Computer-Aided Argument Mapping and the Teaching of Critical Thinking: Part I

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Abstract

This paper is in two parts. Part I outlines three traditional approaches to the teaching of critical thinking: the normative, cognitive psychology, and educational approaches. Each of these approaches is discussed in relation to the influences of various methods of critical thinking instruction. The paper contrasts these approaches with what I call the "visualisation" approach. This approach is explained with reference to computer-aided argument mapping (CAAM) which uses dedicated computer software to represent inferences between premise and conclusions. The paper presents a detailed account of the CAAM methodology, and theoretical justification for its use, illustrating this with the argument mapping software *Rationale*™. A number of *Rationale*™ design conventions and logical principles are outlined including the principle of abstraction, the MECE principle, and the "Holding Hands" and "Rabbit Rule" heuristics. Part II of this paper outlines the growing empirical evidence for the effectiveness of CAAM as a method of teaching critical thinking.

Key words: Critical thinking, argument analysis, computer-aided argument mapping, argument mapping, Rationale.

1. Introduction

There have been a number of approaches to the teaching of critical thinking, and a number of different methods of instruction purporting to achieve critical thinking gains in students. I will outline these briefly before discussing the recent innovation of computer-aided argument mapping (hereafter, CAAM). My contention in the paper is that CAAM is a novel visualisation approach that is an advance both on previous visualisation approaches, as well as previous approaches to the teaching of critical thinking. In this two-part paper I outline both the educational and pedagogical rationales for the CAAM method, the empirical evidence in its favour, and student testimonials supporting the use of CAAM in the classroom. The data supporting CAAM is thus triangulated: I provide evidence from controlled experimental studies; students' owns views of the approach; and evidence from the theoretical and empirical literature. I believe that together these data represent a compelling case for CAAM as a robust approach to the teaching of critical thinking that deserves serious consideration in the context of contemporary educational practices.

2. Definitional Comments

A few definitional remarks are needed. Computer-aided argument mapping, or CAAM, refers to a recent approach to the teaching of critical thinking by means of argument analysis, using dedicated software specifically designed for the purpose of representing arguments in visual form. CAAM will be further explained in the body of the paper. For the purposes of this paper I will take "argument analysis" to mean the following: the ability to recognise, understand and construct both reliable and unreliable inferences from premises (i.e., reasons, objections and counter-objections) to conclusions (or contentions). I consider argument analysis as a necessary element of being able to think critically.

I acknowledge that there are many different definitions of critical thinking, not all of which are as specific as my definition of argument analysis. Many are broader in nature, for example, Ennis's definition: "reasonable and reflective thinking focused on deciding what to believe or do" (Ennis, 1985, p. 45) or the definition by Facione: "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or conceptual considerations upon which that judgement is based" (Facione, 1990, p. 3).

I do not disagree with these definitions, but I will focus not on what critical thinking *is*, but on what constitutes a *teachable* skill in relation to critical thinking. My aim, in other words, is less definitional and more pragmatic. Using a narrower definition, it should be possible, I believe, to focus the educational aims in relation to the teaching of critical thinking, i.e., to what can be taught in a classroom given realistic time-tabling constraints, as opposed to attempting to attain — using wider, more encompassing, definitions of critical thinking — what it may take a lifetime to achieve. Teaching how to recognise and construct reliable inferences using CAAM is achievable, and the evidence shows this.

Before turning to these matters, however, it is best to cover some important historical ground. This will help us locate CAAM in the context of other, more traditional approaches to the teaching of critical thinking. This, in turn, makes clear the benefits of CAAM over traditional approaches.

3. Three Standard Approaches to Teaching Critical Thinking

3.1 The Normative or "Philosophical" Approach to Critical Thinking.

Historically, the teaching of critical thinking was based on what is sometimes called the "philosophical" or normative approach (Lewis & Smith, 1993; Sternberg, 1986). This approach emphasises the way we distinguish strong or valid inferences from weak or invalid inferences. A critical thinker on this view is a person who has the skills needed to employ those distinctions and who is disposed to use those skills. Thus, "the qualities and characteristics of the person rather than the behaviours or actions the critical thinker can perform" (Lai, 2011, p. 5; Lewis & Smith, 1993; Thayer-Bacon, 2000). In essence, a person who is a good critical thinker has a sceptical attitude and can suspend his or her judgement on matters. Richard Paul refers to the "perfections of thought" (Paul, 1992, p. 9) of a critical thinker, and Sternberg refers to this approach as one which emphasises "how people might think critically under ideal circumstances in which the limitations of human information processing system are not in place" (Sternberg, 1986, p. 5). In all cases, the emphasis is on the thinker, and an idealised one at that.

Peter Facione, in his landmark *Delphi Report*, refers to the ideal critical thinker, as someone who is "habitually inquisitive, well-informed, honest in facing personal biases, prudent in making judgements, willing to consider, [and] clear about issues," amongst a host of other personal attributes (Facione, 1990, p. 4). There are a number of useful definitions of critical thinking in this tradition which have been much debated and discussed in the literature (Bailin, Case, Coombs & Daniels, 1999; Ennis, 1985; Lipman, 1988; McPeck, 1981; Paul, 1992 for a comprehensive list, see Lai, 2011).

The normative approach emphasises application and training in the rules of deductive logic, fallacies, reliable inference-making relying on statistics and research methods, and so on. (Consult the table of contents, for example, of any of the more widely-used critical thinking textbooks such as Vaughn, Waller, Govier, or Moore and Parker.) To focus on the case of deductive logic, this approach has a long history dating back to the work and teaching of Aristotle and the schooling of logic in the academy (van Eemeren, Grootendorst & Henkemans, 1996). It is still popular today in many undergraduate colleges around the world where students learn model syllogistic reasoning patterns, such as the tired — but still instructive — example of *modus ponens*: "All men are mortal, Socrates is a man, therefore Socrates is mortal," along with fallacies such as *denying the antecedent:* "If the Queen of England is an American she is a human being; she is not American, so she is not a human being." Sustained and regular practice in inductive and deductive syllogistic reasoning, propositional logic, the predicate calculus, truth tables, and care and attention to common fallacies in reasoning is characteristic of this approach to critical thinking. Advocates of this view claim that instruction in these things will bring about gains in critical thinking in students if practiced assiduously.

The normative view tacitly assumes that generic critical thinking skills can be strengthened by intensive training. In a similar way, general fitness can be enhanced by participation in a variety of sports. This approach recommends building competence in critical thinking by training in chess, mathematics or (most usefully) symbolic logic. We can build competencies in critical thinking skills in the same way as we build competencies in general fitness.

This approach, while useful in some sense in training students in the skill of thinking logically, it is considered largely an idealised approach based on assumed *competence* rather than actual *performance* (Sternberg, 1986, p. 5). For one thing, the rules of logic do not approximate, even closely, how students actually think and behave in a classroom. Few of us (excepting perhaps individuals with extreme autism) reason logically all of the time, even given practice and theoretical instruction, and seldom do we reason syllogistically (everyday human reasoning is more "messy" than that). For another thing, there are innate limitations on the cognitive systems of humans: motivation is often lacking, our memories are at best, limited, and we often lack perfect information to logically analyse situations with the rigor required by the normative approach. It also needs to be recognised that there are situational constraints and personal factors that prevent us from performing at optimal capacity (Sternberg, 1986, p. 7). Despite this, the normative approach looks at critical thinking from the point of view of optimal competence.

Recent work has outlined how off-the-mark this approach is. In a meta-analysis of studies of gains in critical thinking in undergraduate education, Claudia María Álvarez Ortiz found that, when critical thinking is taught in stand-alone philosophy critical thinking classes, the effect size (.34 SD) is about three times larger than the effect (.12 SD) of simply being at university (Alvarez, 2007, p. 69). These results are, for many who advocate this approach, somewhat disappointing.

A second problem with the normative approach using deductive logic is that cognitive transfer does not always occur. There is little evidence that learning syllogisms, for example, easily and spontaneously transfers to new contexts; for example, to arguments in other disciplines (Pithers & Soden, 2000; Willingham, 2007). Willingham notes that thought processes are intertwined with what is being thought about (Willingham, 2007, p. 10). Subjects given one mathematics problem, for example, could not transfer the solution to an identical mathematics problem if the context was different. Generic critical thinking programs, such as that recommended by the normative approach, according to Willingham, only appear to assist students with solving problems of the kind practiced in the generic skill classes, and not other types of problems: "if you practice logic puzzles with an effective teacher, you are likely to get better at solving logic puzzles" (Willingham, 2007, p. 13)

The debate between the "generalists" (those who view critical thinking as a generic skill, which is common to all disciplines) and the "specifists" (those who view it as a discipline-specific skill) is ongoing (Davies, 2006, 2012, forthcoming; Ennis, 1989, 1990; McPeck, 1981; McPeck, 1990; McPeck, 1992; Moore, 2004, 2011; Paul, 1992). As noted by McPeck: "Thinking, by definition, is always thinking about something, and that something can never be 'everything in general' but must be something in particular" (McPeck, 1981). There are some that argue that critical thinking skills should be grounded in critical thinking in the disciplines, and not in generic stand-alone courses (Moore, 2004, 2011, 2011).

I would like to distinguish between the *approach* to critical thinking and factors influencing *method of instruction* at this point. As we have seen, the normative approach to critical thinking assumes the student is an idealised thinker obeying, under ideal circumstances, principles of logical thinking, which it is the job of the instructor to teach and elicit. The method of instruction of this approach in the teaching of critical thinking characteristically involves *formal training* in logic, sustained *practice*, and *theoretical instruction* into logical systems. This, as indicated, is an ultimately flawed approach. However, the central insight of practice, exposure to well-structured model arguments, and instruction in principles of reliable inference making may still be useful in other ways. As we shall see, these factors influencing the different methods of instruction can be deployed in a better approach to the teaching of critical thinking, namely CAAM.

3.2. A Cognitive Psychology Approach to Critical Thinking

As we have seen, the normative approach sees critical thinking from the point of view of competence. By contrast, the cognitive psychology approach sees critical thinking from the point of view of performance (Sternberg, 1986, p. 5). The cognitive psychology approach focuses on how people actually *do* think; not how they *should* think. Unlike the previous approach, this approach emphasises actions and behaviours.

Unsurprisingly, this approach originated in the behaviourist tradition in psychology and the later experimental approaches, where overt actions, behaviours and dispositions to behave were considered a legitimate basis for empirical investigation. The cognitive psychology tradition is interested in how people think critically in the absence of full information, unlimited time, and perfect memory. Usually tests are conducted in laboratory settings to determine conditions of optimal performance (Sternberg, 1986, p. 6). A number of theorists have explicitly adopted this approach to critical thinking (Bransford & Stein, 1984; Bruner, 1960, 1961; Freuerstein, 1980; Sternberg, 1985).

Like the normative approach, this approach also enumerates a list of desirable attributes; however, it is not a list of idealised *standards* required of a good critical thinker; but rather, a list of *actions* and *behaviours* that are expected of critical thinkers. Examples of these overt skills would be interpretation, choosing between alternatives, and formulating good questions.

This is a subtle but important distinction. The normative approach lists attributes such as: "reflective skepticism" (McPeck, 1981, p. 8); "reflective and reasonable thinking that is focused on deciding what to believe or do" (Ennis, 1985, p. 45); "the correct assessing of statements;" "thinking that is goal-directed and purposive," "thinking aimed at forming a judgement where the thinking itself meets standards of adequacy and accuracy" (Bailin et al., 1999, p. 287); "judging in a reflective way what to do or what to believe" (Facione, 2000, p. 61); and so on.

By contrast, the list enumerated by cognitive psychologists is far more pragmatic, process-based and procedural in nature: "the use of cognitive skills or strategies that increase the probability of a desirable outcome" (Halpern, 1998, p. 450); "the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts" (Sternberg, 1986, p. 3). The emphasis, in other words is not on any idealised nature of thought and thinking, but the overt behavioural *strategies* normally adopted by people when confronted with situations where they are required to be critical, and the attitudes or dispositions that are needed to perform well (Lewis & Smith, 1993).

The cognitive psychologist approach is as much interested in *deviations* from the idealised performance in critical thinking tasks (sub-optimal performance by retarded individuals for example), as they are in what would constitute an idealised performance according to a normative ideal. It is a *situational* approach rather than an approach based on formal training in systems of logical inference patterns combined with theoretical instruction and classroom practice. To use a distinction of Ryle, where the normative approach emphasises critical thinking as a type of "knowing-*that,*" the cognitive psychologist approach emphasises critical thinking as a type of "knowing-*how*."

It is perhaps not surprising, therefore, that the cognitive psychology approach emphasises a different method of instruction. According to the cognitive psychology approach, critical thinking is tied to particular learning domains and can only be acquired through properly "situated" activity in each domain. A comparison with sport will illustrate this. Hand-eye coordination, pattern recognition, and other skills are obtained by playing a variety of sports requiring different levels of refinement in terms of these, and other, skills. Tennis, golf, rugby, basketball and netball, for example, all require recognition of patterns of play in a variety of ways. These sports thus constitute particular, situated deployments of a certain skill. Evidence shows that, when presented with a recall task, experts from sports different from that shown in the recall pattern, consistently outperformed non-experts in terms of recall of defensive play positions. Sports people, it seems, acquire a general and transferable "abstract" skill in pattern recognition by playing very different sports which, in turn, contributes to sports expertise (Abernethy, Baker & Côté, 2005).

This is similar to the acquisition of critical thinking skills, according to the cognitive psychology position. Particular instances of critical thinking are learned in a variety of different problem-solving situations or domains. The learner is required to make sense of his or her situation using a range of mental processes, strategies and representations, from which this skill is later transferred. These skills are, under appropriate circumstances, then abstracted to other situations as a general skill with far wider application to very different contexts. Thus, on this view, critical thinking is not an idealised form of rule-governed skill, but a procedurally driven, situated skill requiring exposure to particular domain-specific activities. These situated skills are then potentially generalisable and applied in other, new contexts.

The cognitive psychology approach assumes that, to some degree, learning is constituted by an idiosyncratic set of universal, innate, hard-wired cognitive capacities. Sporting, musical, language, and mathematical prowess is, to some degree at least, hard-wired. This also applies to cognition in general. The cognitive psychology view also assumes evolutionary psychology has an influence on methods of instruction. These capacities are bequeathed by natural selection and conferred by the particular physical and social environments in which we evolve.

The cognitive psychology account thereby sidesteps the problem of general versus specific critical thinking. The mind does not possess and cannot attain "general-purpose" critical thinking skills, according to this view, unless it is abstracted from specific and concrete circumstances where critical thinking is practiced. Moderate versions of the cognitive psychology approach claim that general critical thinking skills emerge gradually in a process of consolidation and abstraction from particular, concrete deployments. More radical versions claim that there are no general critical thinking skills at all; only instances of domain-specific critical thinking. This is different from the normative approach which assumes that *modus ponens*, for example, is a general-purpose inference regardless of context.

On the downside, this approach is seen as problematic because it focuses too much on behavioural strategies, and not the process of thinking itself. In particular, the approach relies on the formulation of a series of disconnected steps and procedures, a "componential" approach (Sternberg, 1986, p. 10), that — in the process of trying to measure critical thinking outcomes — loses the insight that critical thinking involves mental processing as revealed through a form of communication, i.e., language. This arises from the misconception of "critical thinking as a series of discrete steps or skills …[a] miscomprehension [that] stems from the behaviourist's need to define constructs in ways that are directly observable" (Lai, 2011, p. 7). Against this, others have argued that it is in principle possible to follow all the steps required to be a critical thinker on this account, and yet not engage in any critical thought: "the principle [sic] difficulty with a process account ... is its lack of a normative dimension" (Bailin, 2002, p. 363).

Again, the important thing to note here is the distinction between the approach and the method of instruction. The cognitive psychology approach sees critical thinking as a procedural skill; a function of how people act and behave in certain learning domains. The method of instruction it favours in one of *situated cognition* with due recognition of the *evolutionary psychology* of the individual as it has evolved to deal with given environments. Skills do not, of course, arise without suitably favourable circumstances. All skills need development in context and situations where they are best deployed, and are thus adapted to, and reflect those contexts.

3.3. The Educational Taxonomy Approach to Critical Thinking

The third major approach to critical thinking is the educational taxonomy approach. This approach arose from classroom practice and is associated most strongly with Bloom's taxonomy (Bloom, 1956) and Gagné's hierarchy of learning skills (Gagné, 1980). Others were also influential include (Perkins, 1981; Renzulli, 1976). Bloom's framework consists of a cumulative, hierarchical and invariant taxonomy of skills with "knowledge" at the lowest level, followed by "comprehension," "application," "analysis," "synthesis" and "evaluation." Within each level there are a number of sub-categories and these lie on a continuum from simple to complex, concrete to abstract.

On this account, students are supposed to develop in a largely linear fashion along the lines of the taxonomy given appropriate exposure to stimulus conditions, and in response to suitable teaching. According to Kennedy, the three highest levels are often said to constitute "critical thinking" (Kennedy, Fisher & Ennis, 1991). This approach was widely adopted in its time (Gagné, 1980; Perkins, 1981; Renzulli, 1976) and still has many adherents in educational circles.

On this approach, critical thinking is an invariant and cumulative, hierarchic taxonomy. Each level on the scale is assumed to require mastery by students before progressing to the next. The factors influencing methods of instruction are guided by "classroom observation, text analysis, and process analysis of thinking in the classroom." In other words, it is an approach largely guided by conditions of *practice* (Sternberg, 1986, p. 6).

There are a number of concerns about the educational approach to critical thinking. One is that, as the educational approach conflates both the competence and performance aspects, it is unclear the extent to which the approach constitutes a *prescriptive* or a *descriptive* model of the development of critical thinking (Sternberg, 1986, p. 6). Bloom's categories also do not easily guide instruction because they are vague. What constitutes "comprehension," for example, and how does one know if this has been achieved in the classroom? (Ennis, 1985; Sternberg, 1986).

I shall return to the distinction between the approach to critical thinking and the factors influencing the method of instruction in Part II. For now I will outline a fourth kind of approach to critical thinking, and the one most significance to the present work.

4. A Different Approach: Visualisation and Argument Mapping

4.1 The "Visualisation" Approach to Critical Thinking

The argument mapping approach is a special case of what might be called the "visualisation" approach to critical thinking. Historically, visualisation techniques are commonly used in many discipline areas. These techniques range from application as geographical and topographical maps to diagrams and charts of various sorts (e.g., flow charts, pie charts, scatter graphs, Venn, Wigmore, and Nassi-Shneiderman diagrams). These techniques are, in essence, used to make complex information easier to process (Nassi & Shneiderman, 1973; Tufte, 1983). While proponents of argument mapping do not necessarily recognise their work as part of a discernible "visualization" approach, they are guided nonetheless by the broad insight — common to others who use Venn and Wigmore diagrams — that information contained in arguments is best presented in illustrations and not statements, i.e., that the argument analysis component of critical thinking is best taught by representing arguments visually.

Barbara Tversky distinguishes between graphic displays, or "visualizations," that portray things that are essentially visuo-spatial (maps, molecules, architectural drawings), from those that portray phenomena that are non-visuo-spatial. Examples she gives of the latter category include diagrams that map ideas and relationships, e.g., mind maps, concept maps, flow diagrams, organizational charts and graphs (Tversky, 2002). Not all visualizations, it seems, are equivalent in terms of their effectiveness, with some evidence that simpler, less detailed graphics are more effective than more "realistic" graphics (Dwyer, 1978).

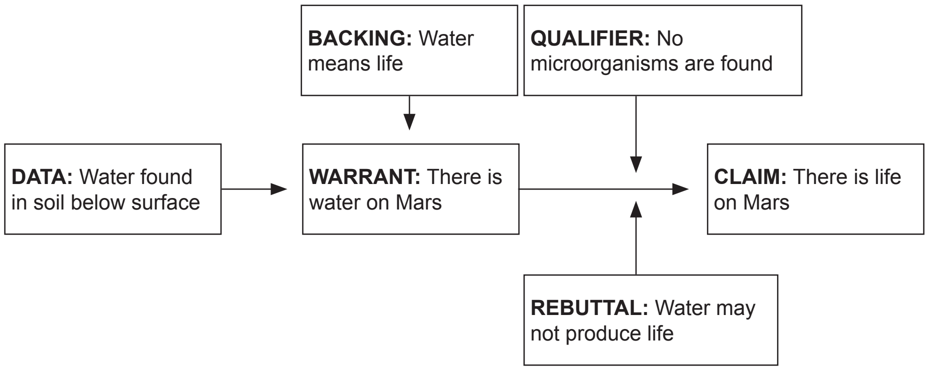
Argument mapping, as a form of visualisation technique, began two centuries ago, but, for reasons given below, has only gained prominence since around 2000. Argument maps are a special case of what might be called "ideas" mapping, as opposed to visuo-spatial mapping. Ideas mapping also includes the commonly-used mind mapping (Buzan, 1974; Buzan & Buzan, 2000) and concept mapping (Novak & Cañas, 2006). There are differences between these mapping types. Briefly, where mind maps display rough *associational* connections between ideas, concept maps emphasise tighter *relational* connections, and argument maps emphasise very tight *inferential* connections (Davies, 2011). Argument mapping is also of a higher order of specificity in terms of the terminology used, and employ different kinds of visual display techniques compared to these older forms of "idea" mapping. We shall see some examples of these display techniques below. We shall also see how argument mapping uses a different combination of factors influencing the different methods of instruction compared to previous approaches to the teaching of critical thinking.

4.2 The Historical Background to Argument Mapping

The exact origins of argument mapping are debatable; however, most attribute the first argument map as dating back to at least the 1830s when Richard Whatley constructed a diagram linking premises and conclusion (van Gelder, 2009; Whately, 1867). Later, John Henry Wigmore developed a method of displaying evidence in legal trials (Anderson, Schum & Twining, 2005). It is generally agreed that argument mapping has been around for more than a century (Buckingham Shum, 2002; Reed & Rowe, 2007).

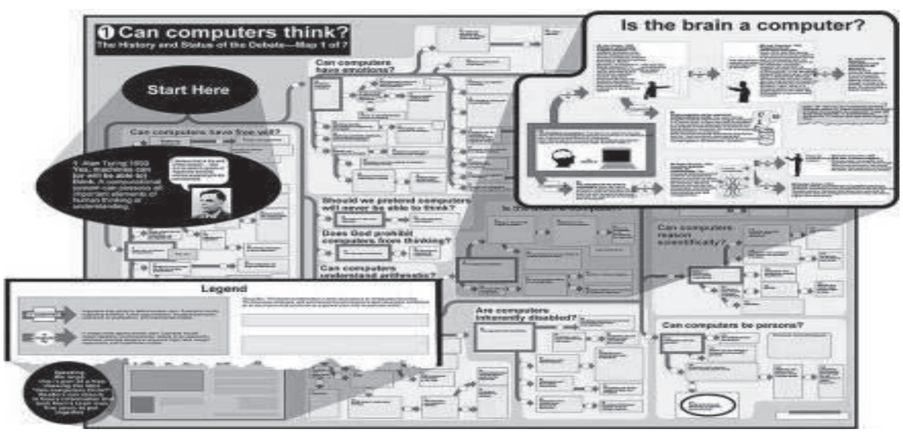
Mapping of academic debates continued with the work of Stephen Toulmin in the 1950s who distinguished between the "geometrical" validity of formal logic, and the more "procedural" validity of everyday reasoning, and who also distinguished "claims," "data," "warrant," "backing," "rebuttals" and "qualifiers" using a simple visual schema (Toulmin, 1958). For a simple Toulmin map for the contention: "There is life on Mars," see Figure 1 below.

Figure 1: A Toulmin-style argument map



(Source: en.wikipedia.org/wiki/Stephen_Toulmin#The_Toulmin_Model_of_Argument)

Figure 2: An argument map in the style of Robert Horn (Horn, 1998).



Much later, Robert Horn, using his own brand of mapping involving clipart characters as well as boxes and arrow diagrams, developed a series of large maps on current debates in Philosophy (Horn, 1998, 1999).

Since the development of personal computers, and the capacity of computers to alleviate mental processing in many tasks, there has been growing attention given to how dedicated software programs can be used to visually represent arguments, and how these can be used to teach critical thinking (Kirschner, Buckingham Shum & Carr, 2002 see, especially the chapter by van Gelder). Since then, there has been a proliferation of these tools including *Araucaria, Argumentative, Carneades, ILogos,* and others (for a list of these argument mapping tools, see Harrell, 2008; see also Scheuer, Loll, Pickwart & McLaren, 2010).

4.3. The Technique of Argument Mapping

Argument mapping differs from conventional approaches to the teaching of argument analysis in a number of ways. The most obvious of these ways is, of course, the use of dedicated visual displays. Where conventional approaches to teaching critical thinking uses mainly prose as the medium of instruction (use of Venn diagrams notwithstanding), argument mapping uses prose *in addition* to graphical representations. As we have seen, conventional approaches also use a combination of *formal training, theoretical instruction, situated cognition,* and *practice* as the factors influencing the different methods of instruction. As we shall see, argument mapping uses all these methods making it, I believe, more likely to be effective as a means of teaching critical thinking. I shall return to this point in Part II of this paper.

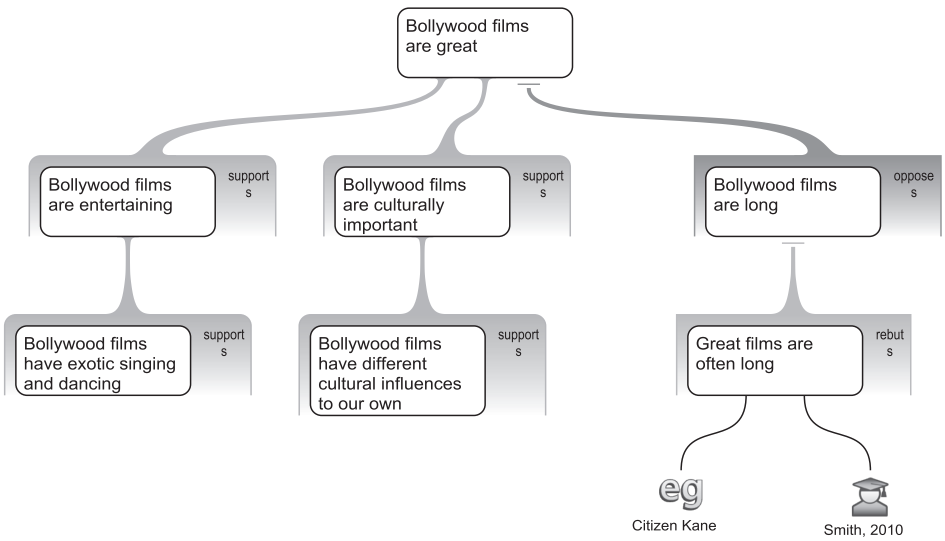
A simple argument map using the argument mapping software *Rationale*™, is given below along with a prose version of the argument as it might appear in a textbook, newspaper or journal.

The Text of the Argument

Some argue that what makes Bollywood films great is the simple fact that they are entertaining. In particular, they are marked by the creative, and sometimes inappropriate and hilarious use, of exotic Indian singing and dancing. However, this is only one element of what makes them of interest to the contemporary film enthusiast. In addition to their entertainment value, Bollywood films are culturally important for a variety of compelling reasons. Most notably, they typically put on display for the viewer cultural influences that are very different from our own traditions in western society. The cultural influences commonly on display in Bollywood films include the food, music, religious practices, and the social and familial relationships and expectations in contemporary Indian society. However, against this it could be argued that Bollywood films are characteristically very long; indeed,

> *much longer than the average Hollywood film, and that this effectively inhibits their claim to greatness. But on the other hand, it has been noted that other great films (such as Citizen Kane) are also often long and yet this has been no barrier to their recognition as great movies (Smith, 2010). (Adapted from: www.austhink.com)*

The Argument Map



Comparing the argument map with the prose version of the argument, a number of advantages present themselves.

4.3(a) Clarity

First, the argument-mapped version is clearer than the prose version mainly because in the map, the inferential connections between the parts of the argument are made explicit. The argument-mapped version is also more economical, and less repetitious. There is simply no need for prose scaffolding to be included in the argument (i.e., words such as "however," "yet," "in particular," and phrases such as "some argue that," "it has been noted that," "it could be argued," "on the other hand," and so on). The visual conventions and layout of the map do that job. So while the prose version is text heavy, the mapped version is text-light, yet the inferences being made are clearer. This is despite the text version being as clear as it can possibly be. (The text is purpose-designed and constructed by the present author: academic prose is typically much denser and far less clear.)

4.3(b) Accessibility

Second, argument maps are designed for immediate accessibility. It is clear, in this example, that there are two supporting reasons and one objection to the contention. The objection also has an objection to it (a rebuttal). These reasons and objections can simply be read off the argument map as easily as counting the boxes. In the prose version, this is far harder, and there is likely to some dispute, even amongst intelligent readers, as to the exact number.

4.3(c) Separability

Third, there is a clear separation between contentions, premises (i.e., reasons and objections) and evidence in the map. This is not the case in the prose version. For example in the objection about Bollywood movies being long, it is hard to tell the role that each sentence plays in the argument. By contrast, in the argument map it is clear that expert evidence from Smith (2010), and an example, is supporting or grounding the claim that: *Great films are often long.* This separation in what *is* a claim, what constitutes *grounding* for a claim, and the role a claim plays in an argument (be it a reason, objection of rebuttal) is made very clear in the argument map by virtue of the design principles employed.

Similarly, the arrangement of priority amongst the claims is made clear by the hierarchical presentation of the argument into a number of tiers, which build upon each other in support (or opposition) to the contention. This is far less clear in the prose version of the argument, without considerable thinking, reading and re-reading of the written text.

But perhaps this is to get ahead of ourselves. Before outlining the advantages of argument mapping as an approach to argument analysis in more detail, we should step back and look at the design conventions used and some of the logical principles employed.

5. Design Conventions and Logical Principles Used in Argument Mapping

These conventions may differ depending on the software used. There are also a number of logical principles employed. For the sake of illustration I shall use those relevant to the argument mapping software *Rationale*™ with which I am most familiar.

5.1 Design Conventions

5.1(a) Contentions, reasons, objections, rebuttals: Unlike a Toulmin-style argument map, the claim or contention typically appears at the top of the map in a grey box. (It may also — though this is far less common — appear on the left or right if the author of the map chooses to transpose the map into a horizontal format. These are options in using *Rationale*™.) While this is not visible in the black-and-white format of this journal, on a screen or on a colour printer, the boxes below the contention are also intuitively colour-coded for immediate accessibility and understanding: green means a reason for the contention; red means an objection to the contention; and orange means an objection to an objection, a rebuttal in other words.

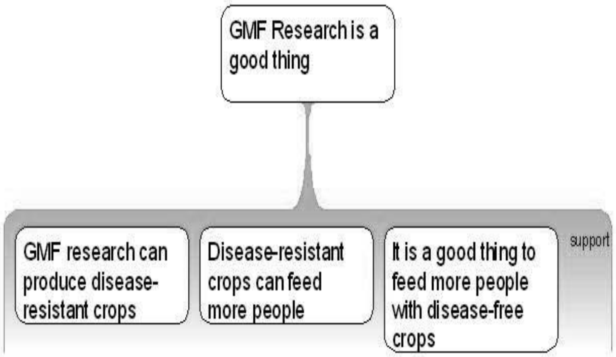
5.1(b) Declarative Statements: Each box contains a declarative sentence that is also a *statement*. A statement is a well-formed proposition for which a truth-value can be determined. For example, interrogative forms ("Can you shut the door?") or demands ("Shut the door!") do not have truth-values, as there is nothing that makes such sentences true or false. On the other hand, modal expressions, "The door should be shut" or declarative statements "The door is shut" are statements that can have a truth-value as reasons can be adduced to support or oppose them. For example, a simple argument might be that "The door should be shut" *because* it is cold outside (reason), and those inside do not want to get cold (evidence or ground of reason). A logical principle in argument mapping it that it is important to have a *singular* proposition in each box of the map. This singular proposition must be stripped of all verbiage, and the claim being made must be transparently clear. Similarly, the contention in an argument must be singular, and very clearly expressed. Students working on mapping arguments find this a difficult task, and it is instructive to see how argument mapping forces them to be rigorous in their expression (Twardy, 2004).

5.1(c) Tiering and hierarchical structure: Linked to the contention are tiers of reasons (green boxes) and objections (red boxes). The first tier reasons and objections are in response to the main claim or contention; the second tier reasons and objections are in response to the first tier reasons; the third tier reasons and objections are in response to the second tier second tier reasons, and so on. Argument maps are thus hierarchical, and "fan-out" from the contention, with the most general reasons being closer to the contention in the first tier position, and the less general, and more specific (but no less significant reasons) lower down. Often arguments fail because higher order claims rest upon lower order untruths, or faulty assumptions. This becomes transparently clear when arguments are mapped. Where there is an objection to an objection in an argument map, this is represented as a rebuttal (orange box). Specific linking words representing the role that a box has in an argument are also added to each box for additional clarity: "supports" (reasons), "opposes" (opposition), and "however" (rebuttal).

5.1(d) Bases Boxes and Grounds: At the terminal point of an argument map, when there are no longer reasons or objections that are being made, "grounds" or "basis" boxes are provided to support the terminal reasons or objections. Thus, arguments eventually terminate or "bottom-out" in evidential support of some kind. In the *Rationale*™ software, "basis" boxes can include legal judgment, quotation, expert source, a concrete example, observation, assertion, data, media source, statistical evidence or expert opinion. Again, arguments can fail because the grounding of the claims is somehow faulty.

5.1(e) Co-premises and open-ended premises: It is worth noting that there are a number of design conventions used in *Rationale*™ not (to my knowledge) found other argument mapping software. One is to show how a reason might be "helped" by another reason which may be tacitly assumed in an argument. Another is a convention to avoid "closing" an argument from further (potential) reasons or objections that might be brought to bear on some proposition. These are known as *co-premises* and *open-ended premises* respectively.

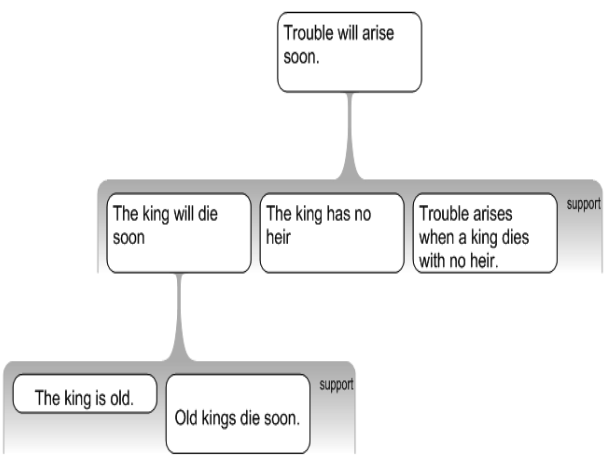
Co-premises: Consider the following argument: "Research on genetically modified foods is a good thing because it can lead to crops that are more disease resistant." In the argument diagram provided below, we can see that one of the reasons relies on (is "helped" by) the addition of other reasons. This is shown by reasons sharing, and being enveloped in, the same reason box in an "umbrella." In this case the assumed premises needed to *link* the premise GMF research can produce disease-resistant crops and the contention *Research into Genetically Modified Food (GMF) is a good thing* are made explicit. The helping premises are: 1) that Disease-resistant crops can feed more people and 2) that *It is a good thing to feed more people with disease-resistant crops.* In argumentation theory these are known as co-premises. It is important to critical thinking to make implicit assumptions explicit even if they seem trivial as they play a role in the construction of the argument, and their "invisibility" can hinder consideration of the argument structure. Again, it is very instructive to see students working through examples of arguments, and learning how to make implicit assumptions explicit in the form of co-premises. Apparently trivial unstated assumptions that lie behind arguments can be difficult for students to spot (Rider & Thomason, 2008).



It is the capacity of CAAM to encourage explicitness for assumed propositions within an argument structure that makes it powerful in critiquing arguments and constructing critically solid argumentation. Consider the following deceptively simple example:

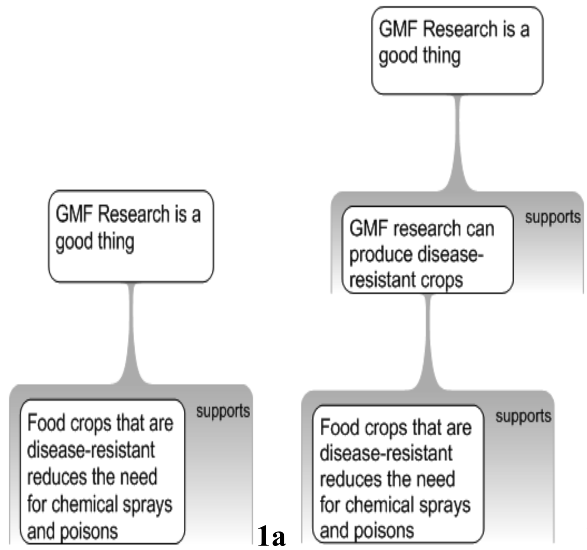
> *There is trouble ahead. The King is old and has no heir.*

At first these sentences appear to be assertions. In fact, they comprise an argument of some depth. Whilst the contention is easy to spot, this example conceals multiple tacit premises, and an intermediate conclusion, as the map below demonstrates.



Open-ended Premises: Note also that premises are enclosed in shaded boxes, with the shading disappearing to white at the end of the reason box. This design feature represents the fact that no argument is ever "closed off" from further potential premises that might be brought forward to add to the analysis with the software thus supporting and encouraging the adding of new premises, highlighting the dynamic, process orientation of argument mapping as acquired skill. No argument is ever really complete; they are merely rendered as well as possible given knowledge of the circumstances at a given time.

5.1(f) Missing rungs. One of the ways argument mapping can aid students is in seeing "missing rungs" in arguments. Often this is difficult to spot in prose because writers often omit information that connects reasons to contentions. For example, if one is confronted with the following examples, it is obvious that 1b is logically clearer than 1a. The reason is that a "missing rung" in 1a, which is supplied in 1b, provides a conceptual link between the contention and the terminal reason supporting it.



1a **1b**

5.2 Logical Principles

In addition to the design conventions, there are also a number of logical principles employed in argument mapping. The first two of these principles are not new to argument mapping, but have wide currency in management literature and business applications.

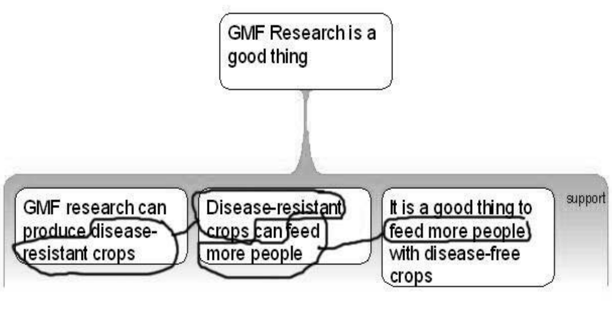
5.2(a) The Principle of Abstraction: Typically, there is a higher degree of *abstraction* in the first tier of reasons and objections, and decreasing abstraction (higher specificity) in the reasons and objections provided lower down. This design convention preserves the intuition that higher-level reasons are grounded by more specific and concrete supporting reasons, and eventually these reasons or objections are based on evidential support provided in the basis boxes. In argument mapping discourse, this is known as the *abstraction principle*, and it is consistent with the views of Minto, and the widely used pyramid-type diagrams used to clarify thinking (Minto, 1995).

Trials with CAAM note the difficulty of "extracting out" the premises and conclusions in a passage of text and arranging them into an argument map. Despite the apparently trivial nature of this task, students have great difficulty doing this, which thus exposes the student's mental model of any argument under consideration (Butchart et al., 2009). Being aware of this mental model as an educator is, of course, the first step to being able to improve on it.

5.2(b) The MECE Principle ("Mutually Exclusive, Collectively Exhaustive"): In argument mapping it is useful to keep in mind the MECE principle (Friga, 2008; Rasiel, 1999; Rasiel & Friga, 2001). In learning about argument mapping it is natural for an instructor to begin to teach students first about grouping concepts before instructing them in grouping arguments. Argument maps represent special kinds of a grouping arrangement with explicit inferences between premise boxes and contentions. But prior to making maps of arguments it is good to teach students useful techniques for mapping associations of concepts. This is not always as easy as it sounds.

For example, a concept map of the general concept "The Beatles," would consist of four constituent members: Paul McCartney, Ringo Starr, George Harrison and John Lennon (the "fifth Beatle" is a figure of speech). This would be a "MECE" group as the associate members of the group are both collectively exhaustive (no further members are essential, i.e., there are "no gaps") and mutually exclusive (each member is a unique identifier, i.e., there are "no overlaps"). By contrast, the group: Paul McCartney, Ringo Starr, Richard Starkey and John Lennon, would not be "MECE": George Harrison is missing so the group is not collectively exhaustive, and two of the names on the list, Ringo Starr and Richard Starkey, are names for the same person, so the items on the list are not mutually exclusive.

5.2(c) The Holding Hands Rule: This rule is unique to argument mapping and was devised by Neil Thomason. Once students move from mapping groups to mapping arguments, they need to be aware of inferential connections between concepts. This raises another level of difficulty. Students need to be taught not merely how to produce singular statements to go into the boxes of the maps they produce, but also to avoid writing down disconnected propositions in different boxes in the argument map. Disconnected propositions, of course, lead to incoherent arguments. The "Holding Hands" rule is a simple rule that prompts the student to avoid "danglers" when mapping. It applies *horizontally* across premises in an argument map. Concepts used in argument maps should "hold hands," i.e., they should be mirrored in associated premises boxes in an argument. In other words, no concept should stand-alone. Using my GMF example earlier, we can see the Holding Hands rule at work:



The Rabbit Rule: The Rabbit Rule, also suggested by Neil Thomason, is a special case of the Holding Hands rule, except it is applied *vertically* in an argument map, i.e., between premises and the contention, rather than horizontally between the premises. This is an even more important rule as, in all valid arguments, the contention needs to be supported by suitable inferences from terms provided in the premises. Teachers of argument mapping find that students easily remember this rule if they remind them "No rabbits can pulled out of hats" (i.e., by magic) when argument mapping. One cannot conclude something about "X," unless "X" is given in one or other of the premises (Rider & Thomason, 2008). The Rabbit Rule is illustrated below.

6. The Case for Argument Mapping

The case for argument mapping being an effective technique when applied to the teaching of the skills of argument analysis needed for critical thinking turns on the differences between representing information visually in the form of a map, compared to representing information in prose. What exactly are the differences?

6.1 Sentences versus Statements

Where paragraphs containing arguments naturally contain sentences, argument maps are comprised of statements. Statements are of a different logical order than sentences. Statements are *logical* entities whereas sentences are *grammatical* entities. The sentences in a passage of prose serve the various aims of the paragraph, which may or may not be argumentative. This may include a need to convince, highlight, describe, or otherwise draw attention to something. Linguistic markers are used in prose to make the paragraph clear and to link it to the paragraphs before or after the passage in question. In writing paragraphs, one of the many aims is to create fluency both amongst the sentences in the paragraph and between the paragraphs themselves. Another aim might be to create a sense of beauty in the turn of phrase. In argument mapping, there are no such requirements. Argument mapping is "language in the raw." Statements, as opposed to sentences, have a more circumscribed function. Their role is simply to state some proposition or other; a proposition that stands in need of defense. Argument maps thus contain statements that stand in a specific set of relationships to other sentences in the map in terms of supporting a contention. There is no requirement for fluency, narrative flow, or linguistic flourishes. This makes argument maps in some ways harder to create, but far easier for the brain to process. I explain why below.

6.2 Sequential Presentation versus Simultaneous Accessibility

Another difference is that argument maps are spatial, not narrative, representations of an argument. The whole argument is visible *en bloc* and immediately. This is in contrast to a prose version of an argument, which, by its nature, is sequentially presented. One idea is raised, then another. The format is narrative-like with one idea being presented separately and then the conclusion being eventually derived towards the end. In long arguments, i.e., over several pages, it might take some time to get to the conclusion and there may be a number of intermediate conclusions that require exegesis on the way to the final conclusion. This requires great subtlety of expression and care in terms of presentation of the ideas. Argument mapping requires no such treatment: the inferences drawn are designed to be accessible and immediate. The aim is not to couch or embed arguments in prose, but instead present them as clearly as possible with as little interference from surrounding language as possible.

6.3 The Use of Lines and Arrows, and Colour Coding

Naturally, prose does not normally lend itself to visual markers of any kind. Either information is available in the form of words in sentences or it is not available at all. This makes the representative resources of prose inherently limited in terms of its power to present information. By contrast, argument mapping utilises the full range of visuo-spatial resources currently available: an intuitive hierarchical structure, colour coding, linking arrows, and box labels to indicate whether points are in support of, or opposition to higher order claims.

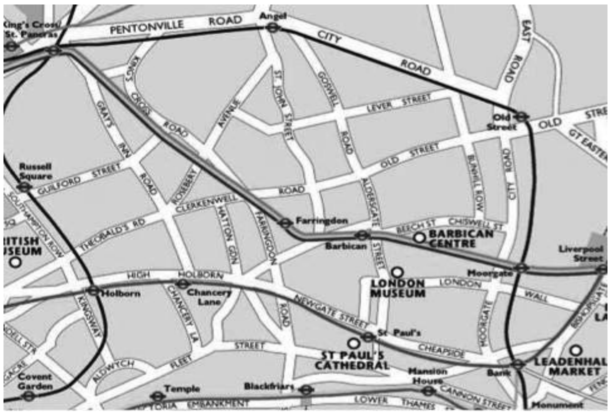
In the case of arguments in prose, it is often a matter of whether the reader can interpret the intention of the writer that results in an argument being understood or failing to be understood. In argument mapping this uncertainty is eliminated as much as possible with the use of intuitive visuo-spatial cues. It is interesting to speculate just how much these visuo-spatial cues will develop and be extended in the exciting frontiers of human-computer interface design, and with the rise in multi-media tools, interactivity, and web-based platforms. A recent innovation is *Arguweb*, the use of arguments on a web-based platform (Reed, 2012).

6.4 The Cognitive Burden of Prose

In a radical departure from traditional prose representations of arguments, the technique of argument mapping tries to augment human intelligence by utilising the representational resources of purpose-designed computer software. This embodies the spirit of Douglas Englebart's vision of the augmentation of human intellect, whereby we develop technologies which can boost our individual and collective intelligence, by complementing our own cognitive machinery (Engelbart, 1962). Just as geographical maps aid humans by allowing us to navigate easily and quickly in space, so argument maps allow us to navigate the complexities of prose. A comparison between a prose version of how to reach a destination (from, say, London Museum to St. Paul's Cathedral), and a map designed to show the same thing is sufficient to illustrate this (source: www.austhink.com):

> *Pentonville Road runs from east to west, then turns into City Road, which comes to a T-junction where East Road meets Moorgate City Road. Running roughly south from Pentonville Road is first Gray's Inn Road and then King's Cross Road, which turns into Farringdon Road after the intersection with Clerkenwell Road. Where Pentonville Road turns into City Road, St. John's Street runs south. As you go along City Road, you come to Goswell Road (which turns into Aldersgate Street) and Bunhill Row running south. As you go down Gray's Inn Road, the first intersection is with Guildford Street, which continues to a T-junction with King's Cross Road. The next intersection, as you continue down Gray's Inn Road, is with Theobald's Rd., which at that point turns into Clerkenwell Road, though you could veer of NE along Rosebery Avenue which crosses King's Cross Road before it joins St. John's Street near the junction of Pentonville Road and City road. Gray's Inn Road terminates at High Holborn, a major E-W road which, as you go east, turns into Newgate Street and then Cheapside. St. Paul's Cathedral is between Newgate Street and Fleet Street, which runs roughly parallel to Newgate. Southhampton Row goes south intersecting with Guildford Street, Theobald's Road and High Holborn, where it becomes Kingsway, which continues south to a T-junction with the curve of Aldwych, which begins and ends on Fleet Street. From Roseberry Road you can head east along Lever Street, which crosses St. John's Street and Goswell Road before finishing at Bunhill Row where it meets City Road. Heading south down St. John's Road, you cross Lever Street and then Clerkenwell Road. Goswell Road also crosses Lever Street and Clerkenwell Road (which at that point becomes Old Street). Goswell Road becomes Aldersgate Street. Hatton Garden goes between Clerkenwell Road and High Holborn. Streets running south from High Holborn are Kingsway, Chancery Lane and Farringdon Road. Chancery Lane is a short street finishing at Fleet Street. Fleet Street ends at a large intersection just east of St. Paul's. Aldersgate Street continues past London Museum (which is at the corner of Alsdersgate and London Wall) down*

> *to Newgate Street. Beech Street runs E from Aldersgate, turning into Chiswell Street before it meets City Road. East Road runs south, past the intersection of City Road, over Old Street and London Wall, where it becomes Moorgate Street.*



Even allowing for the apparent case that some people find visual information harder to process than others, maps are demonstrably easier to interpret than their prose equivalents, assuming an understanding of the basic mapping conventions. Why is this?

6.5 The Limitations of Memory and Cognitive Complexity

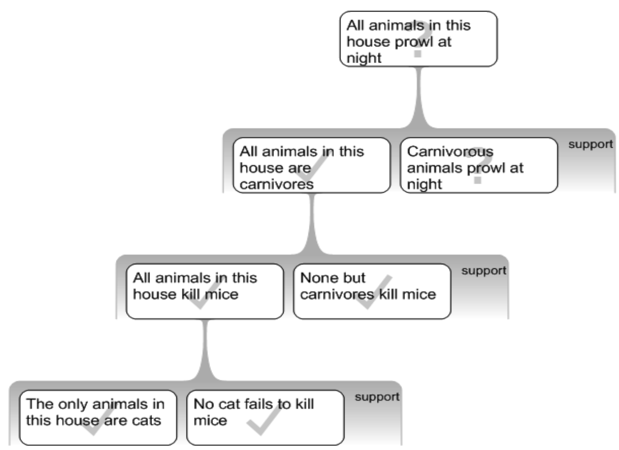
Human memory is limited, as low as four items of information on some accounts (Cowan, 2000), and even this low threshold requires "clumping" of information for ease of retrieval. (Think of how we recall our own mobile phone number, i.e., typically in clusters of four or three digits, and never as an uninterrupted string of ten digits.) Because of the limitations of memory, prose is a notoriously inefficient means of transmitting complex information. Evidence shows that well-designed visual representations help our brains cope with cognitive complexity (Larkin & Simon, 1987; Levie & Lentz, 1982; Levin & Mayer, 1993; Scaife & Rogers, 1996; Schnotz & Grzondziel, 1999; Tversky, 1995, 2001; Winn, 1987, 1989). They do this by "externalizing internal knowledge," which has the effect of reducing the burden of complex information on memory and allowing an off-loading of informational processing (Tversky, 2002). Simply put, there is no necessity to hold everything in one's head when travelling with a map: information is there laid out on a page, or on an iPad, for easy reference. By contrast, as we can see in the example above, a prose description to a destination requires a heavy burden of memory as it provides incremental steps towards a desired geographical location.

6.6 Representational Format

Similarly, as we noted earlier, argument maps display the key propositions supporting a contention in unambiguous detail. It is possible to tell, at a glance, and with virtually no cognitive effort at all, how many first tier reasons (for example) are provided for a given contention. Arguments in prose, by contrast, proceed sequentially and slowly to the contention so that a far greater degree of concentration and memory is required. The more complex the argument; the greater the demands on memory, and the higher likelihood there is of cognitive overload. This is so even in the case of arguments using non-technical words and phrases such as the example below (attributed to Lewis Carroll):

> *Since the only animals in this house are cats, and no cat fails to kill mice, all animals in this house kill mice. Now, given that none but carnivores kill mice, it's clear that all animals in this house are carnivores. Of course, no animals are carnivorous unless they prowl at night. So, all animals in this house prowl at night (Jefferies, 2007).*

While it is quite easy to see the conclusion in this passage ("All animals prowl at night"), it is far harder to determine the inferential steps to the conclusion from the premises. I challenge the reader to stop reading right now and try to do this. Compare this with an argument map version of the same passage:



The case for mapping of arguments is particularly compelling in this regard. The harder, and the more complex an argument is—even if it is expressed in clear, simple, and non-technical vocabulary—the greater the benefit of an argument map in showing the precise connections between the various reasons, objections and rebuttals. Note, the ticks and question marks in the above example represent the degree of plausibility we assign to premises (ticks mean "plausible," crosses mean "implausible," question marks mean "unsure"). Assessing premises in a very intuitive visual way is another feature of argument mapping.

6.7 Dual Coding and Transparency

Evidence from the cognitive science literature appears to support the claims for the advantages of representational format. Visual displays enhance learning for two reasons. One is by virtue of there simply being more than one modality involved. The phenomenon of "conjoint retention" or "dual coding," i.e., using both propositional as well as visuo-spatial information as representational formats, means that there is more than one means by which cognitive processing can occur, and thereby a greater likelihood of processing occurring successfully (Kulhavy, Lee & Caterino, 1985; Paivio, 1971, 1983; Schwartz, 1988) As Barbara Tversky puts it: "two codes, pictorial and verbal, are better than one" (Tversky, 2002, p. 2).

Another reason is because visual displays make the underlying processes and structures clear and transparent (Bauer & Johnston-Laird, 1993; Dwyer, 1978; Larkin & Simon, 1987; Mayer, 1989; Tessler, Iwasaki & Kincho Law, 1995). This enables what is known as "perceptual enhancement" to occur. This is the ability of the human reading a visual display, to simply "read off" conclusions directly from the display using unencumbered perceptual observations. Argument maps are not unique in this respect. Another example of this is the type of diagram used in Economics to show the influence, say, of taxation on movement in a supply-demand curve. How this occurs is partly due to the ability of diagrams and maps to group together all the relevant information needed for problem-solving inferences, thereby avoiding the necessity of humans to engage in long and time-consuming searches across propositions represented in sentences (Larkin & Simon, 1987).

The above points make a theoretical case for why visual representations are an improvement on prose representations. But there are also plausible pragmatic arguments that can be made. These will be outlined in Part 2 of this paper along with the experimental data supporting the use of CAAM.

7. Conclusion

This paper has outlined what might be called the visualisation approach to the teaching of argument analysis, an activity essential for doing critical thinking. In particular, I outlined the computer-aided argument mapping, or CAAM approach, using the software *Rationale*™. The above points constitute the case for CAAM as a useful technique. However, these points do not, by themselves, establish that the current approaches to the teaching of critical thinking are inadequate, or that there is evidence to support the use of CAAM. This will be the subject of Part II of this paper.

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