High Educ
DOI 10.1007/s10734-010-9387-6

Concept mapping, mind mapping and argument mapping: what are the differences and do they matter?

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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

Introduction

In the past 5–10 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.

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Published online: 27 November 2010

The idea of displaying complex information visually is, of course, quite old. Flow charts, for example, were developed in 1972 (Nassi and 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 30 years ago, and arguably even earlier.

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 and enhance student learning.

The purpose and justification for mapping tools

The over-riding aim of all mapping techniques 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 and Saljo 1976a, b; Ramsden 1992). Secondly, for most people, maps are also much easier to follow than verbal or written descriptions, although reservations need to be made in terms of the kinds of "maps" under consideration, for not all maps are equal (Larkin and Simon 1987; Mayer and Gallini 1990). Thirdly, 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 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 et al. 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 simple terms, processing information verbally as well as pictorially helps learning by virtue of using more than one modality. 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 differences in their application. **Mind mapping** allows students to imagine and explore associations between concepts; **concept mapping** allows students to understand the relationships between concepts and hence understand those concepts themselves and the domain to which they belong; **argument mapping** allows students to display inferential connections between propositions and contentions, and to evaluate them in terms of validity of argument structure and the soundness of argument premises. The next section of this paper outlines each tool and briefly reviews their advantages and disadvantages.

The mapping tools

An attempt has recently been made to outline the similarities and differences between different mapping techniques (Eppler 2006). However, no mention was made of the most recent computer-aided mapping tool, argument mapping. This paper updates this earlier paper and outlines three key types of mapping: mind mapping, concept mapping and argument mapping with an emphasis on the software tools used to make the maps.

Mind mapping

Mind mapping (or "idea" mapping) has been defined as 'visual, *non-linear* representations of ideas and their relationships' (Biktimirov and 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 and Buzan 2000). These techniques involved using line thicknesses, colours, pictures and diagrams to aid knowledge recollection. Buzan makes the following recommendations when mind mapping (http://www.mindmapexample.com/samples.php, Buzan and 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 pictorial and graphical design flourishes. An example of a mind map on the topic on things to consider for a presentation is given in Fig. 1.

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 (Farrand et al. 2002b). It is generally easier to remember a diagram than to remember a description. Others have suggested, however, that content is more central to learning than the format in which that content is presented (Pressley et al. 1998).

Mind mapping has been used in a variety of disciplines, including Finance (Biktimirov and Nilson 2006), Economics (Nettleship 1992), Marketing (Eriksson and Hauer 2004), Executive Education (Mento et al. 1999), Optometry (McClain 1987) and Medicine (Farrand et al. 2002a). It is also widely used in professions such as Fine Art and Design, Advertising and Public Relations.[1]

[1] A list of mind mapping software is available ("List of Mind Mapping Software," 2008) and ("Software for Mind mapping and Information Storage," 2008).

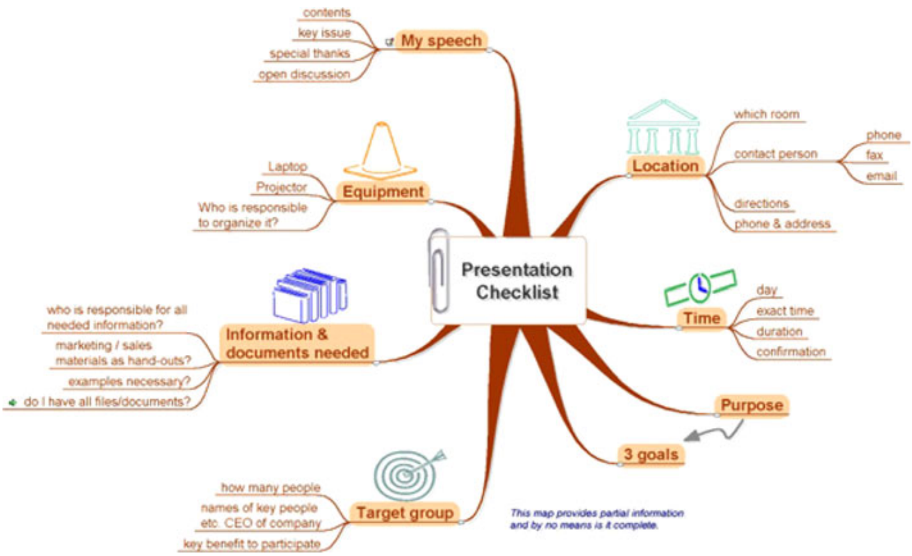

Fig. 1 A Mind Map ("Mind Maps Made With Mind Mapping Tool")

The advantages of mind mapping include its "free-form" and unconstrained structure. There are no limits on the 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 are limited to simple associations. Absence of clear links between ideas is a constraint. Mind maps have been said to be idiosyncratic in terms of their design, often hard for others to read; representing only hierarchical relationships (in radial form); inconsistent in terms of level of detail; and often too complex and missing the "big picture" (Eppler 2006; Zeilik, nd). Mind mapping is also limited in dealing with more complex relationships. For example, mind mapping might be useful to brainstorm the things that are critical for students to recall in an exam (or a presentation, as in the example provided). However, it is hard to see it being useful for a purpose that requires an understanding of how one concept is essential to understanding another. 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.

Concept mapping

Concept mapping is often confused with mind mapping (Ahlberg 1993, 2004; Slotte and 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 and Cañas 2006). *Cross-links* using connective terms (usually prepositional phrases) such as "leads to", "results from", "is part of", etc., are used to show relationships between concepts represented. Examples (not shown here) 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. Two quite different concept maps are given below on the focus question: *What is the purpose of concept mapping?* Fig. 2.

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 generally more tightly structured. Mind maps emphasise diagrams and pictures to aid recall of associations; concept maps generally use hierarchical structure and relational phrases to aid understanding of relationships. However, concept maps can take a variety of forms ranging from hierarchical, to non-hierarchical forms, and even data-driven maps where the input determines the shape of the map. One recent form of the latter involves a statistical process known as agglomerative cluster analysis when analysis is made of terms that appear in a text across a number of respondents which are then

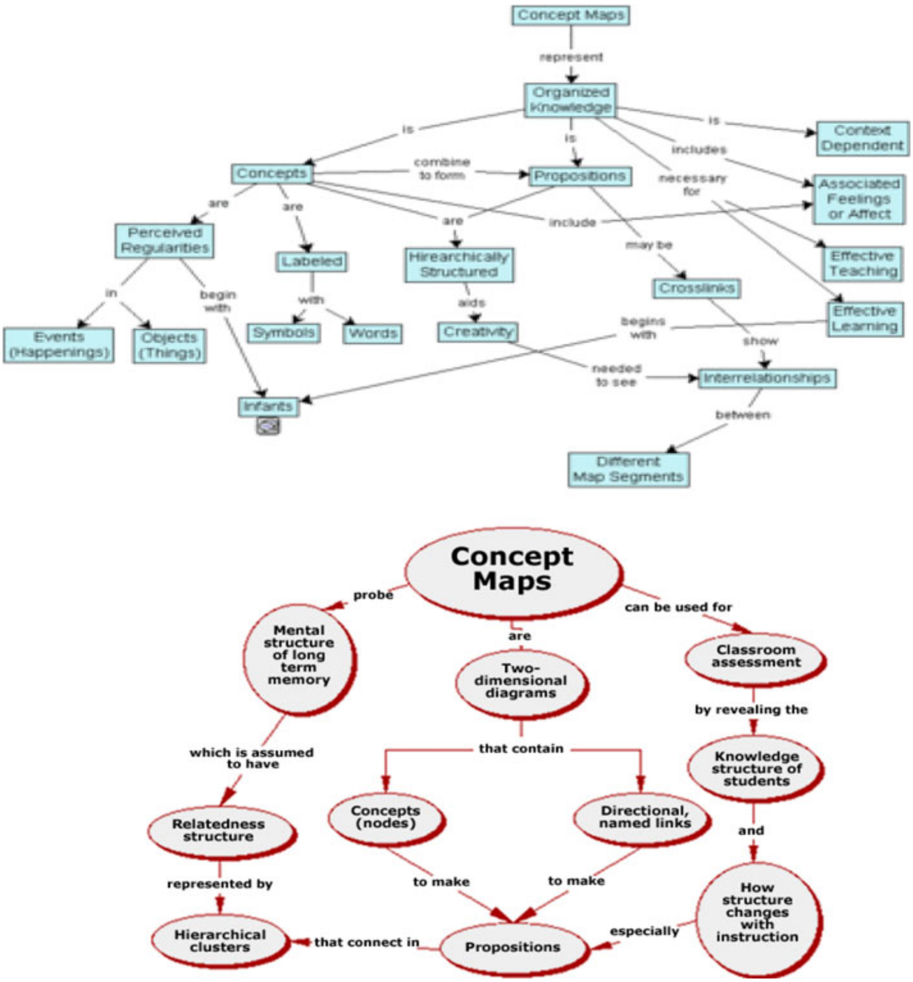

Fig. 2 Two different Novakian-style concept maps using the software *CMap* (http://cmap.ihmc.us/conceptmap.html) (from "Concept Map," 2010; Zeilik nd)

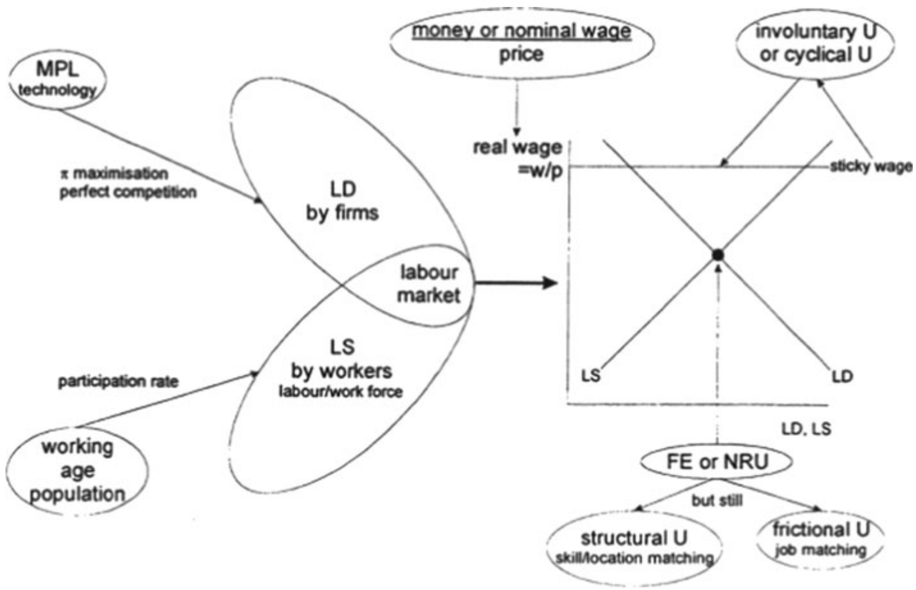

Fig. 3 Non-linear concept map on labour market economics

"clustered" to form a diagrammatic representation (Jackson and Trochim 2002; Trochim 1989).

A non-hierarchical, style of concept map on the influence of labour market on the economy is given in Fig. 3. While non-hierarchical, this map has more similarities to a concept map than a mind map as it endeavours to establish appropriate relationships between the economic concepts rather than simple associations. However, it has similarities to a mind map as well in terms of its looser, non-hierarchical, unstructured form.

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 and Cañas 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 and Gowin 1984). The resulting diagrams are sometimes known as "Novakian maps" in honour of their founder. As noted, alternative approaches are also available (Jackson and Trochim 2002).

Recent additions to the Novakian format include attempts to capture "cyclical" relationships representing complex natural and social systems (Safayeni et al. 2005). Technology has aided the popularity of concept mapping by means of dedicated software tools such as CMap Tools (Cañas et al. 2004) and Compendium.[2] Such is the interest in concept mapping, an annual international conference began in 2005.

There are several stages in developing a Novakian concept map. However, the stages are very different from developing a mind map:

[2] 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).

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 concepts may or may not be used in the final map (Novak and Cañas 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 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 (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 et al. 2005; Leauby and Brazina 1998; Maas and Leauby 2005; Simon 2007; van der Laan and Dean 2006), Finance (Biktimirov and Nilson 2003), Engineering (Walker and King 2002), Statistics (Schau and Mattern 1997), Reading Comprehension (Mealy and Nist 1989), Biology (Kinchin 2000), Nursing (Baugh and Mellott 1998; King and Shell 2002; Schuster 2000; Wilkes et al. 1999), Medicine (Hoffman et al. 2002; McGaghie et al. 2000; West et al. 2000), Nursing (Beitz 1998) and Veterinary Science (Edmonson 1993).

Research has also been done on concept mapping as an assessment tool (Gouveia and Valadares 2004; Jonassen et al. 1997; van der Laan and Dean 2006) and as a way to assist academics in course design (Amundsen at al. 2008) and in managing qualitative data (Daley 2004). Several empirical studies have ascertained the validity of the use of concept maps (Markham et al. 1994; Ruiz-Primo and Shavelson 1996).

The main advantage of concept mapping is precisely its relational aim. 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 and Lockhart 1972; Maas and Leauby 2005). Concept maps enable 'the elements of [learning] to relate to how cognitive knowledge is developed structurally by the learner' (Maas and Leauby 2005, p. 77).

The main disadvantages of concept mapping are that they require some expertise to learn; they can be idiosyncratic in terms of design; and because of their complexity they may not always assist memorability, with learners faced with designing concepts maps often feeling overwhelmed and de-motivated (Beitz 1998; Eppler 2006; Kinchin 2001). Others have noted that the rigid rules used for identifying concepts and their multiple relationships does not make the process simple or easily to learn, and the linear nature of concept maps mean that they are not adequate to capture more complex relationships between concepts. In particular, they do not enable easy separation of concepts of critical importance from those of secondary importance (Daley 2004).

It is also impossible to distinguish identification of concepts from identification of arguments using a concept map. For example, it is easy to imagine developing a concept map that canvasses the causes and effects of the global financial 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. For example, it is difficult to imagine how a concept map could represent an argument for the claim that: *"The US should have intervened earlier in the global 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.

Argument mapping

A relatively recent innovation, developed since 2000, is computer-aided argument mapping (CAAM). Available in a wide-range of software formats,[3] 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 in mind maps, and concepts are the main relationships in concept maps, inferences between whole propositions are the key feature of argument maps.

"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 proposition that *The Reserve Bank will increase interest rates* is given in Fig. 4. At the first (top) level of the argument there is the *contention.* This is followed in this example by a supporting **claim** (under the link word "because") and an **objection** (under the link word "but"). These are, in turn, supported by more claims of support or objection (which become rebuttals when they are objections to objections): In the software, claims, objections and rebuttals are coloured differently. Finally, **basis boxes** which provide defence for the terminal claims, are provided at the end of the argument tree.

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 evidence has been provided ("statistics", "expert opinion", "quotation").

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 also allows for an automatically-generated description of the argument in text-form. 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. However, this impressive facility is indicative of where software tools are headed.

[3] Harrell provides a comprehensive list of argument mapping software (Harrell 2008).

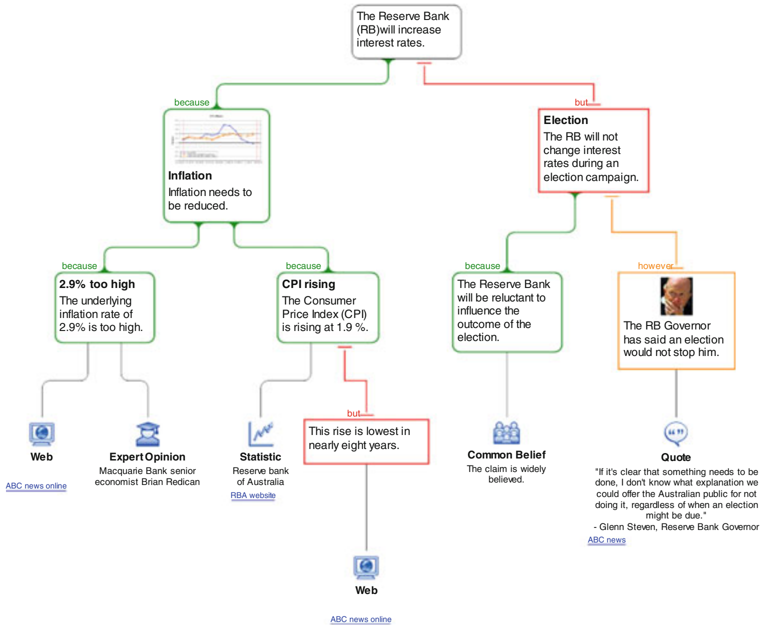

Fig. 4 Argument map using the software *Rationale* (http://www.austhink.com)

As noted, CAAM is still fairly new. Nonetheless, there have been several studies demonstrating its impact on student learning, especially improvements in critical thinking (Twardy 2004; van Gelder 2001; van Gelder et al. 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. A very recent study demonstrated greatest gains in students with the poorest argument analysis skills in two separate studies over the course of one semester (Harrell 2011)

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 between propositions). 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 is 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. However, 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 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 “A convergence of mapping tools?”).

Table 1 summarises the differences between the three forms of mapping discussed in this paper.

Notice 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, suggestions will be made on the new directions that this evolution might take.

An important area of difference between the mapping techniques is in the register and formality of language used, i.e., the differences in linguistic “granularity” (see column to far right of table). Whereas in mind mapping the language is fairly “loose”, and can capture a variety of associative relationships, in argument mapping the linguistic relationships are limited to whole propositions or statements linked by logical connectors such as “because” or “however”. Argument mapping requires precise rules of construction. This forces *explicit* connections between propositions (from premises to conclusions or contentions). Argument mapping thereby demonstrates a specific utility and considerable fitness to purpose. Mind mapping does not have these constraints. Concept mapping occupies a space in-between the loose and tightly constrained language in argument maps, and the looser, tangential, associative language of mind maps. Concept maps typically involve the use of prepositional phrases such as “in relation to”, “is a result of”, and so on; but, as we have seen, sometimes these rules are not adhered to. Compare, for example, the very different examples of concept maps given earlier. The non-linear economics concept map has elements of a more constrained mind map as well as having similarities to a concept map.

This highlights an important difference in terms of flexibility. Mind maps can sometimes take on similarities to concept maps, and can occupy a more structured place further along the continuum between the three mapping types. It has a wider utility. This is not

Table 1 Summary of the differences between knowledge-mapping software

	Purpose	Structure	Level of abstraction	Nodes	Linking devices	Linking words	Language register and "granularity"
Mind maps	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")	Loose
Concept maps	Relations between concepts	Hierarchical, tree-like	Medium generality	Boxes	Arrows	Relational phrases ("in relation to", "is composed of", etc.)	Medium
Argument maps	Inferences between claims (conclusions) and support (premises)	Hierarchical, tree-like	Low generality	Boxes and lines	Lines, colours, shading	Inferential linking words ("because", "not", "however")	Tightly constrained

the case with argument maps which have a very specific utility. Therefore there is an asymmetry in terms of the degree to which the mapping types can overlap in function. The rules for mind mapping do not make any specific assumptions about learning as a process or the nature of knowledge. The rules are "looser" and therefore a mind map can sometimes take on the characteristics of a concept map. By contrast, a map that would satisfy the rules for an argument map, cannot be a mind map because the rules of application are much stricter. A concept map occupies something of a middle ground, but is closer in form to a mind map than an argument map (I am indebted to an anonymous reviewer for this point).

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 "The purpose and justification for mapping tools"**.** However, specific details which might explain why mapping tools work were not discussed.

Knowledge mapping allows meaningful learning to occur

Hay et al. usefully distinguish between "non-learning", "rote learning" and "meaningful learning" (Hay et al. 2008). Using the pedagogical views of Kolb and Jarvis (Jarvis 1992; Kolb and 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 et al. 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 possess. *Meaningful learning*, by contrast, occurs when new perspectives are integrated into the knowledge structure and prior concepts of the student. The Fig. 5 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).

Mapping allows the presentation of new material to build on existing knowledge

Having a 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 us take each of these points in turn.

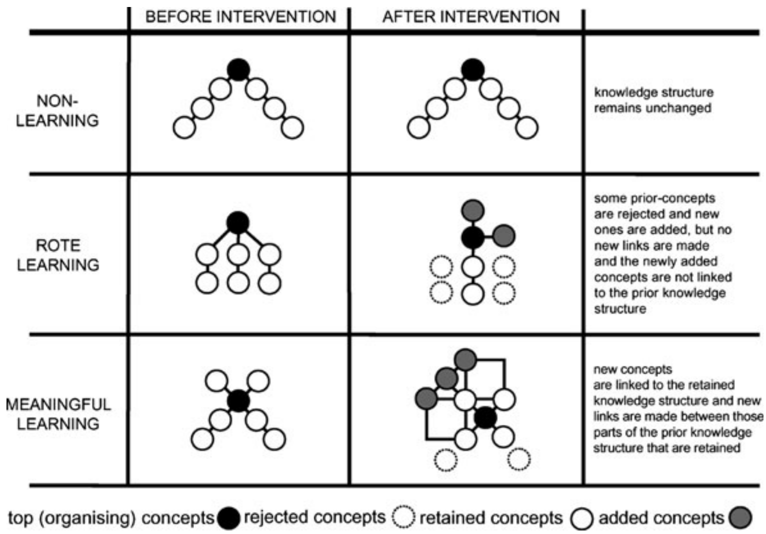

Fig. 5 Different kinds of learning in an intervention involving students using concept mapping under test conditions (Hay et al. 2008, p. 299)

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. 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 results 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 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 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 and Simon 1987). Memonics also assist this. In "The purpose and justification for mapping tools", a reason was given for this. Maps allow the separate encoding of information in memory in visual and well as propositional form.

Mapping allows students to build new and meaningful knowledge links by 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 and 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 to use engagement activities, such as problem-based learning, to teach, in a way that will engage students in learning and 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 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. 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 (Fig. 6).

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 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 forms of mapping have their place in the context of teaching and learning. Maps of associations (mind maps), causes and effects/relationships (concept maps) and maps of reasoning (argument maps) should all be presented in lectures in preference to linear narrative chains. This enables 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.

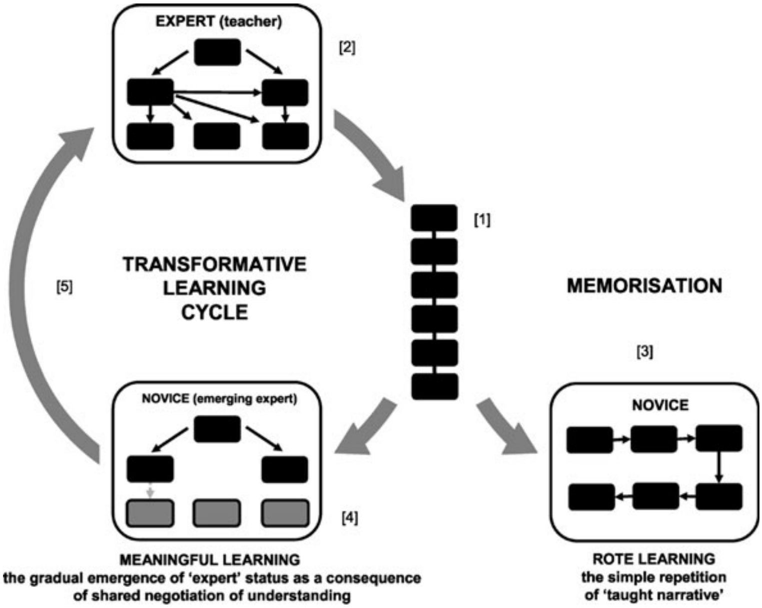

Fig. 6 The narrative sequence involves an expert [2] giving a linear presentation [1]. Students may either adopt meaningful learning [4] or memorisation [3] (from Hay et al. 2008). Meaningful learning is possible only if engagement with the material is allowed enabling the construction of knowledge in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

A convergence of mapping tools?

This next section is somewhat speculative. 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 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 is 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. Work has already been done on a complementary approach integrating conceptual diagrams, mind maps, concept maps and visual metaphors into an over-arching educational strategy beginning with conceptual diagrams, then mind maps, then concepts and finally visual metaphors (Eppler 2006). However, this approach did not consider the considerable advantages of argument mapping, and treats the mapping tools separately. I am envisaging a single mapping tool that does the role of each of the mapping tools that exist at present.

What would a convergent 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 and Dean 2006). 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 material they have written themselves) supporting nodes in the map. This third form of learning requires considerable research and analytical skills.

Each form 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 2009a). 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.

If the various mapping tools can be integrated then a number of opportunities arise. For one thing, the disadvantages and limitations of the discrete tools are no longer constraints. An example will make this clear.

An excerpt from a concept map on an inventory for financial accounting showing the relationship between revenues and cash flows is provided in Fig. 7. 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 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 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 other assessment modalities such as essays or exams, or tutorial participation.

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. 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"

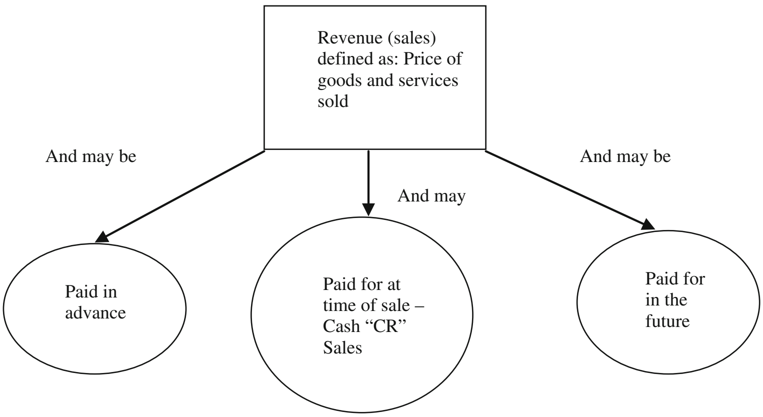

Fig. 7 A partial concept map on the relationship between revenues and cash flows

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 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 in Fig. 8.

A convergence of mapping tools might proceed in other ways. As noted earlier ("Argument mapping"), 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.

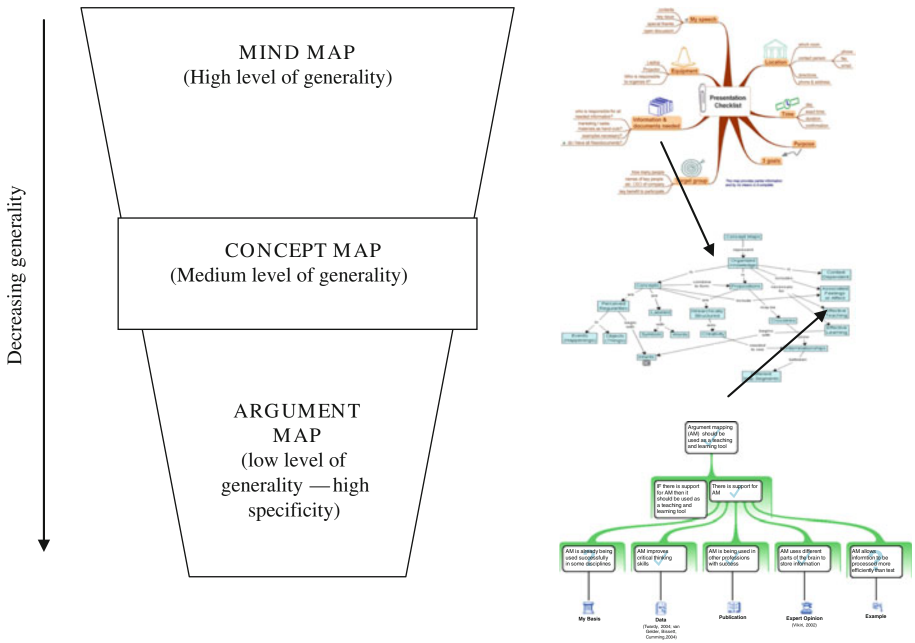

Fig. 8 Proposed convergence of knowledge mapping technologies into a single integrated platform. The central concept map may be devised initially to demonstrate familiarity with the relationship between key concepts in a topic. At given points, or "nodes", certain concepts may be further elaborated in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

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 2009b):

- *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.
- *The issues phase*. This involves further clarity on the issues 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 requires some idea of the evidential support that is needed in the essay. This part of the preparation would benefit from concept mapping and mind mapping.
- *The research phase*. This involves knowing where 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 drawn from wide reading. Argument mapping may be used here.
- *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 by 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 is provided in Fig. 9:

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 2009b). This might translate into an argument map proforma which could then be modified and made more detailed.

This paper has been somewhat speculative in terms of the directions in which a converged mapping tool might take us in the future. 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.

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. The paper has outlined the differences between the main forms of map-making: mind maps, concept maps

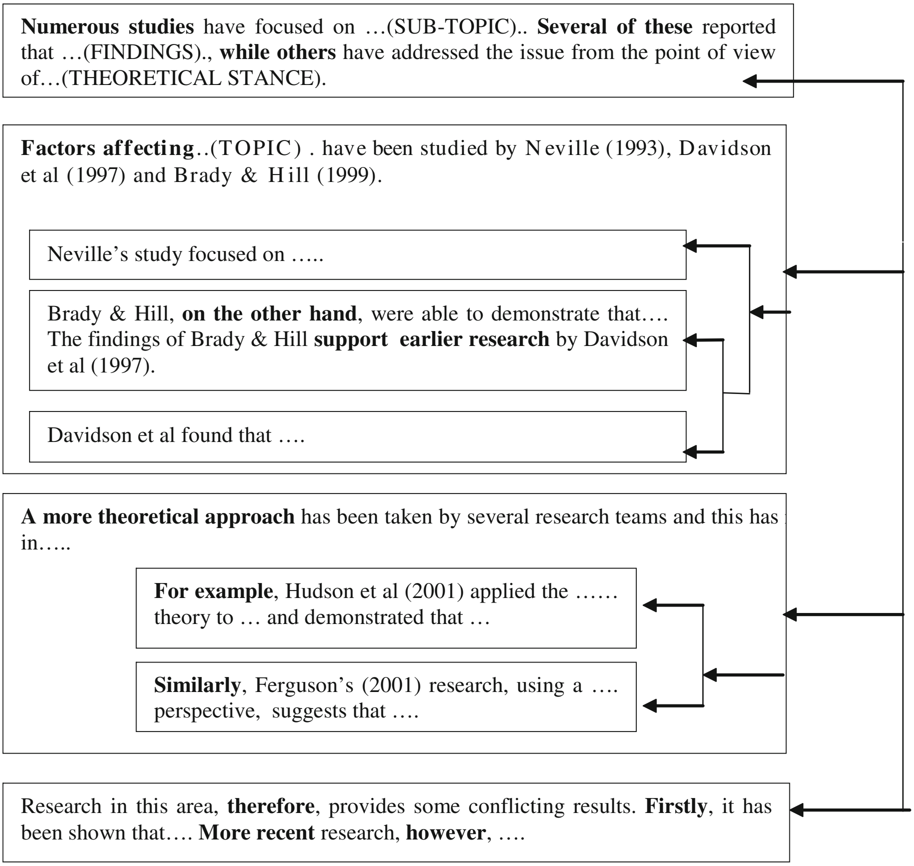

Fig. 9 A template for a writing taxonomy (Rochecouste 2005)

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 for both students and teachers that will enrich and provide new directions in education in the future.

Acknowledgments My thanks to Tim Beaumont and two anonymous reviewers from the journal for useful comments on earlier versions of this paper.

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