: Universidad Publica de Navarra.
- Chei-Chang, C. (2008). The effect of Concept Mapping on Students' Learning Achievements and Interests. *Innovations in Education and Teaching International, 45*(4), 375-387.
- Concept Map (2007). Retrieved June 21st, from [http://en.wikipedia.org/w/index.php?title=Concept\\_map&oldid=139167845](http://en.wikipedia.org/w/index.php?title=Concept_map&oldid=139167845)
- Cowan, N. (2000). The Magical Number Four in Short-Term Memory: A Reconsideration of Mental Storage Capacity. *Behavioral and Brain Sciences, 24*, 87-185.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of Processing: A Framework for Memory Research. *Journal of Verbal Learning and Verbal Behaviour, 11*, 671-684.
- Davies, W. M. (2008). "Not Quite Right": Helping Students to Make Better Arguments *Teaching in Higher Education, 13*(3), 327-340.
- Davies, W. M. (2008, forthcoming). Computer-Aided Argument Mapping (CAAM): A Rationale Approach. *Higher Education*.
- Edmonson, K. M. (1993, April 12-16). *Concept Mapping for the Development of Medical Curricula*. Paper presented at the Annual Meeting of the American Educational Research Association, Atlanta, Georgia.
- Entwistle, N. (1981). *Styles of Learning and Teaching; an integrated outline of educational psychology for students, teachers and lecturers* Chichester: John Wiley.
- Eriksson, L. T., & Hauer, A. M. (2004). Mind Map Marketing: A Creative Approach in Developing Marketing Skills. *Journal of Marketing Education, 26*(2), 174-187.
- Farrand, P., Hussain, F., & Hennessy, E. (2002). The Efficacy of "Mind Map" Study Technique. *Medical Education, 36*(May), 426-431.

- Farrand, P., Hussain, F., & Hennessy, E. (2002). The efficacy of the 'mind map' study technique. *Medical Education*, 36(5), 426-431.
- Gouveia, V., & Valadares, J. (2004). *Concept Maps and the Didactic Role of Assessment*. Paper presented at the First International Conference on Concept Mapping.
- Harrell, M. (2008). iLogos. Retrieved 7/11/08, from [http://www.phil.cmu.edu/projects/argument\\_mapping/](http://www.phil.cmu.edu/projects/argument_mapping/)
- Hay, D., Kinchin, I., & Lygo-Baker, S. (2008). Making Learning Visible: The Role of Concept Mapping in Higher Education. *Studies in Higher Education*, 33(3), 295-311.
- Hay, D., Wells, H., & Kinchin, I. (Forthcoming). Using Concept Maps to Measure Learning Quality. *Higher Education*.
- Hoffman, E., Trott, J., & Neely, K. P. (2002). Concept Mapping: A Tool to Bridge the Disciplinary Divide. *American Journal of Obstetrics and Gynecology*, 187(September), S41-S43.
- Horn, R. E. (1998). *Mapping Great Debates: Can Computers Think?* Bainbridge Island, WA: MacroVU Press.
- Irvine, H., Cooper, K., & Jones, G. (2005, 24th-25th November). *Concept Mapping to Enhance Student Learning in a Financial Accounting Subject*. Paper presented at the Accounting Educators' Forum, Sydney, NSW.
- Jarvis, P. (1992). *Paradoxes of Learning* San Francisco: Jossey-Bass.
- Jonassen, D. H., Reeves, T. C., Hong, N., Harvey, D., & Peters, K. (1997). Concept Mapping as Cognitive Learning and Assessment Tools. *Journal of Interactive Learning Research*, 8(3-4), 289-308.
- Kinchin, I. M. (2000). Concept Mapping in Biology. *Journal of Biological Education*, 34(2), 61-68.
- King, M., & Shell, R. (2002). Teaching and Evaluating Critical Thinking with Concept Maps. *Nurse Educator*, 27(5), 214-216.
- Kolb, D., & Fry, R. (1975). Towards an Applied Theory of Experiential Learning In C. L. Cooper (Ed.), *Theories of Group Processes*. London: Wiley and Sons.
- Kulhavy, R. W., Lee, J. B., & Caterino, L. C. (1985). Conjoint Retention of Maps and Related Discourse. *Contemporary Educational Psychology*, 10, 683-699.
- Larkin, J. H., & Simon, H. A. (1987). Why a Diagram Is (Sometimes) Worth Ten Thousand Words. *Cognitive Science*, 11(1), 65-100.
- Leaby, B. A., & Brazina, P. (1998). Concept Mapping: Potential Uses in Accounting Education. *Journal of Accounting Education*, 16(1), 123-138.
- List of Concept Mapping Software. (2008). Retrieved 30th November, from [http://en.wikipedia.org/w/index.php?title=List\\_of\\_concept\\_mapping\\_software&oldid=139133393](http://en.wikipedia.org/w/index.php?title=List_of_concept_mapping_software&oldid=139133393)
- List of Mind Mapping Software. (2008). Retrieved 29 October, from [http://en.wikipedia.org/w/index.php?title=List\\_of\\_mind\\_mapping\\_software&oldid=139428677](http://en.wikipedia.org/w/index.php?title=List_of_mind_mapping_software&oldid=139428677)
- Maas, J., & Leaby, B. A. (2005). Concept Mapping: Exploring its Value as a Meaningful Learning Tool in Accounting Education. *Global Perspectives of Accounting Education*, 2, 75-98.
- Markham, K. M., Mintzes, J. J., & Jones, M. G. (1994). The Concept Map as a Research and Evaluation Tool: Further Evidence of Validity. *Journal of Research in Science Teaching*, 31(1), 91-101.
- Marton, F., & Saljo, R. (1976a). On Qualitative Differences in Learning, I-Outcome and Process. *British Journal of Educational Psychology*, 46, 4-11.
- Marton, F., & Saljo, R. (1976b). On Qualitative Differences in Learning, II-Outcome as a Function of the Learner's Conception of the Task. *British Journal of Educational Psychology*, 46, 115-127.
- Mayer, R. E., & Gallini, J. K. (1990). When is an Illustration Worth Ten Thousand Words? *Journal of Educational Psychology*, 82(December), 715-726.

- McClain, A. (1987). Improving Lectures: Challenging Both Sides of the Brain. *Journal of Optometric Education*, 13(Summer), 18-12.
- McGaghie, W. C., McCrimmon, D. R., Mitchell, G., Thompson, J. A., & Ravitch, M. (2000). Quantitative Concept Mapping in Pulmonary Physiology: Comparison of Student and Faculty Knowledge Structures. *Advances in Physiology Education*, 23(1), 72-81.
- Mealy, D. L., & Nist, S. L. (1989). Postsecondary Teacher Directed Comprehension Strategies. *Journal of Reading*, 32(6), 484-493.
- Mento, A., Martinelli, P., & Jones, R. M. (1999). Mind Mapping in Executive Education: Applications and Outcomes. *Journal of Management Development*, 18(4), 390-407.
- Mind Map. (2007). Retrieved June 21st, from [http://en.wikipedia.org/w/index.php?title=Mind\\_map&oldid=137011347](http://en.wikipedia.org/w/index.php?title=Mind_map&oldid=137011347)
- Nassi, I., & Shneiderman, B. (1973). Flowchart Techniques for Structured Programming. *SIGPLAN Notices*, 8(8).
- Nettleship, J. (1992). Active Learning in Economics: Mind Maps and Wall Charts. *Economics*, 28(Summer), 69-71.
- Novak, J. D. (1981). Applying Learning Psychology and Philosophy to Biology Teaching. *The American Biology Teacher*, 43(1), 12/20.
- Novak, J. D., & Canas, A. J. (2006). The Theory Underlying Concept Maps and How to Construct Them. *Technical Report IHMC Cmap Tools 2006-01* Retrieved 21/6/07, from <http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf>
- Novak, J. D., & Gowin, D. (1984). *Learning How to Learn*. New York: Cornell University Press.
- Paivio, A. (1971). *Imagery and Verbal Processes*. New York: Holt, Reinhart and Winston.
- Paivio, A. (1983). The Empirical Case for Dual Coding. In J. Yuille (Ed.), *Imagery, Memory and Cognition*. Hillsdale, N. J.: Lawrence Erlbaum.
- Pressley, M., Van Etten, S., Yokoi, L., Freebern, G., & VanMeter, P. (1998). The metacognition of college studentship: A grounded theory approach. In J. D. D. J. Hacker, & A. C. Graesser (Ed.), *Metacognition in Theory and Practice* (pp. 347-367). Mahwah, N. J. : Erlbaum
- Ramsden, P. (1992). *Learning to Teach in Higher Education*. London: Routledge.
- Rochecouste, J. (2005). *Constructing Taxonomies for Student Writing*. Paper presented at the European Association for the Teaching of Academic Writing. from <http://eataw2005.hau.gr/pages/about.htm>
- Ruiz-Primo, M. A., & Shavelson, R. (1996). Problems and Issues in the Use of Concept Maps in Science Assessment. *Journal of Research in Science Teaching*, 33(6), 569-600.
- Safayeni, F., Derbentseva, N., & Canas, A. J. (2005). A theoretical note on concepts and the need for Cyclic Concept Maps. *Journal of Research in Science Teaching*, 42(7), 741-766.
- Schau, C., & Mattern, N. (1997). Use of Map Techniques in Teaching Applied Statistics Courses. *The American Statistician*, 51(May), 171-175.
- Schuster, P. M. (2000). Concept Mapping: Reducing Clinical Care Plan Paperwork and Increasing Learning. *Nurse Educator*, 25(2), 76-81.
- Schwartz, N. H. (1988). Cognitive processing characteristics of maps: Implications for instruction. *Educational and Psychological Research*, 8, 93-101.
- Simon, J. (2007). Concept Mapping in a Financial Accounting Theory Course. *Accounting Education*, 16(3), 272-308.
- Slotte, V., & Lonka, K. (1999). Spontaneous Concept Maps Aiding the Understanding of Scientific Concepts. *International Journal of Science Education*, 21(5), 515-531.
- Software for Mind mapping and Information Storage. (2008). Retrieved 30th October, from <http://www.mind-mapping.org/>
- Tufte, E. R. (1983). *The Visual Display of Quantitative Information* (2nd ed.). Cheshire, CT: Graphics Press.
- Twardy, C. (2004). Argument Maps Improve Critical Thinking. *Teaching Philosophy*, 27(2), 95-116.

- van der Laan, S., & Dean, G. (2007 forthcoming). Assessment to Encourage Meaningful Learning in Groups: Concept Mapping. *Journal of Accounting Education*.
- van Gelder, T. (2001). *How to Improve Critical Thinking Using Educational Technology*. Paper presented at the Meeting at the Crossroads: Proceedings of the 18th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education, University of Melbourne.
- van Gelder, T. (2007). The Rationale for Rationale™. *Law, Probability and Risk*, 10.1093/lpr/mgm032.
- van Gelder, T., Bissett, M., & Cumming, G. (2004). Enhancing Expertise in Informal Reasoning. *Canadian Journal of Experimental Psychology*, 58, 142-152.
- Vekiri, I. (2002). What is the Value of Graphical Displays in Learning? *Educational Psychology Review*, 14(3), 261-312.
- Walker, J., & King, P. (2002). *Concept Mapping as a Form of Student Assessment and Instruction*. Paper presented at the 2002 American Society for Engineering Education Annual Conference and Exposition.
- West, D. C., Pomeroy, J. R., & Park, J. K. (2000). Critical Thinking in Graduate Medical Education: A Role for Concept Mapping Assessment. *The Journal of the American Medical Association*, 284(9), 1105-1110.
- Wilkes, L., Cooper, K., Lewin, J., & Batts, J. (1999). Concept Mapping: Promoting Science Learning in BN Learners in Australia. *The Journal of Continuing Education in Nursing*, 30(1), 37-44.
- Winn, W. (1991). Learning from Maps and Diagrams. *Educational Psychology Review*, 3(3), 211-247.