Chapter 6
Cognitive and Pedagogical Benefits of Argument Mapping: L.A.M.P. Guides the Way to Better Thinking

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Abstract Experimental evidence shows that in dedicated Critical Thinking courses "Lots of Argument Mapping Practice" (LAMP) using a software tool like *Rationale* considerably improves students' critical thinking skills. We believe that teaching with LAMP has additional cognitive and pedagogical benefits, even outside dedicated Critical Thinking subjects. Students learn to better understand and critique arguments, improve in their reading and writing, become clearer in their thinking and, perhaps, even gain meta-cognitive skills that ultimately make them better learners. We discuss some of the evidence for these claims, explain how, as we believe, LAMP confers these benefits, and call for proper experimental and educational research.

6.1 The Promise of LAMP (Lots of Argument Mapping Practice)

LAMP is a teaching method where students practise Argument Mapping often and rigorously, and receive timely feedback on their efforts. Evidence suggests that copious argument mapping practice confers substantial cognitive and

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pedagogical benefits. It clarifies thinking, deepens reading comprehension, improves critical thinking, and improves written argumentation. It can promote an enquiring classroom.

Students reaped these benefits from practising a particular kind of Argument Mapping, which we will outline here. If what our initial explorations suggest is correct, we are potentially looking at one of the most important innovations in learning, because LAMP can be used in many types of classroom, such as advanced secondary, gifted and talented education and standard university. We need rigorous, sustained research if we are to realize these possibilities.

6.2 The AM in LAMP

The Argument Mapping involved in LAMP – the kind of mapping we do with a software tool like *Rationale* – is driven by a single question: Given a claim, what reasons (justification, evidence) do I have for and against it? In this way, an Argument Map seeks to represent the best interpretation of the rational considerations brought out by the overall debate. In a sense, it aims to extract the logical essence of the arguments, leaving out the purely discursive elements and uninteresting past, failed moves, and inserting the hidden premises (unstated assumptions) necessary to make the inferences more explicit. Constructing a good argument map requires considerable thought about the claims and evidence and understanding the basic issues, and is far from a mechanical process following an inflexible set of rules. How a student (or anyone) goes from that understanding to assessing the argument itself is rarely taught at any educational level, even though it is crucial.

Although it has evolved to help people (whether academic, in business or other) think through complex issues and decisions, *Rationale* was originally designed to teach Critical Thinking. Its theoretical, cognitive and pedagogical principles spring from a formal understanding of argument, with its roots in Aristotelian syllogism, rather than from tracking the history of a debate. That said, *Rationale* is intended as a tool for representing real, every day, "messy", informal arguments; but with a far greater rigour than they normally have.

One aspect of this greater rigour is the articulation of unstated premises. Consider the following brief argument from a letter to the editor: "The public should be concerned about the rising rat population, because it is a public health risk." Even as simple an argument as this has literally hidden complexity.

Figure 6.1 is a *Rationale* diagram of the argument.[1] It shows a single reason, made up of three premises, supporting a conclusion. (In *Rationale*, reasons are coloured green, objections are red and rebuttals – objections to objections – are orange. See the picture of a more complex map at the end of this article.) The letter explicitly

[1] For more details about *Rationale*™, including its conventions and more examples, see http://rationale.austhink.com/

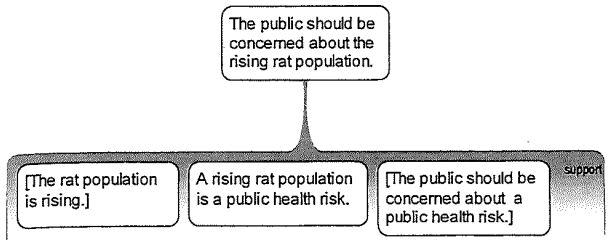

Fig. 6.1 Argument map of short letter to editor

stated only one of its premises, namely, that a rising rat population is a public health risk; but the Argument Map shows all the premises required to make the inference clear, whether stated or not. Unstated premises are put into square brackets, to indicate that these are the mapper's additions to what is explicitly stated in the text. Articulating the implicit, but crucial, unstated premises is an essential skill for reasoning carefully, particularly for responding to someone else's reasoning.

Especially in political contexts, the explicit argument is often a string of unproblematic truisms, while the argumentative work (such as it is) is being done by things left unstated. Unless these are identified, it is near impossible to assess the argument – or even figure out what it is.

With Argument Mapping, most students do learn to recognize many of the unstated premises, challenging though learning that lesson is. Several heuristics help students learn how to locate missing premises.

Holding Hands The Holding Hands heuristic prompts the mapper to look for key concepts that just "dangle" – that is, are found in only one box. In a fully detailed map of a reason or objection, every key term appearing in a premise or in the conclusion must also appear ("hold hands with") either in another premise or in the conclusion. In Fig. 6.1, the key terms "rising rat population", "public", "should be concerned" and "public health risk" hold hands.

The most powerful application of Holding Hands is the "Rabbit Rule" – to pull a rabbit out of a hat, there must be a rabbit in the hat to begin with. "You can't conclude something about rabbits if you haven't been talking about rabbits." More generally, "Every important term in the conclusion must appear at least once (i.e. in at least one premise) in each reason bearing on that conclusion."[2] The Rabbit Rule proves to be remarkably helpful for students. It helps them notice the missing (unstated) premises that so often do so much of the argumentative work.

[2] Footnote for logicians: Some arguments containing logical operators such as universal quantifiers (e.g. categorical syllogisms) legitimately contain such operators as danglers. For example, in 'All men are mortal; Socrates is a man; therefore Socrates is mortal' the key term 'All' is legitimately a dangler.

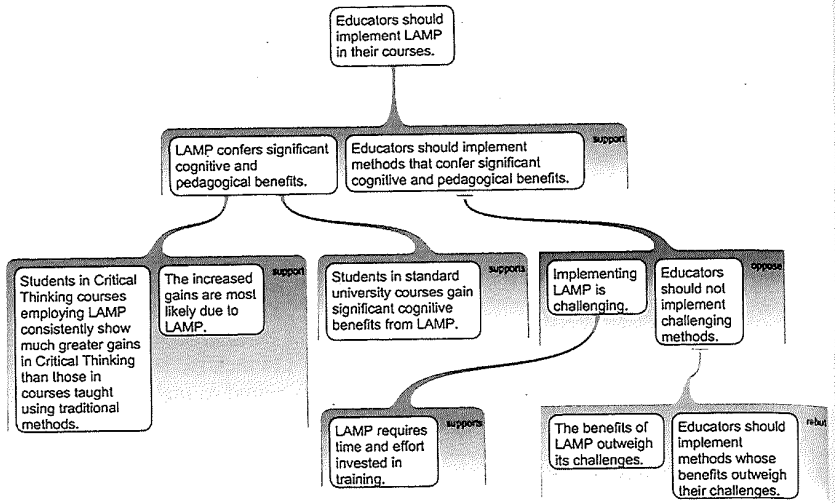

Fig. 6.2 Sample argument map showing some of the colour conventions

In very simple cases, students can easily provide the hidden premise(s). E.g., given "Socrates is a man, therefore Socrates is mortal" they happily add "All men (or all people) are mortal." The Rabbit Rule takes this basic ability and helps the student to apply it to far more complex and subtle cases. The Rabbit Rule illustrates how a heuristic can help an argument map depict the logical structure of the prose original. Like the others below, the Rabbit Rule teaches how to read and write maps and how to distinguish a good map from a poor one – and, by extension, a good argument.

Still, observing Holding Hands exhaustively can be laborious and tedious, and in many cases the suppressed (unstated) premises uncovered are commonsensical and unproblematic. When mapping a complex argument, an experienced mapper need not represent every hidden premise. In fact, most of the time many (perhaps most) of the hidden premises should not be made explicit, otherwise one can't see the forest for the trees. And with reasonably complex arguments, too many trivial premises can result in a most intimidating map, of little use to anyone. Bram van Heuveln (2004) has proposed a "Forest Formula": one should only make explicit those claims with which the inference is sufficiently transparent. He continues, "However, it is not always clear what 'sufficiently transparent' is." Sufficient transparency is almost certainly audience-relative and this whole area needs much careful investigation.

So, students should learn both how to apply Holding Hands and when (and when not) to actually follow it in their maps. Thus, the best way to render an argument is often far from obvious (Fig. 6.2).

In addition to not stating entire premises, people often also leave key qualifications even out of their explicit claims. This brings us to our second heuristic.

How Many? How Much? Most of the time, people's explicit statements leave out key qualifications and, even worse, speakers don't reflect on the qualifications they leave out. Consider someone saying, "Harriet is bad tempered, since she is redheaded".[3] What is being assumed? That all redheaded people are bad tempered? That all redheaded women are bad tempered? That most redheaded people are bad tempered so, on balance, any redhead is more likely to be bad tempered than not? That most redheaded women ....? That all redheaded people in my social circle, ...?? Etc., etc.

It is clear that students benefit from discovering how often they – and almost everyone else – drop these crucial quantifiers, making rational discussion that much harder. Training students to semi-automatically ask, "How many? How much?" helps with this discovery.

Going in Circles Doesn't Get You Anywhere is another useful heuristic. Overt, simple textbook-type examples of circular arguments are rare; people rarely say "Bill is at the store because Bill is at the store." But, by argument mapping, one soon discovers that subtler circular arguments are remarkably common. Reconstructing arguments one often finds the only plausible way to put the argument into the map is to make it circular. One naturally tends to fight this temptation – "Surely all of those words couldn't just be going around in a circle!" But often enough it is. Hidden circular arguments illustrate once again Richard Whatley's (1836) insight: "A very long discussion is one of the most effective veils of Fallacy; a Fallacy which when stated barely would not deceive a child, may deceive half the world if diluted in a quarto volume".

The Principle of Charity is a crucial heuristic for counteracting the strong tendency to caricature the reasoning of those who disagree with us. While philosophers have several versions, we are happy with our simple one: Would the author agree that you have presented her claims fairly? The Principle of Charity requires that students try to identify the fairest interpretation possible.

These heuristics and principles do not automatically guarantee a good argument; a non-circular argument may have no danglers, have its quantifiers all in place and yet still be blatantly fallacious (e.g., "All balls are round; All oranges are round; therefore All balls are oranges"). Such heuristics simply help a student recognize what needs to be added to the explicit prose to produce a well-formed argument map. But, it is also true that students who master them will be far ahead of the general public in thinking clearly.

[3] Based on an example from Scriven (1977).

6.3 The L..P in LAMP

Naturally, Argument Mapping by itself will not automatically confer such Critical Thinking gains, any more than running for the bus every day will make one an Olympic sprinter. That's where "Lots of ... Practice" comes into LAMP. These results were premised on the hypothesis that Critical Thinking is a very complex skill, and that maximum improvement, therefore, requires the same kind of training regime that improvement in any complex skill requires – be it fine-furniture making, Olympic swimming, or mathematical prowess. Based on the research by Ericsson et al.[4] the students' training regime involved extensive, deliberate practice with feedback in mapping and evaluating arguments.

In the dedicated Critical Thinking subjects, the students in the experimental groups did a range of exercises, but primarily mapped and evaluated other people's arguments. Most of these arguments were contained in short texts (around a paragraph long) drawn from the printed media. They were therefore real, messy texts, not texts that were contrived or specifically written to express arguments clearly, so mapping them required interpretation and comprehension. In all, each student tackled around 20–30 arguments in a semester for assessment with feedback. Around the same number of arguments again was available for non-assessable practice exercises, with model answers; but we do not know what proportion of students availed themselves of those.

Once they mapped each argument, students had to evaluate it by assessing the plausibility of the claims and the strength of inferences and record their judgments on their maps. (*Rationale* has an evaluation function that enabled them to do this. Figure 6.3 shows what an evaluated map looks like, using colour variation to represent the strength of each inference.) Students then wrote a short (half page) critique of the argument.

In addition to these critiques, students also mapped their own arguments, such as arguments from their essays in other subjects.

In classes where we integrated LAMP into standard courses, students primarily mapped their own arguments for their essays and weekly mini-papers. These were argumentative responses to their weekly academic readings, so students read longer articles, drew their own conclusions and mapped their own case for those conclusions. Although they were encouraged to begin by mapping the arguments contained in the readings, they were not required to do so and those maps were not assessed. Academic authors' arguments were, however, mapped in class; with students either working in small groups or working as a whole group being led by the tutor.

An ideal dedicated LAMP subject would last for an entire semester of, say, 15 weeks, or would be an intensive of 2 or 3 weeks. It would have short lectures primarily focused on the days' lesson, and most class time would be spent in

[4]For a comprehensive view of acquiring expertise, see Ericsson et al. (eds.) (2006). The basic results can be found in Ericsson and Lehmann (1996).

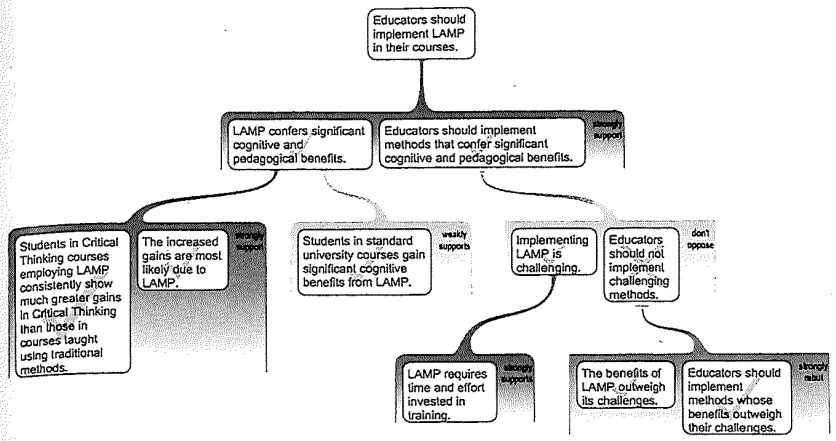

Fig. 6.3 Sample evaluated argument map showing some evaluation conventions

making maps and in students discussing each other's maps. Students would have many assignments and would get immediate feedback as far as possible. That is, they would be able to turn in at least part of their assignments and get useful feedback within, say, 10 min. Computerized assessment of some aspects of the maps would make this easier by providing rapid accurate feedback for students while relieving the teacher of a considerable amount of the grading and commenting on student work.

As most educators will appreciate, we are not yet able to give students rapid feedback on their maps – although Ericsson's and other research on expertise emphasizes the considerable advantages of immediate feedback. The computerized feedback is not yet available, but it is, we hope, just a matter of time before it becomes available.

Given how far the initial experiments were from an ideal LAMP situation, the massive improvement found in them is all the more impressive. Alvarez's meta-analysis found that such critical thinking courses produced gains of around 0.70 SD in one semester, about twice as much as standard critical-thinking courses (Alvarez 2007, pp. 69–70 *et seq.*) and about six times as much as a semester of a standard undergraduate course. The tests used in the reviewed studies were standard critical-thinking tests. In taking these tests, the students did not make argument maps, did not have access to argument-mapping software, and were under considerable time–pressure.

Since those initial experiments, and since the original version of this chapter was published, we have collaborated with other educators in an IARPA-funded research project to improve the textbook and other materials and test the pedagogical efficacy of LAMP. The team conducted further experiments, with a total of around 140 adult students in 7 different groups. These experiments combined

Table 6.1 Two experimental conditions

	Normal scrutiny (experiments 1 to 6)		Extraordinary scrutiny (experiment 7)		All expts	
	Standardized ES	95 % CI	Standardized ES	95 % CI	Standardised ES	95 % CI
CCTST (5 exp'ts)	0.847	[0.57, 1.12]	–	–	0.847	[0.57, 1.12]
HCTA (2 exp'ts)	0.721	[0.46, 0.98]	0.008	[−0.45, 0.47]	0.539	[0.32, 0.76]
LSAT (All exp'ts)	0.370	[0.24, 0.50]	−0.054	[−0.38, 0.27]	0.307	[0.18, 0.43]
All	0.505	[0.40, 0.61]	−0.033	[−0.29, 0.22]	0.424	[0.32, 0.52]

LAMP with Mastery Learning and Peer Instruction principles. They were conducted with a variety of subjects in a variety of settings, ranging from midshipmen at the US Naval Academy through Canadian Border Services Agency (CBSA) analysts and NATO analysts at RAF Molesworth to bright undergraduates in an American and an Australian university; so not all teaching formats conformed to traditional university teaching. In each experiment, the students were pre- and post-tested using two of the following critical thinking measures: the California Critical Thinking Skills Test (CCTST), the Halpern Critical Thinking Assessment (HCTA) and the Logical Reasoning subsection of the Law School Aptitude Test (LSAT). As with the previous experiments, during the pre and post testing, students did not have access to argument mapping software. Thus, the tests measured the transfer from argument mapping-based learning to critical thinking questions without argument mapping.

There were two experimental conditions. In accord with previous critical thinking research, subjects in Experiments 1 through 6 (Normal Scrutiny) were taught to scrutinize co-premises for *prima facie* plausibility. In Experiment 7 (Extraordinary Scrutiny), they learned how to scrutinize such co-premises in far more detail and to unpack many of them into background causal and conceptual presuppositions, which in turn were to be scrutinized. Although time-consuming to teach and to apply, such extraordinary scrutiny is often crucial in important espionage, legal, and scientific investigations. Still, subjects in this experiment did much worse on the time-limited standardized tests than subjects in the other six experiments.

As Table 6.1 shows, the Normal Scrutiny results reinforce the existing evidence for the effectiveness of argument mapping courses in improving the critical thinking skills that standard tests do measure.

The improvements on the first two tests that are explicitly designed to measure critical thinking are considerably greater than improvements on the LSAT, with its high literacy loading. The LSAT was designed to predict first year law school grades. While the LSAT is, beyond question, an excellent instrument for measuring critical thinking *ability*, we are not sure of its usefulness in measuring *improvement*

in that ability – except perhaps in certain very specific contexts.[5] This is because doing well in the LSAT depends on so much more than critical thinking ability: reading speed, general literacy, and working memory capacity, all of which strongly influence LSAT performance; yet we never expected LAMP to substantially improve any of these.

The results of the Extraordinary Scrutiny experiment reflect that standard critical thinking tests do not measure the intensive scrutiny skills the experiment was intended to teach. Extraordinary scrutiny of test items takes considerable working memory and slows down performance scores in timed tests. Yet, in some circumstances, extraordinary scrutiny is crucial to thinking clearly on important issues. Thus, there is a danger that, when present critical thinking tests are used, excellent courses that emphasize Extraordinary Scrutiny may wrongly be seen as ineffective.

To briefly summarize the IARPA results: using standard critical thinking tests and standard LAMP techniques, one can expect about 2/3 of a SD improvement in critical thinking ability – twice what one gets from other techniques and about six times the average student's improvement in an average semester.

6.4 Experimental Evidence for LAMP's Cognitive and Pedagogical Benefits in Dedicated Critical Thinking Courses

With regard to Critical Thinking courses, the combined university and IARPA evidence for LAMP is straightforward: university students doing a semester's subject with reasonably intensive practice in analysing and evaluating short arguments *improved in their ability to think critically twice as much as students in traditionally-taught Critical Thinking courses, and three to four times as much as students taught in standard undergraduate courses.*[6] These dramatic results were obtained from several hundred students and professional analysts at half-a-dozen institutions of very different types, and were consistent over several years and with different teachers.

[5] We have reason to believe (from personal communication) that the LSAT has been successfully used to measure improvements in critical thinking in an as-yet-unpublished experiment involving argument mapping at Princeton University. Note, however, that Princeton undergraduates are a highly select bunch who, unlike the average subject of our experiments, already possess the high level of literacy needed to get a substantial improvement on LSAT critical thinking.

[6] For reviews of the earlier experimental evidence , see Twardy 2004; van Gelder *et al.* 2004 and Alvarez (2007).

6.5 Evidence About LAMP in Standard (i.e., Non-CT) Classrooms

What does this mean for the teacher in the regular university or secondary classroom where, except in the rarest of circumstances, intensive Critical Thinking training *per se* is not an option? Unlike the strong evidence for dedicated Critical Thinking subjects, here the evidence is anecdotal. Although further research with extensive trials is very much needed, our own experiences are encouraging.[7]

All the data below come from a first year philosophy subject, two second/third year subjects and two honours (fourth year) subjects. In total, about 500 students were taught over 3 years. In some subjects, argument maps were integrated into the lectures. In all subjects, students' homework required argument maps of the readings.[8]

From our experience of integrating LAMP into standard university classes, it is clear that it can be done without sacrificing content, at least when the teacher and teaching assistants are sophisticated mappers.[9] We do believe that it confers broader cognitive and pedagogical benefits, though the evidence is much more informal than in the case of dedicated Critical Thinking classes. In the case of all of the following improvements, we strongly believe students using Argument Mapping progressed much further and much faster than in ordinary classes. Yet we must stress that the evidence here is anecdotal. In putting forward these claims, we aim at persuading readers not so much of their truth, as of the importance of subjecting them to proper experimental scrutiny. If there is substance to our observations, LAMP deserves much greater attention from educational researchers than it has hitherto received.

We perhaps should say something about doing careful scientific research in this area. It is difficult, expensive and time-consuming. It is not easy to get an adequate sample size of students in intervention and control groups. It is harder to get an appropriate control group of classes, ones taught by equally committed teachers using traditional methods. While there are several reasonably good standardized tests for Critical Thinking, they are really only useful for pre- and post-testing for a critical thinking subject. We know of no well-validated standardized subject related tests, such as a test of critical reasoning in history, or philosophy, or political science.

[7] In one subject we gathered feedback half-way through the semester. The results of that feedback are given here whenever relevant.

[8] Since the first edition of this chapter was published, other instructors have used versions of LAMP in standard undergraduate courses. One as-yet-unpublished experiment was conducted at Princeton University and compared LAMP results with a control, with encouraging results (personal communication). As far as we are aware, this is the only controlled, pre-post-tested study of an argument mapping intervention in a standard classroom. We hope there will be more.

[9] We have mostly used Argument Mapping in university subjects, though we have had some experience with senior secondary and with gifted primary school students, as well as with professional adults in the IARPA project.

In the absence of such tools, the researcher must rely on inter-subjective expert ratings of student papers. While valuable, such ratings can face several difficulties. First, the questions have to be such that the rater cannot distinguish pre-intervention from post-intervention material, except perhaps by the change in question. But, often after a LAMP subject, students use many more connective words such as "thus" and "because". Such words can inform the rater of which group the subject was in, thereby breaking the blind. Second, it is unfortunately not obvious that all experts in such disciplines really are experts in assessing the logical structure of the argument presented. I.e., not all well-established academic "experts", regardless of their other qualifications, really have mastered argumentation in their discipline. This can become a tricky, socially awkward issue. Finally, it is not easy getting grants required to get robust data.

Still, these difficulties can be overcome and we intend, in the fullness of time, to overcome them. All offers of help gratefully received.

Let us now turn to specific ways students appear to have improved.

6.5.1 *Students Became Better at Questioning Arguments*

The written assignments and tutorial discussions increasingly showed that students understood objections and how to raise them. For example, they became far better at targeting their own criticisms to specific parts of a given argument, and began to see how to substantiate and justify their criticisms beyond simply stating their disagreement.

Students also became better at distinguishing objections to a conclusion from objections to one of the reasons for that conclusion. We believe that Argument Mapping greatly helped learning this key distinction and applying it in practice. But we only have informal evidence for this, striking though the effect appeared to us.

6.5.2 *Students Became Better at Reading*

The quality of weekly tutorial discussions and of weekly written assignments, where students were required to read and comment on a small set of readings, improved as the semester progressed.[10] Discussions and assignments exhibited a greater understanding of the material and of its significance in the broader context of the weekly topics. Students read less for "general feel" and more for conclusions and arguments. They became much better at such crucial basic tasks as distinguishing premises from conclusions.

[10] Their maps, also, reflected this shift, though it is difficult to separate their mapping skill from their understanding.

The difference can be dramatic. For example, before a semester of argument mapping in an introductory Philosophy of Science class, we asked students to identify the main conclusion in the first few pages of Popper's warhorse article, "Science: Conjectures and Refutations" (1952). Many pointed to something that was salient or interesting for them, such as "astrology is a pseudoscience". They did not seem aware of the role this claim played in Popper's argument. After a semester of argument mapping, they were much more likely to approximate the main contention – in Popper's case, along the lines that true science makes bold conjectures and then tries to falsify them.

6.5.3 *Students Became Clearer in Their Own Thinking*

Again, our impressions were formed primarily from the students' written work and from the tutorial discussions. What's more, students themselves seemed to think that Argument Mapping helped them think more clearly. In the mid-semester feedback, 63 % agreed with the statement "Argument Mapping helps me think more clearly"; 15 % disagreed. In addition, 85 % of students agreed with the statement, "Argument mapping makes me think harder about what I am arguing" (7 % disagreed and the rest were uncertain). What we've gleaned is that LAMP clarifies students' thinking in regard to specific issues.

We also suspect that LAMP improves students' metacognitive skills because it would be surprising if the acquisition of the concepts of conclusion, reason, objection, etc., did not give students categories for understanding and reflecting on their own thinking; it would be odd if the process of identifying hidden premises both in others' arguments and in their own did not make them aware in general that their thoughts depend on unarticulated, often problematic, assumptions.

6.5.4 *Students Became Better at Argumentative Writing*

We saw considerable improvement in students' weekly mini-essays in two ways. First, there was a gradual shift from what we term "argument by association" to real arguments; i.e. a shift from "Here's everything I can think of to say about such-and-such" to "Here are the arguments for and against the claim that such-and-such". As one student wrote, Argument Mapping made writing papers "more difficult, because it seemed that all of my ideas had to somehow connect with each other"!

Second, students' later attempts were better structured, both in the order of presentation and in the use of indicators – expressions that clarify the evidential or inferential relationships between ideas. In one informal poll, about 60 % of the students said Argument Mapping interfered with their ability to write BS rapidly,

which we took as a good sign.[11] Ironically, 46 % also thought that it interfered with their ability to express themselves clearly. It is unclear what the second, rather high, figure means. Are students simply complaining that their writings must be more logically coherent? In that case, we can happily live with the objection. Or is there some deeper concern being expressed? More research is needed.

Our listing these benefits of integrating LAMP into a standard subject is not to say that dedicated Critical Thinking classes using LAMP are not preferable. They almost certainly are. It is, however, to say that we believe that substantial improvements in critical thinking can happen in regular classrooms, if they regularly use argument maps both in lectures and class discussion groups. This should be tested in several ways, over a range of subjects from history to English, student levels, and teacher understanding of argument maps. Integrating argument maps into lectures as well as discussion groups is another dimension that needs much more exploration. We do not expect a simple picture to emerge from such research, but do expect considerable improvements in subjects where students are expected to learn how to reason on their own about the material. We also expect that our techniques would be considerably improved if not abandoned altogether for better ones.

6.6 How LAMP Confers These Benefits

Fundamentally, we believe that LAMP, whether taught in dedicated critical thinking subjects or in standard content subjects, works because of two interrelated factors. First, Argument Mapping clarifies students' inchoate concept of argument. Second, lots of quality practice ensures that students truly grasp the concepts in a practical and applied (as opposed to vague and theoretical) way.

We strongly suspect that these factors, in combination, produce much better results than either would produce in isolation. In other words, we suspect that students would not get the same substantial benefits either from occasional Argument Mapping alone or from lots of quality practice using a more discursive argumentative method.

It is unclear why LAMP is so effective. Perhaps it is because Argument Mapping makes highly abstract (inferential/evidential) relationships explicit by representing them as spatial relationships; perhaps also because the kind of practice it affords is very precise and constrained; perhaps also because in mapping one lays aside most words so one can better see the logical structure.

These are big questions for the psychologists and educationalists, and we can only gesture towards them here. Instead, in this section we will address some of the practical skill elements we think responsible for the benefits we have observed.

A key element in all of what follows is the ability Argument Maps confer on the instructor to give targeted and timely feedback. It goes without saying that students simply putting sentences in boxes does not automatically lead to any of the benefits

[11] 'BS' was code for bovine excrement.

above. Some students, when asked to accompany a written response with an Argument Map, write their response and then just cut-and-paste their vacuous prose into boxes – a practice with no value whatsoever. For the teacher, however, a lousy map immediately exposes the student's fuzzy thinking. It is less tempting to try reading sense into a map, perhaps simply because of the discrete nature of diagrams: we are not seduced by the apparent continuity of prose. If we fail to understand a paragraph, we may put it down to our own lack of concentration. Failure to understand a map, however, is a clear indication that mapping conventions have been sloppily applied and the failure to communicate clearly lies squarely with the student.

A map helps the teacher give very quick feedback on structure and clarity of thought. For example, a teacher's putting a question mark on an inference arrow, or identifying a term as a "Rabbit", immediately tells the student that that inference doesn't follow. If the task is to analyze someone else's argument the teacher can provide a model map to which students can compare their own. Disagreements in interpretation can focus subsequent debate. Educational research has shown that prompt feedback is much more effective than detailed comments received long after a student completes a task. The minimal and transparent nature of maps makes this feasible. An in-class mapping exercise allows the tutor – or indeed other students – to comment on maps as the students are engaged in constructing them and while the thoughts are fresh in their minds.[12] By contrast, imagine trying to give feedback while students are writing prose!

We should note that marking is fastest and most useful once a student has learnt to map reasonably well, otherwise it can be difficult to distinguish problems with grasping mapping conventions and problems with thoughts. By the same token, the basic principles of mapping (with the possible exception of identifying hidden premises) are generally not difficult to understand; so if poor mapping persists beyond an initial introductory period it is not unreasonable to conclude that the difficulty is with the thinking rather than with mapping per se.

Maps make "moves" in argumentation highly visible. Both student and teacher can instantly see the strategies employed by the student in tackling an issue, just by looking at the configuration of red and green boxes on the map. Students can quickly learn that arguments containing objections (and rebuttals to those objections) are likely to be less vulnerable than arguments made up of mountains of green boxes. Because of the mapping conventions, a map will also quickly alert a student to an unrebutted objection, and hence to a weakness in their case. Again, see the sample map at the end of this article.

[12] For a glimpse at some of the benefits of fast feedback and collaborative learning see Mazur (1997).

6.6.1 *Improved Reading Comprehension*

Reading and mapping an argumentative piece of prose is very complex. When they attempt to map someone else's argument, students must ask, "What is this person actually saying?" "What are the reasons given?" Students must determine what is part of an argument and what is irrelevant. They must distinguish an argument from additional, background information, rhetorical flourishes, repetitions, paraphrases, elaborations and illustrations. Beginners often try to fit onto the map every sentence of a text or every interesting point, whether or not it is germane to ascertaining the truth of the conclusion.

Students must also distinguish the main argument(s) from subsidiary or minor arguments. Then they must identify the different parts of an argument – the main conclusion (not always articulated by the author), reasons for and against, evidence, rebuttals and so on – and make explicit the roles different claims play in relation to one another. They must distinguish an author's rebutting an objection from an author's self-contradiction. They must be able to paraphrase the author's claims, refining them by simplifying, clarifying, making them easier to understand and more precise, eliminating vagueness and ambiguity where possible (e.g. by using quantifiers), and they must do all this without misrepresenting the author's intent. In addition, they must be able to fill in the blanks of all that is implicit in the prose presentation of an argument. They may need to extrapolate, abstract, and identify hidden premises sensibly and fairly. Students understand an argument more clearly to the extent that they manage to articulate its assumptions successfully. Attempting to articulate someone else's assumptions requires that mappers actively and consciously interpret texts in a way they are otherwise unlikely to pursue.

When all this is done in the context of the overall class topic, students can better see the connections between the arguments of different authors. It is easier for them to see the bigger picture when they have clarified its parts. Of course, seeing the bigger picture further enables them to grasp the significance of the detail, and this dynamic interplay between part and whole significantly enhances their understanding both of any particular author's perspective and of the overall issue or debate.[13]

How does LAMP help a student master all those "musts"? We think it is primarily that, by mapping an argument's logical structure, the student becomes aware of each of these tasks. The mapping process itself makes each requirement more salient, in no small part by eliminating those parts of the prose that do not contribute to answering the questions: What is the author saying? Is it true? Once the goal is clear, students begin to look for ways to achieve it; and perhaps the more they practise trying to meet these requirements, the better they become at meeting them.

[13] The failure to truly understand what we're reading extends far beyond students. In one workshop, hardened bureaucrats were scandalised when they realised they were unable to articulate the argument in a memo. 'And yet,' they said, 'this is so utterly familiar! I read things like this all the time!'

6.6.2 *Improved Questioning of Arguments*

Once students understand that an Argument Map is driven by the question, "Why should I believe that?", they begin to better grasp the key notion that an argument is based on justification and evidence. This fundamental understanding enables them to query claims that lack support, and begin to spot inferential leaps.

Careful analysis makes an argument much easier to interrogate. Having identified the premises, including hidden ones, a student can question their reliability and raise objections. Having made the inferential relationships explicit, a student can evaluate their strength: "How well does this support that conclusion?" "Does this really follow?" Finally, having articulated all the arguments presented by an author, the student can ask, "Are there any important considerations missing?"

More generally, maps make thorough evaluation possible. Around four decades of psychological research has shown that there is a range of cognitive biases affecting judgment.[14]

One widespread bias is our tendency to forget or downplay evidence against our beliefs. Making all the arguments explicit prompts people to consider a greater number of relevant considerations, not just the most salient or favourable ones.

How would this work? Why would argument mapping get people to explicitly state otherwise unstated material? After all, crucial objections and awkward facts are not likely to be implicated by holding hands. The answer may lie in students' different psychological attitudes towards prose and maps.

We have observed that, when writing prose, students strongly tend to just present the case for their position with, at most, a bit of a caricature of the opposition. They seem to have little appreciation for J. S. Mill's lovely insight in *On Liberty*: "He who knows only his own side of the case knows little of that".

Argument Mapping, on the other hand, when the map has not become too complex, seems to bring out students' recognition that often different people have differing positions, that those alternatives do not necessarily show that the other person is an idiot, and so they should be presented with at least some attempt at accuracy and fairness.

We suspect that there is a couple of reasons for the different attitudes toward argument maps and prose presentations. First, for reasons which remain obscure, putting arguments into an argument map tends to make students see the propositions more as a logician would, rather than as an advocate would. Perhaps it is because the argument maps stress the logical structure and considerably downplay rhetorical manoeuvers. Second, with the pro-argument there in its logical clarity, somehow objections seem psychologically more accessible. But we really don't yet understand why this should be.

[14]There is a huge literature on these topics. For an accessible, well-written introduction, see Kahneman (2013). The classical anthology is Kahneman et al. (eds.) (1982). A more recent excellent anthology is Schneider and Shanteau (eds.) (2003).

Students can learn to evaluate a map systematically. In the courses that achieved substantial gains in Critical Thinking skills, students were required to assess each claim for truth, reliability or credibility, as well as explicitly assessing the strength of each inference and, where appropriate, the extent to which the case presented was complete (i.e. to look for major considerations that might be missing). When these judgments are recorded on a map, weaknesses such as unreliable sources, dubious premises, questionable assumptions and fallacious reasoning are made highly visible, as is the way they infect a whole chain of argument. Only when they have carefully assessed every sub-argument and questioned the case's completeness can students assess the main contention and draw a reliable conclusion. Not only are such cumulative judgments more rigorous than any we perform by relying strictly on our memory; they also give a student a much deeper understanding of what it takes to be justified in holding a belief.

6.6.3 *Greater Clarity of Thought*

Good mapping requires students to put clear, concise statements in each box, which encourages them to "distil" the key ideas in an argument and express them through a precise sentence. This, combined with the fact that they may not insert extraneous information into a map, discourages waffle (a consequence many resent). When mapping their own arguments, students must keep answering the question, "What am I really trying to say?" They are constrained to be much more explicit about what they think. In order to map their own opinion, they must articulate it much more precisely and argue for it much more cogently than they are likely to do in prose, which has a much higher "fudge factor". Mapping also prompts students to support contentious claims and to anticipate and rebut objections. Further, articulating their own assumptions clarifies their own thinking,

When constructing maps collaboratively, students discover where they disagree with one another; and through their discussion they more deeply understand their own and their fellow students' positions.

6.6.4 *Improved Writing*

The box and arrow diagrams emphasize in students' minds how claims are evidentially related – what counts as evidence for or against what – since that is what the lines in argument mapping mean. Mapping prompts students to move away from the usual tendency to respond to questions in a vague and thematic way (what might be called the "keyword" or "essay-by-free-association" approach: here's everything I know/can think of saying about X) and try to construct an argument instead. We

are convinced that even our bright university students' intuitive grasp of arguments is extremely poor.[15] Few can initially tell the difference between a conclusion arrived at by chains of inference and something simply paraphrased and repeated in the spirit of "What I say three times is true". For all too many students, "therefore" means "and here's another thing I've thought of".

A students' prose can easily obscure an argument's logical poverty, not least of all from a sympathetic teacher, since the teacher can intuitively construct connections between ideas that may not, in fact, be present in the student's head. By overly liberally interpreting what students write, we may be robbing students of the opportunity to learn both how to think clearly and how to articulate those thoughts clearly.[16] Argument mapping puts the onus back on the student to construct and communicate a cogent argument.

Even as they come to far better grasp the notion of an argument, still all too often students think as they write. Consequently, their prose is little more than the diary of their amorphous journey through a brainstorm of ideas. When students construct their map, reach their conclusion and so clarify their thoughts before starting to write, they can convey their reasoning more clearly and in a more structured way. This is not simply because they know what they think and what they want to say before they start writing – a significant benefit in itself. It is also because the map's structure suggests good ways of structuring the paper.[17]

Since mapping encourages a more careful reading of other people's texts, students are likely to treat other authors' opinions more fairly and with more insight. They can better detect vagueness both in their own and in others' ideas, and accordingly present tighter arguments. Rhetorical questions, caricatures and melodramatic overstatements may at best be cognitively vacuous and at worst actively limit or constrain subsequent thinking. They are more plausible in prose than in maps. For instance, if someone says "Textbooks are rubbish" they don't really mean it universally and categorically – it's clearly an exaggeration – but they may nevertheless feel subsequently constrained (by some psychological need to remain consistent) to dismiss all textbooks and so not do the hard work of engaging with such serious issues as whether or not, for example, the way textbooks often simplify topics is a good or bad thing educationally. Beginning with a map, the student can avoid heading in melodramatically overstated directions.

[15] This is not surprising. As Deanna Kuhn (1991) showed, people's grasp of argument is poor in general. Kuhn's own studies were conducted in the US; but there is no need to assume the situation is better elsewhere.

[16] See Thomason (1990).

[17] There are ways for a teacher to focus on and scaffold this process of producing written prose from a map. We have constructed both a step-by-step guide for doing so and exercises to hone the skill.

6.7 The Enquiring Classroom

Generally, we believe that employing LAMP in classes creates an atmosphere of enquiry. Because mapping is structured, students better understand the task before them and so can benefit more by discussions with their fellows.[18] Further, maps often help some students who are reluctant to speak in class. Pointing to a map and saying, "Can you think of any evidence that this is or is not true?" or "Do you think this is a good reason to believe that?" can clarify the task for such students.

The bane of most classroom discussions is that they often meander all over the place, go off on tangents and miss the point. Maps help keep discussion on track. The teacher simply has to literally point to a contentious statement on the map and re-focus attention on it by asking such questions as: "How do you see that as bearing on this point?" "Do you mean that this statement is not true because...?" "Remember we're trying to decide whether or not to accept this statement (or whether or not this is a strong reason/objection). How does this discussion help us do that?" "How can we put your point onto the map?" The visual representation of an argument makes it much easier to return the discussion back to where the meander started from.[19]

In our experience, mapping an argument helps depersonalize the argumentative process in a liberating way, increasing candour on sensitive issues and defusing tensions by making disagreements more impersonal. Jeff Conklin has reported a similar phenomenon in organizations, using his form of dialogue mapping. Mapping seems to make it easier to disassociate a point made from the person who made it. Objections are not inadvertently treated as *ad hominem.* Criticisms are seen as directed at statements or inferences on the map, not at their source. Students' views are given a certain validation or legitimacy by being added to the map; and once added, statements or judgments are part of the (abstract) argument and need not be seen as representing a particular person's point of view. The teacher can encourage this attitude further by saying things like, "What do you imagine someone who disagrees with this might say?" or "Can you think of something someone might say to support this point?", thereby prompting students to think of arguments as abstract links between ideas rather than as expressions of one's dearly held beliefs.[20] Still, more research is needed.

[18] On the benefits of peer instruction, see Mazur (1997) and Thomason (1990).

[19] Thirteen out of twenty-eight students (46 %) agreed that argument maps helped keep tutorial discussions on topic, seven (25 %) disagreed, while eight respondents were undecided.

[20] We have seen this not only in classroom situations but in the corporate world as well. When facilitating a meeting on a politically sensitive issue where no one was prepared to be seen to be breaking with the 'party line', we found that genuine, valuable discussion got going only once someone said, 'I don't actually think this, but someone might say...', whereupon others joined in and voiced much underlying anxiety in this way.

6.8 Other Teachers' Experiences with LAMP

Since the first publication of this volume, other teachers have embraced LAMP. One very reluctant convert was a participant in the IARPA-funded experiments, who had this to say afterwards:

> I was a sceptic when I agreed to be part of the project. After teaching the class, I now think that argument mapping is considerably more effective than I'd previously thought. I now think that a mapping-heavy approach to teaching reasoning is promising, and worth pursuing. I've integrated more mapping into my standard CT course, and I now require students to purchase and use *Rationale*.

Another teacher, who had also originally been sceptical, incorporated argument maps into his small university seminars on Kant in a different way:

> We spent the semester working through the first Part (Critique of Aesthetic Judgment) of the *Critique of Judgment*. Each week students had to bring in maps of whichever sections we read that week. In most classes I spent a significant amount of time going over my own map of the relevant section(s). For their first graded assignment, they turned in a short paper, a map of the paper, and maps of the relevant sections of Kant. [...] I spent very little time explicitly teaching the maps in class, other than talking about co-premises, the Rabbit Rule, and adding implicit premises. Discussion of their maps in class was usually brisk; I didn't do it every class. Nevertheless, the students' maps have improved markedly over the course of the semester.

Despite spending little class time explicitly teaching Argument Mapping, his experience was that students understood the text much better than when using traditional methods, and that they produced argument maps that were "markedly better" than their papers – clearer and more understandable than the written or verbal discussions they presented.

> Many students seem to think that they need to sound 'educated' or 'literary' or something like that. The papers are often badly written, wordy, hard to follow, while the maps of those very papers are clear and to the point.

Although his class was too small to permit sweeping generalisations about argument mapping, written student comments are heartening.

Question: Did your mapping of Kant's CJ help you to understand it? Please explain.
Student: "Yes! I would read a passage and think I understood what he was saying, but the maps actually made me focus on his specific words and what they meant. The maps also helped me see and pick out his arguments."
Question: How would you compare (a) the process of reading Kant while trying to map his arguments with (b) the process of reading Kant without trying to map the arguments?
Student: "I would not have understood it [Kant's text]. Or, I would have read it and come to a conclusion completely different than the one he intended. This class without maps would have been impossible for me."

6.9 Conclusion

LAMP is Lots of Argument Mapping Practice, where the students analyze and comment on the strength or weakness of arguments, receiving timely feedback from instructors. They map their own arguments, as well as arguments contained in real texts of varying lengths.[21] Students engaging in LAMP derive substantial cognitive and pedagogical benefits.

There is good evidence that LAMP, rigorously applied in a semester of a dedicated Critical Thinking subject or in intensive many-day workshops, confers spectacular gains in critical thinking skills compared to standard courses. However, solid research on its benefits and costs when used in a standard classroom is not yet available. What we have offered here is a preliminary judgment based mostly on our experiences as instructors and partly on students' self-reports. Admittedly the evidence is thin. We need proper experimental and educational research. Are our judgments really justified? If we are right about LAMP and it can benefit younger students, how can it best be incorporated into classrooms? Is there an optimal age at which Argument Mapping should be introduced? Does LAMP work with all kinds of students? What are its effects on students less sophisticated than ours? Do other kinds of mapping confer similar benefits? What sorts of benefits might be derived from a simpler type of argument mapping, where students map reasoning but aren't required to identify hidden premises? How much practice makes a difference? How much training do instructors need in order to employ LAMP successfully? How and why does it really work? Far too many questions remain. Until they are answered our own conviction is the best we have.

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[21] By 'real' texts we mean genuine texts derived from published sources, not artificially simple texts contrived by us. The task of understanding and mapping real examples of arguments is much harder, since such arguments are seldom clearly laid out in prose.

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Chapter 7
Scaffolding School Students' Scientific Argumentation in Inquiry-Based Learning with Evidence Maps

Alexandra Okada

Abstract This chapter reports a research work investigating the potential of Evidence-based Dialogue Mapping to scaffold young teenagers' scientific argumentation. Our research objective is to better understand students' usage of dialogue maps created in Compendium to write scientific explanations in inquiry based learning projects. The participants were 20 students, 12–13 years old, in a summer science course for "gifted and talented" children in the UK. Through qualitative analysis of three case studies, we investigate the value of dialogue mapping as a mediating tool in the scientific reasoning process during a set of inquiry-based learning activities. These activities were published in an online learning environment to foster collaborative learning. Students mapped their discussions in pairs, shared maps via the online forum and in plenary discussions, and wrote essays based on their dialogue maps. This study draws on these multiple data sources: students' maps in Compendium, writings in science and reflective comments about the uses of mapping for writing. Our analysis highlights the diversity of ways, both successful and unsuccessful, in which dialogue mapping was used by these young teenagers. It also presents future work on knowledge maps for social personal and open environments by including examples from the OpenLearn, weSPOT and ENGAGE projects.

7.1 Why Is It So Hard to Argue Scientifically?

Within the school science education research community, there is increasing concern about the weakness of students' scientific thinking skills, particularly about the quality of argumentation. Teaching how to argue with evidence is essential for students to understand how scientific knowledge is constructed and validated. In

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