# Evidence-Based Dialogue Maps as a Research Tool to Investigate the Quality of School Pupils' Scientific Argumentation

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**Abstract**

**This pilot study focuses on the potential of Evidence-based Dialogue Mapping as a participatory action research tool to investigate young teenagers' scientific argumentation. Evidence-based Dialogue Mapping is a technique for representing graphically an argumentative dialogue through Questions, Ideas, Pros, Cons and Data. Our research objective is to better understand the usage of Compendium, a Dialogue Mapping software tool, as both (1) a learning strategy to scaffold school pupils' argumentation and (2) as a method to investigate the quality of their argumentative essays. The participants were a science teacher-researcher, a knowledge mapping researcher and 20 pupils, 12-13 years old, in a summer science course for "gifted and talented" children in the UK. This study draws on multiple data sources: discussion forum, science teacher-researcher's and pupils' Dialogue Maps, pupil essays, and reflective comments about the uses of mapping for writing. Through qualitative analysis of two case studies, we examine the role of Evidence-based Dialogue Maps as a mediating tool in scientific reasoning: as *conceptual bridges* for linking and making knowledge intelligible; as support for the *linearisation task* of generating a coherent document outline; as a *reflective aid* to rethinking reasoning in response to teacher feedback; and as a *visual language* for making arguments tangible via cartographic conventions.**

## 1. Why is it so hard to argue scientifically?

There is increasing concern about the weakness of pupils' scientific thinking skills, particularly about the quality of argumentation within the school science education research community. Teaching "scientific argumentation", which is defined by Suppe (1998) as the coordination of evidence and theory in order to support or refute an explanatory conclusion, model or prediction, is not an easy task. Teachers need to support students in understanding how scientific knowledge is constructed and validated. They need to equip young teenagers with the ability to assess claims and argue with evidence.

Scientific argumentation skills do not come naturally. Teachers need to assist pupils in making their thinking explicit, helping them to clarify and shape their reasoning around the norms and

criteria which underpin scientific discourse (Hogan and Maglienti, 2001:683). Simon, Erduran and Osborne (2002) emphasise scientific reasoning is a special form of discourse that needs to be developed and appropriated by pupils through suitable tasks, and through "structuring and modelling". In order to help pupils scaffold scientific argumentation, teachers need to show how to set out strong components and establish good connections. They also need to be able to investigate pupils' argumentation by acting as teacher-researchers.

A good scientific argument is constituted by both domain knowledge and argumentative knowledge. Simon et al. (2002:2) point out "*scientific rationality requires a knowledge of scientific theories, a familiarity with their supporting evidence and the opportunity to construct and/or evaluate their inter-relationship.*" Means and Voss (1996) also highlight that subject knowledge and personal experience to elaborate arguments are two important components for argumentation. In order to argue, pupils need to use both scientific concepts and their own arguing skills to ground their reasoning. The more knowledge is integrated in their arguments, the richer is their argumentation (Schwarz and Glassner, 2003:230).

Previous work highlights the importance of developing methods for teachers to help pupils who often struggle to connect data and theory in order to validate arguments (Kuhn, 1991; Means and Voss, 1996; Hogan and Maglienti, 2001). Schwarz and Glassner (2003:232) report that pupils do not know how to connect, check or challenge arguments, and apply them in further activities: "*In science, children 'see' arguments; however they are 'paralytic' concerning the argumentative activities of which these scientific arguments may be the subject*".

There are methodological challenges for analysing argumentation and its quality in audio, video, and written work. Simon et al. (2002) describe the effort required to identify the main claim in an argumentative discourse by identifying which claims are substantive or subsidiary, through repeated analysis of audio records to hear the force of various statements. Another difficulty is in the "normative reconstruction" of arguments from natural discourse (van Eemeren et al., 1993, p. 38). For instance, it can be difficult to determine what constitutes data or warrants for an argument when they are not preceded by words such as "because", "since" or "as" (whereas counterarguments can be more easily identified through markers such as "but" and "however"). Schwarz and Glassner (2003) also agree that difficulties in argumentation analysis are not surprising, since it is intellectually demanding even for professional researchers to tease apart the argumentative moves that peers make.

This pilot study, the first in a long term research programme, focuses on the potential of a technique called *Evidence-based Dialogue Mapping* as a participatory action research tool to investigate young teenagers' scientific argumentation. An Evidence-based Dialogue Map is a graphical representation of argumentative reasoning or dialogue, designed to focus attention on the connections between Questions, Ideas, Pros, Cons and Data. We have developed an open source software application called *Compendium* which enables electronic Evidence-based Dialogue Mapping. Compendium provides a set of icons and coloured arrows to represent these five elements and their inter-relationships.[1]

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[1] An earlier report of this work which is less focused around Dialogue Mapping as a research methodology, and reports more pupil data, is presented by Okada (2008).

"Participatory action research aims to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people" (Reason & Bradbury, 2001:1). Our broader research programme is framed in terms of the following questions, which we revisit in our conclusion:

- **Scientific knowledge and mapping.** Strong scientific argumentation is based on a good understanding of the domain and the skills of being able to communicate and critique in an appropriate way one's own reasoning, and that of peers. This question focuses on how evidence-based Dialogue Maps help a teacher-researcher to analyse the interplay between domain and argumentation knowledge: how can each one sharpen the other?
- **Scientific writing and mapping.** What are the effects of translating between the non-linear graphical languages of maps, and linear presentations in speech or prose? Does translating speech or writing into a map lead to new insights? How does creating a Dialogue Map influence written and spoken presentations that are derived from it?
- **Cartographic literacy.** The cognitive skills of crafting good concept, dialogue and argument mapping take effort to develop. Which of these skills do science teachers find easy or hard to learn themselves, and to foster in pupils, and could they be communicated in more age-appropriate, multimodal/media ways?
- **Pedagogical interventions and learning activities.** While highly motivated pupils may learn concept and Dialogue Mapping from a brief, solitary exposure, we are interested in its development as an intellectual discipline with wide application in the curriculum. How should Dialogue Mapping be introduced to pupils and staff? What are the key roles for staff/peer interventions? What kinds of activities provide orientations that lead to better or worse deliberations?
- **Software design.** While brief, small scale mapping can be done with pen and paper, software clearly adds new possibilities, e.g. in terms of the unlimited canvas, iterative revision, reusable structures, customisable language, embedded multimedia, storage and retrieval, and working over the internet. What do trials with pupils and staff tell us about the digital tools we are offering them?

The specific research objectives in this study are to better understand the usage of Evidence-based Dialogue Maps created in Compendium as both (1) a learning strategy to scaffold school pupils' argumentation, and (2) as a method to investigate the quality of their argumentative essays.

## 2. Adapting Dialogue Mapping for scientific argumentation

Dialogue Mapping is a knowledge mapping technique developed over 20 years by Conklin (2006) to build shared understanding during discussions. Dialogue Mapping extends the Issue-based Information System (IBIS) created by Rittel in the 1970s to solve ill-structured problems in urban planning and upstream design – denominated "wicked problems". IBIS is a rhetorical grammar with three core elements, *issues, positions and arguments*, which can be rendered as textual outlines and as "graphical IBIS" (gIBIS) networks of *Question, Idea and Pro/Con* nodes that grow with the conversation (Conklin and Begeman, 1988).

This pilot study focuses on a face-to-face science course called "Totally Wild Science" based on the *Cracking Science* approach developed by Sherborne (2006). This one-month course formed part of a summer programme at Canterbury University in the UK for 'gifted and talented' children. In this research, we observed twenty pupils, judged by their schools to be high-calibre students in science, who volunteered to attend this course during their school holiday in August 2006.

**The participants comprised a science teacher-researcher, a knowledge mapping researcher and twenty 12-13 year old pupils (11 boys and 9 girls). They used the *Compendium* mapping software and the Moodle learning management system to record data during face-to-face activities. This study draws on multiple data sources: discussion forum postings, Dialogue Maps by the science teacher-researcher's and pupils, pupils' essays and reflective comments about the uses of mapping for writing.**

In order to show how Dialogue Mapping can be used to represent pupil argumentation, we selected this example below, which collates responses posted online at the summer school where pupils were asked: "what makes a good scientific argument?".

## Totally Wild Science - FORUM

| | |
|---|---|
| 😊 | Questions by science teacher - Wednesday, 23 August 2006, 12:10 PM<br>Describe what you think makes a good scientific argument. |
| 🔔 | by Alex - Wednesday, 23 August 2006, 01:10 PM<br>A logical, well thought out statement that works in putting your thought across in a few concise sentences. |
| 😊 | by Kim - Wednesday, 23 August 2006, 01:12 PM<br>it must include questions, answers and explanations of the reason why. |
| ❤️ | by Beth - Wednesday, 23 August 2006, 01:17 PM<br>Evidence and strong pros and cons and a good topic to base the argument on. |
| 🧍 | by John - Wednesday, 23 August 2006, 01:23 PM<br>a good question, a good strong fact with an even better argument |
| 🧑 | by Peter - Wednesday, 23 August 2006, 01:27 PM<br>An argument showing both sides fairly with evidence for them and some biased comments for the side that you support but be careful you don't contradict yourself. |

Figure 1 Responses from *Totally Wild Science* Course in Moodle recorded during a face-to-face activity.

A map is the product of the interests and constraints under which a mapper works: Figures 2 and 3 show two different Dialogue Map interpretations of the online discussion forum postings in Figure 1. If the discussion forum was analysed by beginners, they might capture sentences more or less as they were uttered, and make links based on the temporal sequence (Figure 2).

**Question**
**Answer**
**Pro**
**Cont**

it must include questions, answers and explanations of the reason why.

Evidence and strong pros and cons and a good topic to base the argument on.

What do you think makes a good scientific argument?

A logical, well thought out statement that works in putting your thought across in a few concise sentences.

a good question, a good strong fact with an even better argument

and some biased comments for the side that you support

An argument showing both sides fairly with evidence for them
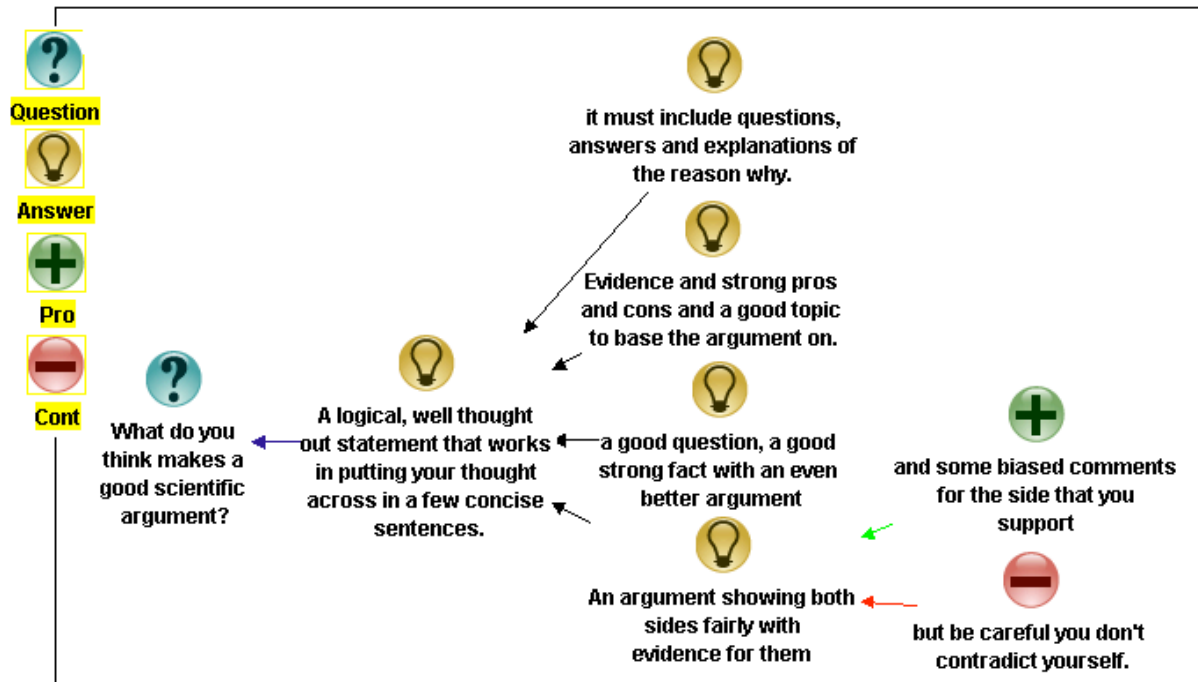
but be careful you don't contradict yourself.

Figure 2. Dialogue Map of Figure 1 in Compendium: *chronological* structure

If the discussion was captured by experts more experienced with Dialogue Mapping, or with more time for reflection available, then a greater level of reconstruction is likely, producing a map with more succinct labels, less repetition, and clearer organising Issues (Figure 3). The emphasis thus shifts from chronological structure to logical structure.



A good question,

Possible answers

What do you think makes a good scientific argument?

A logical, well thought out statement that works in putting your thought across

What makes the statement "work"?

concise

strong fact

Evidence

What kind of evidence?

explanations

Facts for and against: strong pros and cons

How do you decide?

Use comments to bias to your view

Have to be fair

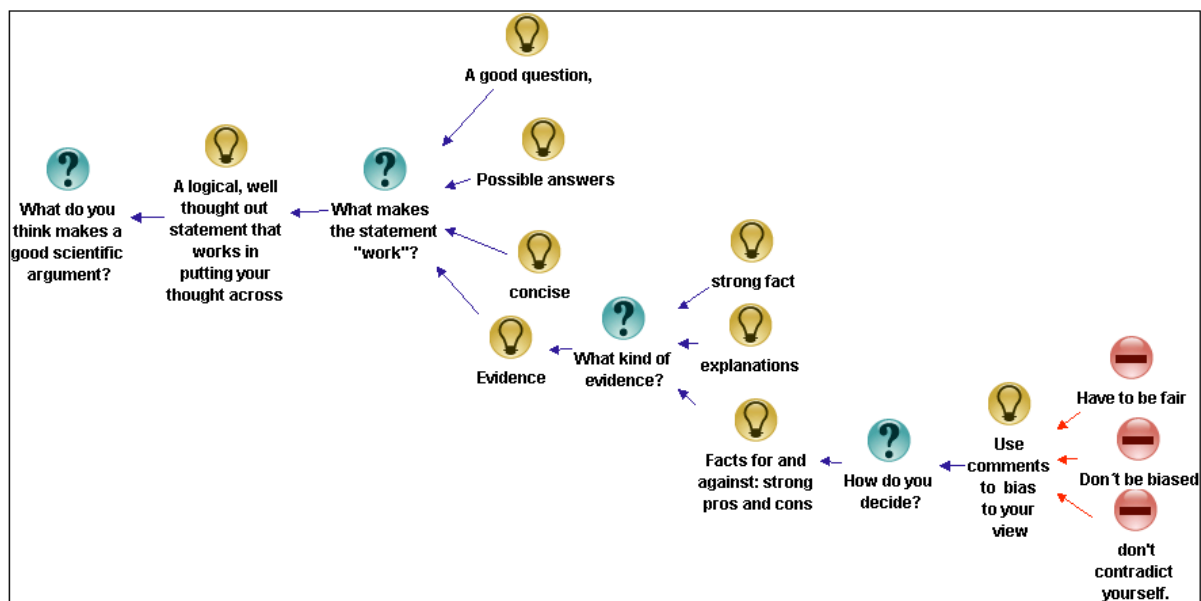Don't be biased

don't contradict yourself.

Figure 3. Dialogue Map of Figure 1in Compendium: *logical* structure

The challenge is how teacher-researcher intervention around the software can scaffold students to move firstly, from naturalistic reasoning/discourse to a tangible map that makes reasoning available for inspection (e.g. Figure 1), and from there into conceptual reconstruction through

the refinement of the map (e.g. Figure 2). While IBIS provides a relatively intuitive language, as we discuss next, it is missing a key element central to scientific argumentation: evidence.

## 3. Evidenced-based Dialogue Maps

In scientific reasoning, it is important that pupils can ground their claims in scientific concepts rather than personal convictions. The quality of their arguments is also better if they can connect not only supporting arguments, but also counterarguments (thus resisting confirmation bias), and data as backing for claims. Simon et al. (2002) adopt the well-known Toulmin (1958) model (shown in Figure 4) as the basis for teachers to guide pupils in structuring their argumentation scientifically and assessing the quality of their argumentation.
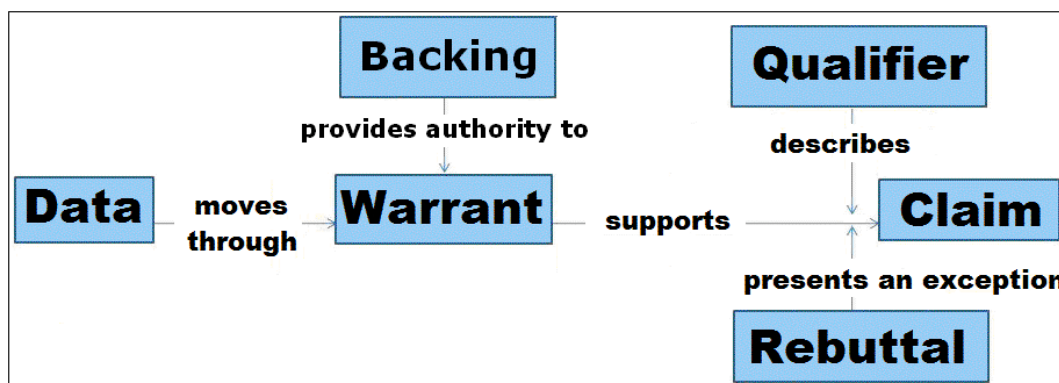


Figure 4: Toulmin argumentation scheme

In Toulmin's scheme:
1. **Claim** is the position on the issue and the essence of the argument.
2. **Data** are initial grounds for the argument serving as evidence that can be accepted as factually true.
3. **Warrant** is the reasoning that supports the connection between the data and the claim. Argumentation research has since identified many different kinds of warrant (cf. Walton's work on presumptive reasoning schemes). When teachers introduce *scientific* reasoning to *school pupils*, Simon et al. (2002) argue the need to highlight some basic differences between "motivational" arguments (i.e. based merely on convictions), "authoritative" (an *argument by expert opinion*), and more "substantive" arguments (e.g. based on example, classification, generalization or cause and consequence).
4. **Rebuttal** states the exceptions to the claim and is an exception to the truthfulness of the argument.
5. **Backing** provides authority for the use of the Warrant
6. **Qualifiers** may limit the scope of the Warrant's application.

Although Toulmin had extremely pragmatic intentions with the development of his scheme, there is widespread evidence that it can be difficult to structure reasoning in real time within the Toulmin scheme, or even post hoc as an analyst, as noted by Simon et al. (2002); see also Newman & Marshall (1991). It requires the differentiation of sub-elements, and the normative reconstruction of missing elements, to create the required micro-structure. The rationale for requiring such discipline is of course that it introduces cognitive rigour; the tradeoff is that it

requires such effort on the part of the analyst that motivation is lost, a particular risk with pupils.

Since our work is concerned with the cognitive compatibility of argumentation schemes to create practical tools (cf. Buckingham Shum et al. 1997), the learnability of an approach for school teachers, learning support assistants and pupils is important. The challenge for us is how to negotiate the cost/benefit tradeoff between increased expressiveness of the notational scheme (ie. more node and link types), learnability, and the benefit this yields for rigorous thinking. Given the success of IBIS in non-educational contexts as an intuitive language that non-experts can understand, we decided to reduce the complexity of Toulmin by expressing only four of its elements in the IBIS language.

Toulmin's model can be re-expressed in Dialogue Mapping's IBIS language as shown in Figure 5 (Carr, 2003), creating what we call an *Evidenced-based Dialogue Map*. Following Dialogue Mapping's conversational paradigm, the link arrows go from right to left since they *respond to* or otherwise build on prior contributions, as shown by the various link types (*supports*, *challenges*).[2]



Figure 5: Toulmin scheme, interpreted as IBIS, to create the template for an *Evidenced-based Dialogue Map*

All conversations are framed by an opening *Question*, which sets the context (and to a degree establishes the scope that might be addressed by the use of *Qualifiers* in Toulmin's scheme). An *Idea* (= Toulmin *Claim*) *responds to* the *Question*, while arguments are expressed as *Pros* (= *Warrant*) that *supports* the Idea, and counterarguments are expressed as *Cons* (= *Rebuttal*) that *challenge* the Idea. To highlight the need for explicit evidence to back a *Pro* or *Con* (in order to pre-empt arguments that are mere opinion), we introduce the *Data* node. A *Pro* or *Con* node might initially summarise in its label what in Toulmin scheme would be the *Warrant*, plus, optionally, *Backing* and/or *Data*: for instance, "The UN Climate Change Panel concluded that humans are contributing to global warming through increased CO2"). This first step is simply to force the pupil to demonstrate that there is an argument of some sort for/against an Idea. What we call the *Data* node is then a further step that asks them to provide a reference of some sort that documents the *Pro*/*Con*, making more explicit the authority, such as a hyperlink to a UN document, a CO2 growth graph, or authoritative support for the UN's expertise. We are, therefore, not requiring that pupils make Toulmin's distinctions between *Backing, Warrant, Qualifier and Data*.

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[2] Recent anecdotal reports from our primary school deployments of Compendium indicate that younger children than those reported in this study (e.g. 10-11 year olds) may find the right-to-left link direction less intuitive than a vertical arrangement as shown in Appendix 1: links flow from the leaves of the branches up to the root Question at the top. Compendium can automatically lay out the graph vertically on request, which is the design used in other argument mapping tools such as Rationale and bCisive [www.austhink.com].

Thus, we are striving to derive a language that proves sufficiently intuitive and visually engaging that it highlights some of the most important distinctions for both teachers and pupils. While it is possible to expose argument micro-structure further for more advanced teachers/pupils, this comes at the cost of greater complexity. For instance, should pupils wish to interrogate a *Pro* argument that claims support for an *Idea* by an expert scientist, the teacher might consider exposing the detailed premise and critical question structure of an *argument by expert opinion* (Walton 1995) as illustrated in Buckingham Shum & Okada (2008).

To summarise, our hypothesis is that Evidence-based Dialogue Mapping, delivered via Compendium, is useful for teacher-researchers investigating the quality of pupils' argumentation, for the following reasons:

1. It helps pupils structure their initial reasoning by differentiating visually some important steps in scientific deliberation, without requiring excessive effort.
2. Through pupil discussion and teacher feedback, these visualised components help elicit further thoughts, which are added to the map.
3. Since the Dialogue Map highlights visually if claims are backed up by arguments and documentary evidence, this representation helps pupils and teachers assess the strengths and weaknesses of the reasoning.
4. Once the reasoning is strengthened, the map helps pupils' transition to a linear, conventional prose summary of their argument in response to the question.

These four steps were used to plan the learning activities described in the following section.

## 4. Methodology

### 4.1 Evidence-based Dialogue Maps in Compendium as a participatory action research tool

### 4.1.1 Orientation

Our analysis in this paper focuses on the summer school's environment project, *"Global Warming – what do you think will happen in the future?"* A set of activities using Dialogue Maps was developed by the author (Okada, 2008) and the science coordinator (Sherborne, 2008), based on a participatory action research cycle (Reason & Bradbury, 2001), as summarised in Figure 6 .
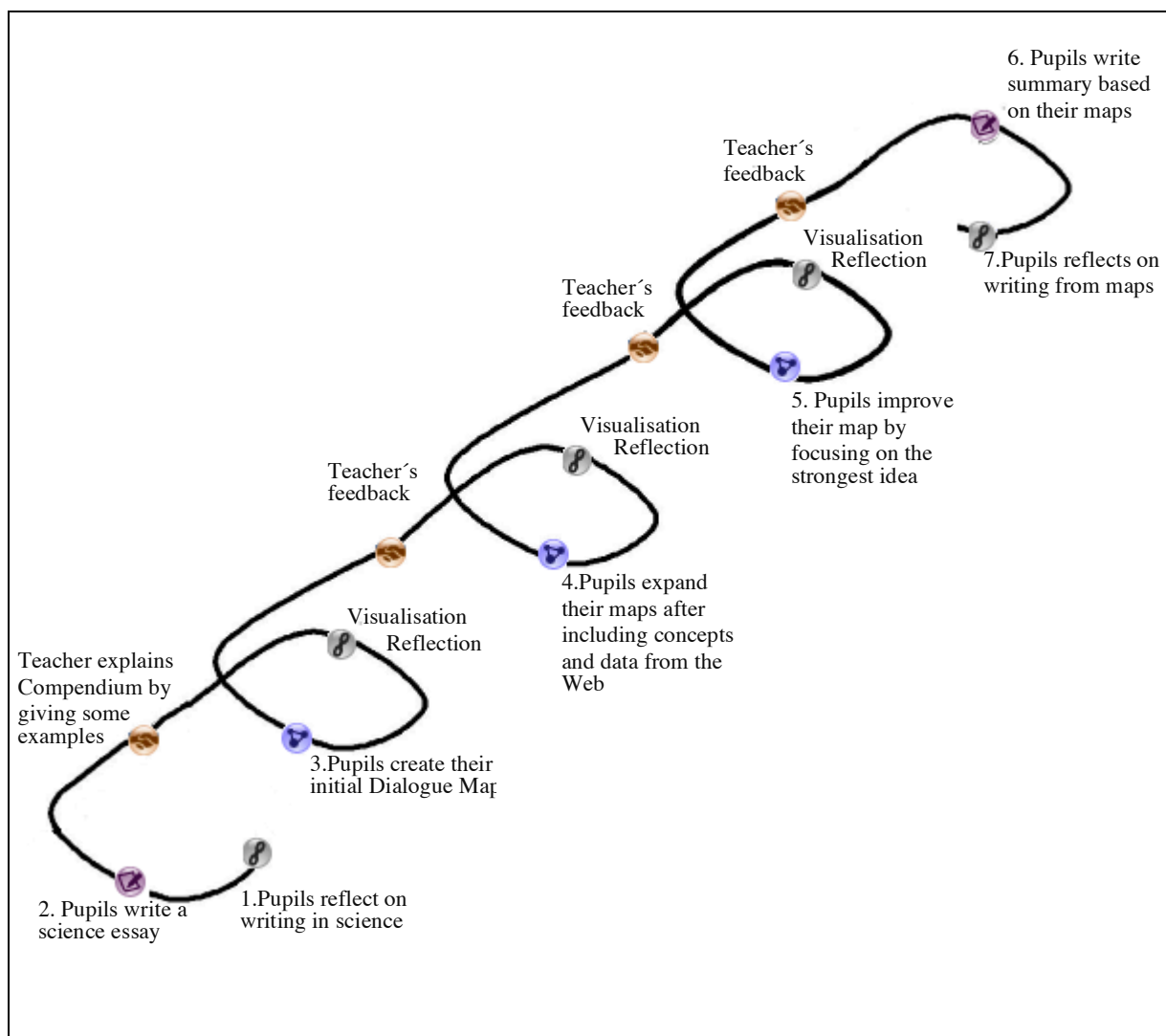
**Figure 6. Learning activities to integrate Evidence-based Dialogue Maps as a tool for participatory action research**

Compendium was introduced by the knowledge mapping researcher, who demonstrated how the discussion between the science teacher and pupils could be recorded in Compendium, as described above. Some examples were presented to illustrate a Dialogue Mapping structure. The science teacher explained the importance of organising scientific arguments through these icons by creating some examples of maps following the structure of Figure 5, emphasising that each Idea responding to a Question should be connected to Pros, Cons and Data.

Seven activities were developed for pupils integrating action and reflection. The goal was to engage pupils in action learning, using their maps to represent, visualise, reflect and improve their arguments as a spiral process. The participatory nature of this approach may help teachers and pupils internalise their findings and build action upon it more promptly (Reason & Bradbury, 2001).

**Table1. Learning activities - using Dialogue Mapping for arguing and writing about global warming**

|   | Learning activity |
|---|---|
| 1 | "Reflecting on Writing in Science": 1. How much do you like writing in science? (1= not at all, 3=OK, 5=I really like it) Give reasons. 2. What do you think makes a good scientific argument? |
| 2 | "Writing about Global Warming": Write down a composition in pairs about "What will be the impact of Global Warming (crops, diseases, ecosystem, water or weather)?". Give reasons and share it in the forum discussion. |
| 3 | "Mapping Scientific Arguments": Use Compendium for arguing about "What you think will happen in the future in the UK?" Represent your answers, arguments, "facts and evidence" . |
| 4 | "Mapping data from the web": Enrich the map with significant information from the internet and prepare a better argumentation structure. |
| 5 | "Editing and improving map": Improve scientific arguments in the map by using teacher's feedback and focussing on the strongest idea. |
| 6 | "Writing from your map". Export your map as an image or a list. Bring it into Word. Write your composition from this map and share your map and text |
| 7 | "Reflecting on writing from maps": Share your opinion about your learning, the use of Compendium and Dialogue Mapping applied to writing. |

### 4.1.2 Data

The method of this qualitative research was case studies involving qualitative analysis. We collected discussions, maps, essays and notes posted by pupils and the teacher in Moodle. We also collected the teacher's private annotations during the project. The analysis consisted of three stages: (1) preliminary consideration of all recorded data (40 maps, 40 messages and 20 essays); (2) detailed examination of each pair of pupils who worked together analysing what they have produced (3 maps, 4 messages and 2 essays); (3) deep study of two cases which were selected because they were distinctive, as defined by Tables 2 and 3.

### 4.1.3 Criteria for analysing the extracts

We defined operationalisations for four levels of argumentation in the Dialogue Maps (Table 2) and five for writing (Table 3). These two tables were used as a reference to guide the case studies analysis. These criteria were defined based on the desired learning outcomes, and as criteria to assess the quality of argumentation.

| Level of argumentation | Description |
|---|---|
| (1) Very Weak | Only claims, no argument |
| (2) Weak | Claims and (weak) warrant (based on convictions) |
| (3) Moderate | Claims, (weak) warrants and rebuttals or data |
| (4) Strong | Good Claims, good warrants, rebuttals / data |

**Table 2. Criteria for analysing quality of Dialogue Maps**

| Level of writing | Description |
|---|---|
| Very Weak | Few words, no sentences, weak argumentation |
| Weak | Few sentences with weak or simple argumentation |
| Moderate | Connected sentences with simple argumentation. |
| Good | Well connected sentences with strong argumentation. |
| Very Good | Good paragraphs with strong argumentation and domain knowledge |

**Table 3. Criteria for analysing level of writing**

## 4.2 CASE A

Case A illustrates quite structured mapping, which helped pupils to generate evidence-based claims, and teachers to analyse their arguments. Their maps provided visual guidance for them to identify claims for which they could develop arguments using their existing knowledge, as well as claims for which they could not.

Figure 7 presents this pair of pupils who dislike writing in science as well. Beth "*hardly ever does it and always gets stuck for an answer*". For Ben "*doing it fully and properly is V. Tedious and Tiresome*". They were able to describe what makes a good scientific argument. However, they had serious difficulty in writing an argument.

In Figure 7, we can see their written response to a question constituted by a short line posted in the initial Moodle discussion forum. Their writing was based on short answers of a few words, with no sentences, and critically, no arguments. They did not give reasons for their answer and they were not able to justify their ideas using "*evidence*" or "*Pros and Cons*".

Teacher: Write down for your topic: (1) What you think will happen in the future in the UK? (2) Give reasons for your idea.
Re: Writing about Global Warming - Group Ecosystem by Beth and Ben
Impacts on nature. Disappearance of many wetlands and extinction of some species.

Figure 7. from the Forum II – Writing about Global Warming

Figure 8 shows a map created by the author with the science teacher to analyse the level of argumentation in the writing. Pupils presented only one claim, "Impacts on nature", which is related to the disappearance of many wetlands and extinction of some species. They did not present any warrant, data or rebuttals (in Toulmin's terms), which would be expected to show

as Pro, Con or Data icons in the Dialogue Map. Their level of arguing and writing is therefore classified as very weak (level 1).
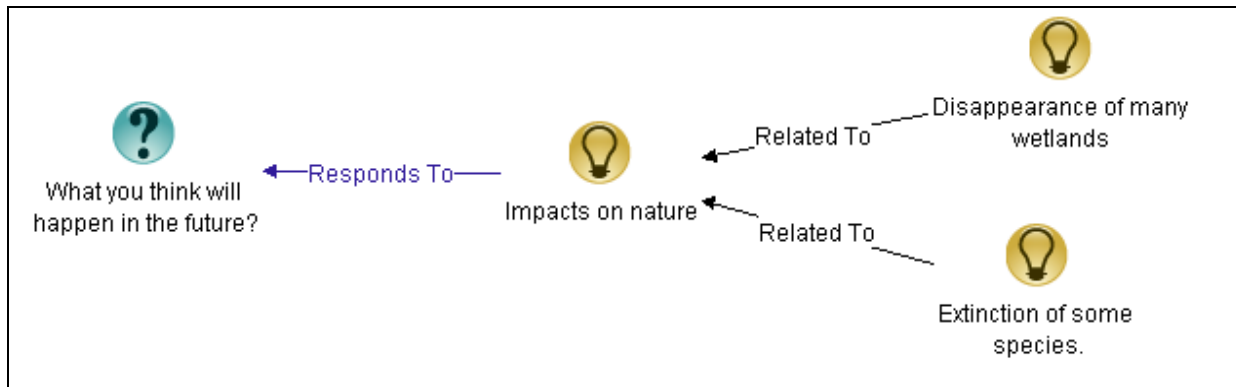


Figure 8 – Teacher's Dialogue Map analysis of pupil's answer described in Figure 7

Figure 9 shows Beth and Ben's first Dialogue Map in Compendium. They generated a Question, two Ideas, a Pro and a Con. Interestingly, for each Idea, they represented a clear intention of supporting and challenging it by bringing Pros and Cons. For the second Idea, they were able to bring an argument and a counterargument. However, they were not able to explain their claims properly or connect Data to them.



Figure 9 from the Forum III – Mapping Scientific Arguments

It was possible for the teacher to see immediately from the 'placeholder' Pro and Con nodes with question marks as labels where the pupils lacked information, and what role they saw this playing in their analysis. By looking at the text of each node, the science teacher could also identify problematic assumptions in their argumentation associated with scientific understanding (e.g. if it gets colder there will be no sun) and pose follow-on questions.
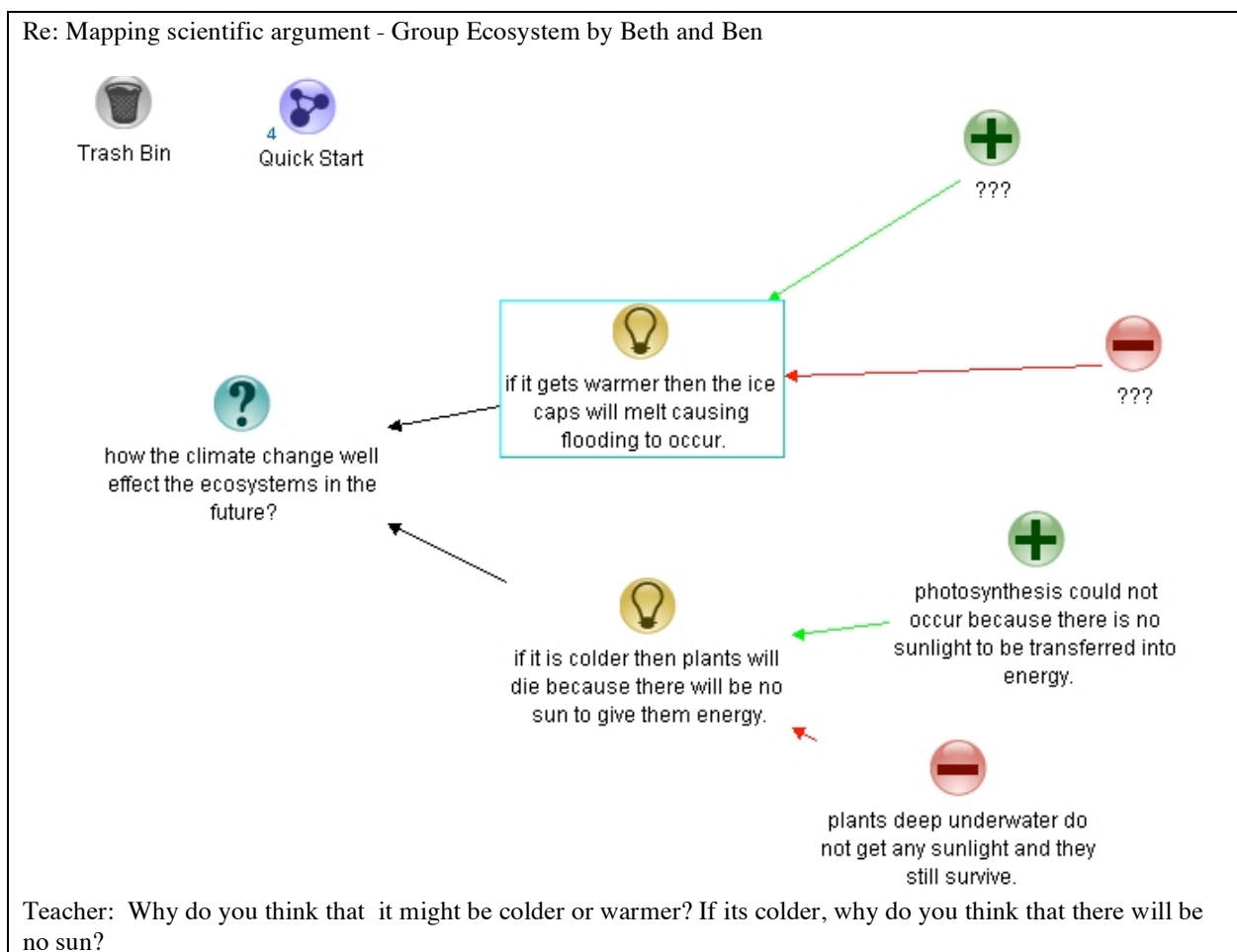
In order to analyse the level of argumentation embedded in their Dialogue Map, we examined each component directly. They represented two claims using proper sentences but they were not able to establish good connections. Their level of argumentation in their first map (Figure 9) is better in the map than in their writing (Figure 8) because they include warrant and rebuttals, but it was not significantly improved. Looking at their second claim they applied successfully the concept of photosynthesis in order to justify that "*plants will die*" since "*there is no sunlight*". However, this warrant was not substantive. They did not explain the connections between "*climate change*", "*it might be colder*" and "*there will be no sun*". This association was based only on their personal convictions. Their map suggests that they do not have a clear understanding about the relationship between Global Warming and the Gulf Stream.

In this case, we would argue that while the visual IBIS language in Dialogue Mapping prompted them to bring warrant and rebuttals to ground each of their ideas, the nature of the argumentation did not show improvement, particularly due to the lack of science concepts presented in their map. They were not able to apply sufficient science concepts to support their main claims. The macrostructure of their reasoning was good (i.e. at the level of good IBIS form), but the microstructure was weak.

Figure 10 shows their map extended with data from two websites during the activity to map data from the web. Pupils brought two notes from the Web. Mapping resources from the Web was neither easy nor fast. For them, bringing data into the map did not mean simply dragging and dropping sentences into Compendium. They had to think about what to select and where to connect it. It is easy to visualise in the map where "*they got stuck for an answer*". Although they could not answer the teacher's question (Figure 9) to improve their two initial Ideas, they selected two new pieces of information that helped them elaborate three arguments around a new Idea.

Considering their new claim "*climate change can eventually destroy the ecosystem*", their argumentation improved (from level 2 to level 3). They presented substantive warrants based on data ("*plants and animals…are in real danger*", "*global warming is devastating…*"). However, their argumentation falls short of the ideal, through the lack of any rebuttals.
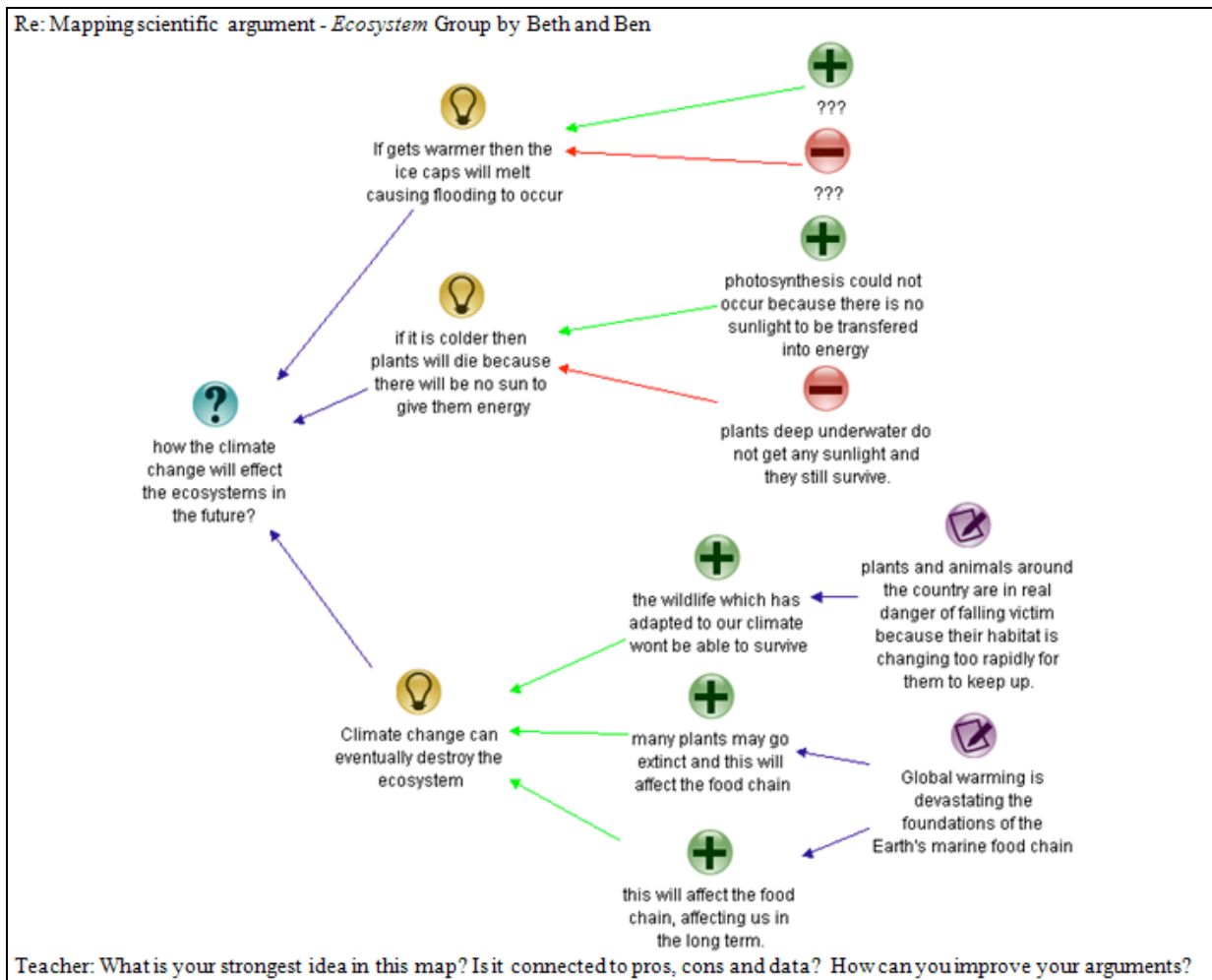
Figure 10 from Forum IV – "Mapping data from the web" (note the teacher's feedback prompting for improvements to the map)

Figure 11 shows their map edited after comments from the teacher. From this map they elaborated their writing. Comparing this map with their previous one, their main change was focussing on their strongest Idea by bringing more arguments, counterarguments and notes. The part of the map where they "*got stuck for an answer*" they decided to delete.

As we can see, there was a significant improvement of the level of argumentation in their map (level 1 at the beginning and level 4 at the end) and in their writing (from "very weak" to "good"). They were able to bring more science concepts and also include other perspectives such as social and ethical issues. The science teacher considered the first paragraph good, but the second one could have been better if they had added more science concepts rather than personal opinion.

**Re: Writing from your map – *Ecosystem* Group by Beth and Ben**



Re: Writing from your map - *Ecosystem* Group by Beth and Ben

"We think that the climate change will eventually destroy the system as we know it today because the wildlife which has adapted to our climate won't be able to survive, many plants may go extinct and this will affect the food chain, affecting us in the long term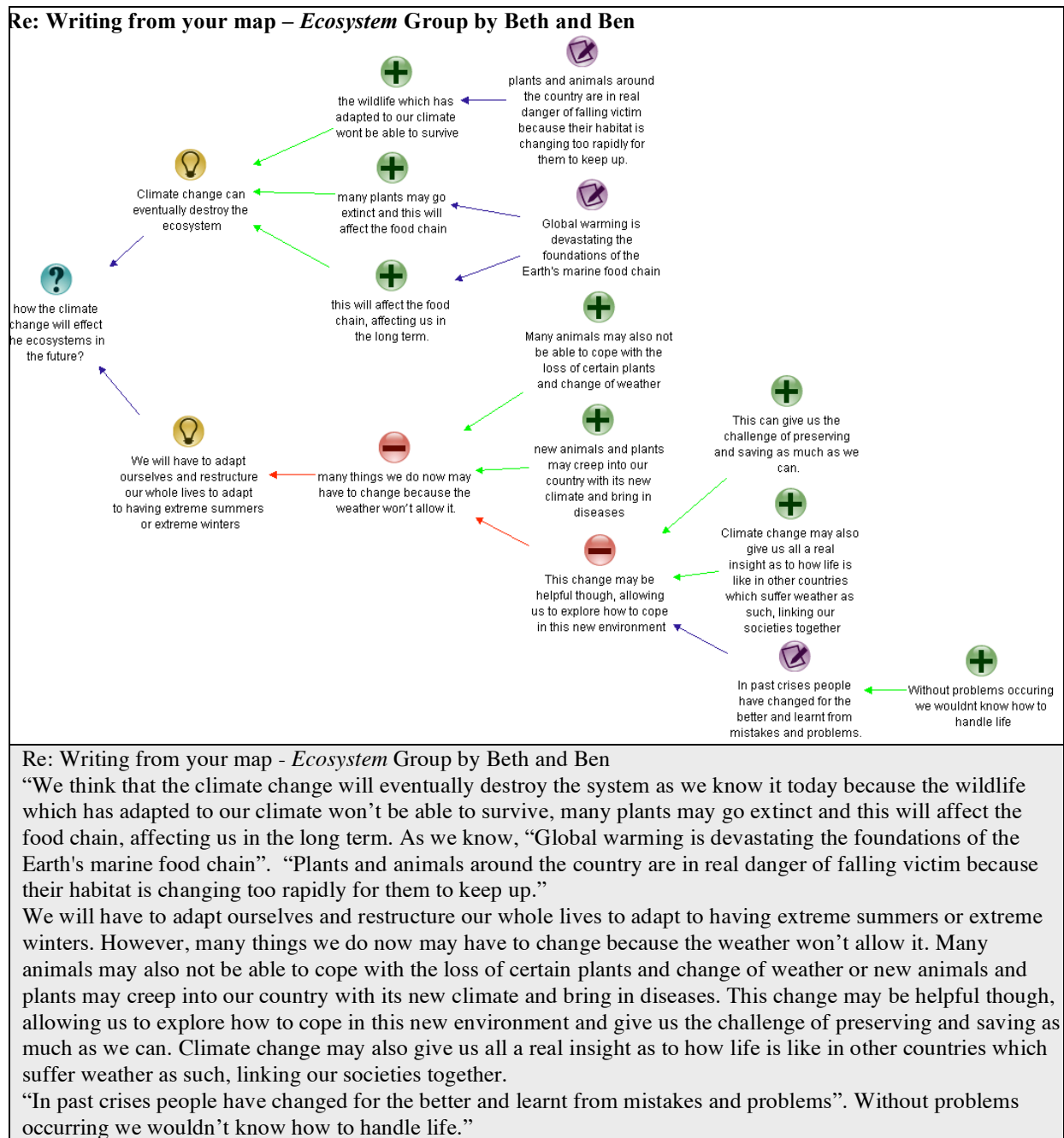. As we know, "Global warming is devastating the foundations of the Earth's marine food chain". "Plants and animals around the country are in real danger of falling victim because their habitat is changing too rapidly for them to keep up."

We will have to adapt ourselves and restructure our whole lives to adapt to having extreme summers or extreme winters. However, many things we do now may have to change because the weather won't allow it. Many animals may also not be able to cope with the loss of certain plants and change of weather or new animals and plants may creep into our country with its new climate and bring in diseases. This change may be helpful though, allowing us to explore how to cope in this new environment and give us the challenge of preserving and saving as much as we can. Climate change may also give us all a real insight as to how life is like in other countries which suffer weather as such, linking our societies together.

"In past crises people have changed for the better and learnt from mistakes and problems". Without problems occurring we wouldn't know how to handle life."

Figure 11 from the Forum V – Writing from your map

At the end, the discussion forum reflected something of the pupils' experiences. They had different opinions about how useful these maps were for constructing scientific argument. Ben found them "*very useful*" and "*would use this type of map again*". Beth replied "*useful*" but "*probably wouldn't (use it again) because it took a bit too much time*". Both of them described how maps helped them in several ways: to "prove up their point", "think of many ideas", "construct a good fair balanced scientific argument" and "link arguments together with words for their composition".

They did not have difficulties using Compendium, which they considered "*fairly easy*", "*it was fine*". The "*few problems*" were "*along the way like whether the nodes were right*". We

might summarise this as: the software was easy to use, but the intellectual work of mapping was hard.

In summary, Dialogue Mapping, from the perspective of these pupils and the teacher-researcher, functions as a "*sophisticated*" strategy for scaffolding and assessing argumentation. Students were able to use the most significant components to construct "*a good fair BALANCED scientific argument*", and to visualise "*all the information they need in the shortest form possible*". Dialogue Mapping can also be an "*easy way to sum up ideas for a report*." All these comments were written in the discussion forum.

However for these pupils, the process of thinking about the nodes is not trivial, nor quick. It takes a "*LONG time*". As Conklin (2006) states there is lots of interpretation involved in Dialogue Mapping. In Compendium, for each node that they dragged and dropped into the screen, they had to tackle several implicit questions, such as "Is this icon right?, "Is this text right?", "Is this connection right?" (see Buckingham Shum et al, 1997 for detailed analysis of these cognitive tasks). Debating their map with colleagues and teachers requires them to address other relevant questions such as "Is this a strong idea?", "Is this idea supported by robust evidence?" "Is this idea connected to Pros, Cons and Data?", "Are these arguments and counterarguments based on science concepts or on personal convictions?", "What is the source of this data?", Is this a reliable source?" If pupils and the teacher-researcher can be engaged in all these kinds of questions, then questioning "whether the nodes are right" means questioning if their reasoning is scientific.

## 4.3 CASE B

Case B presents another role for Dialogue Maps, namely, *self assessment*. This example illustrates a pair of pupils who began with difficulties choosing Compendium icons to represent their argumentation, but once they and the teacher were able to visualise their arguments through the right icons, they could recognise easily which parts should be clarified, deleted or extended. The good use of icons helps them "*make their points clearer and easier to understand*" and also make it "*easier for teacher to mark their ideas*". Rapid "*formative assessment*" feeding back to the learner is widely recognised as a major factor in enhancing achievement.

In the first discussion forum, this pair of pupils explained that writing is neither as fun, nor as practical, nor as easy as presentations. For Chris "*It is boring*". For Carl "*writing is ok*", *but "presentations to people you know are easier*". They wrote fluently, addressing the topic set by the teacher's question, and giving good explanations of what makes a good scientific argument.

Figure 12 (focused on the topic of global warming's impact on disease) shows writing with good scientific reasoning. Their text was based on two short paragraphs, in a few, well-connected sentences.

| Teacher: Write down for your topic: (1) What you think will happen in the future in the UK? (2) Give reasons for your idea |
|---|
| Re: Writing about Global Warming - Group Diseases by Chris and Carl |
| Global warming will either make Britain (focusing here for now) a lot warmer, or shut down the gulf stream and make it a lot cooler. Either way, we will face a rise in disease as cold weakens the immune system and heat causes dehydration, heatstroke and other health problems.<br>Of course, if you take into account the cause of global warming, pollution, you have even more problems. Pollution causes eye and lung diseases. |

Figure 12 from the Forum II – Writing about Global Warming

Figure 13 shows two maps created by the authors to analyse the level of argumentation embedded in the pupils' writing. We present two maps to show our own analytic process. The first, more process-oriented map, reflects how the pupils actually reasoned in their writing, reflecting that while there are two opposing views (UK will heat up or cool down), either way, they still support the main claim with respect to increased disease, which was their assigned focus. We can see that they included all the main components to ground their claim: Claim, Warrant, Rebuttal, Pros and Data ("evidence to back up their ideas"). The level of their argumentation and writing was thus judged very good. The second map highlights that there is one central claim (increased disease) supported by three different arguments, and choosing not to highlight graphically the debate about possible causes, using instead textual summaries in the Pro nodes' labels.
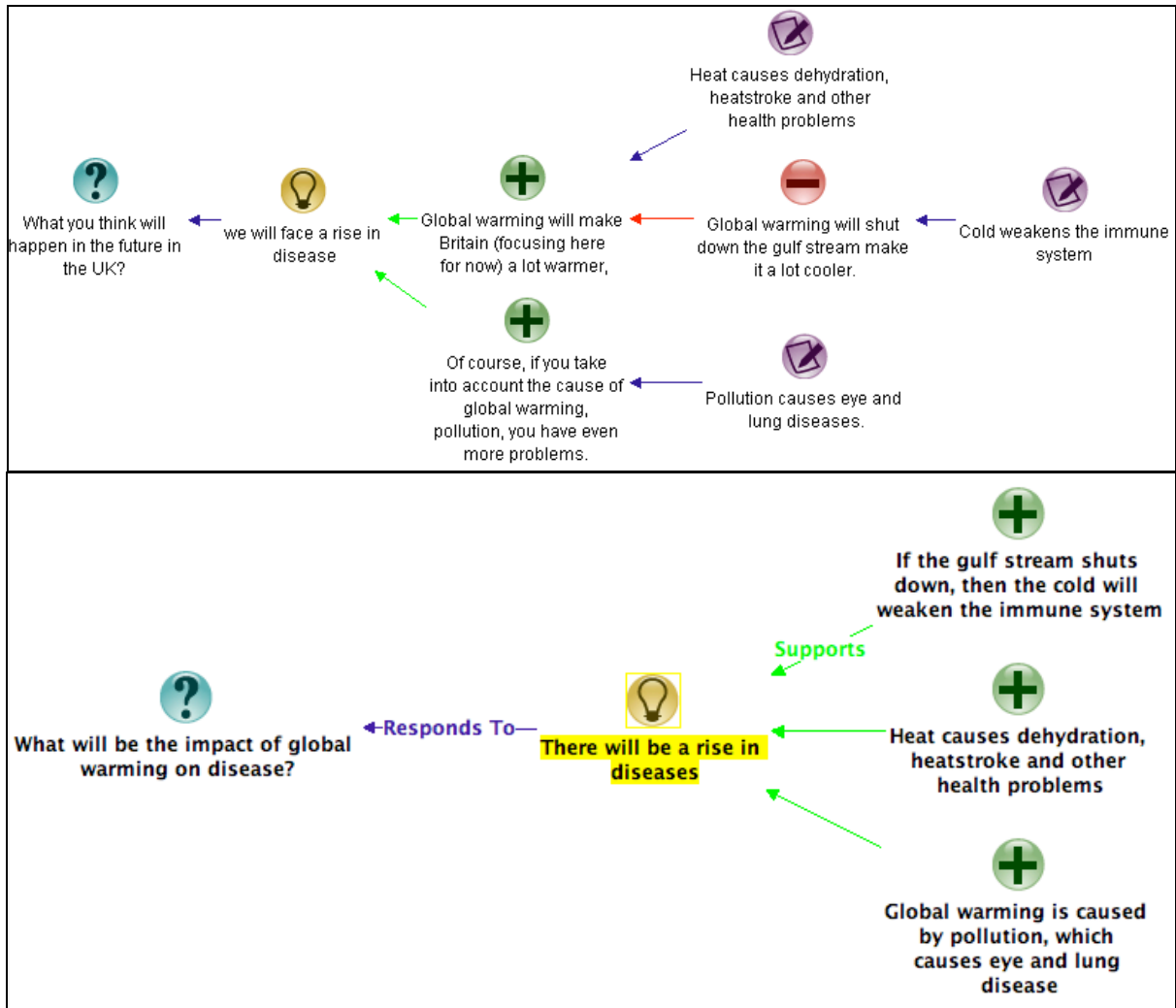
Figure 13 – Two Dialogue Maps by the authors, analysing Figure 12 with different emphases (see Appendix 1 for an example of an alternative analysis, using a vertical tree layout and intermediate Questions)

Figure 14 shows the pupils' first attempt to Dialogue Map their reasoning. They generated more questions and more claims building on what they wrote originally, extracting the different issues from their initial statements, and opening up discussion about them. They also described science concepts giving more details.
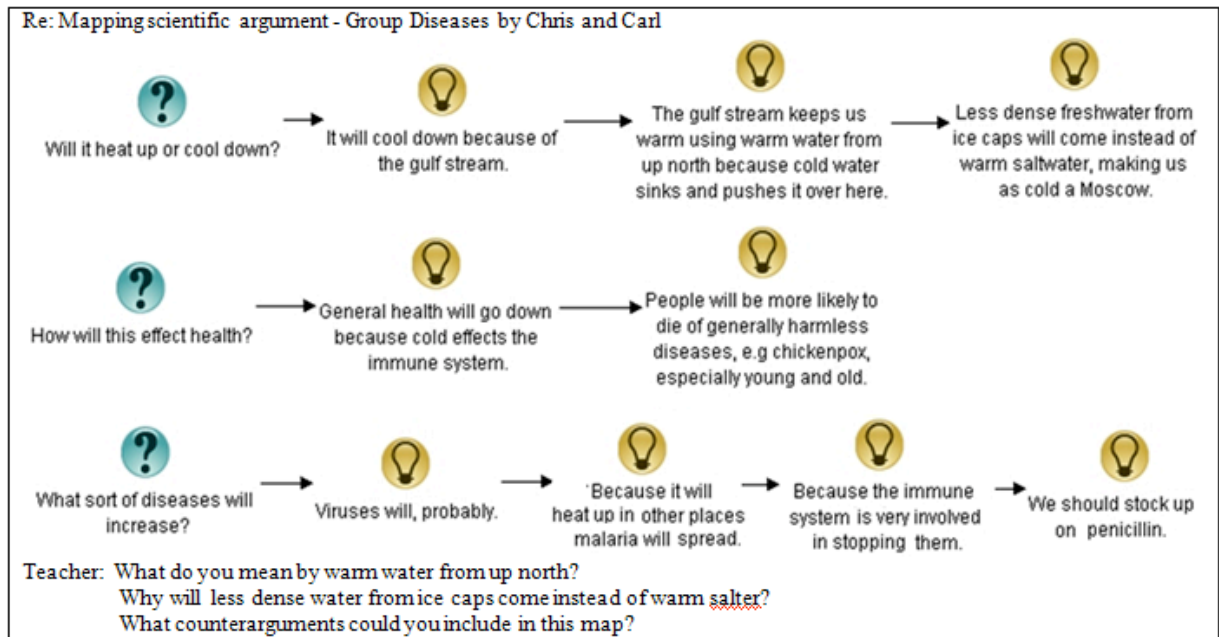
Figure 14 from the Forum III – Mapping Scientific Arguments

However, their arguments in the map were not as clear as in their writing (where they considered Pros and Cons and Data for their main Claim.) If they had included all these components in the science argument, then the maps would be better. As they had difficulty in choosing the icons, they could not visualise which parts could be improved. They represented all of them as Ideas in three linear sequences as if they were writing, which suggests that, in fact, they could have written these arguments without creating the map.

In this map, pupils were able to present warrants based on their science knowledge. However, the science teacher noticed they did not show a clear understanding about why the UK might cool down. Moreover, they did not include any counterargument. They had also difficulties in representing data through proper icons. The level of argumentation dropped from level 4 to level 2.

Figure 15 represents their map supplemented with information from the Web. They added more data, questions and arguments. They also represented the roles played by their ideas through different icons and established more connections between them. However they still were not able to explain clearly the effect of Global Warming and the Gulf Stream. They were also not sure about the difference between Ideas and Pros.
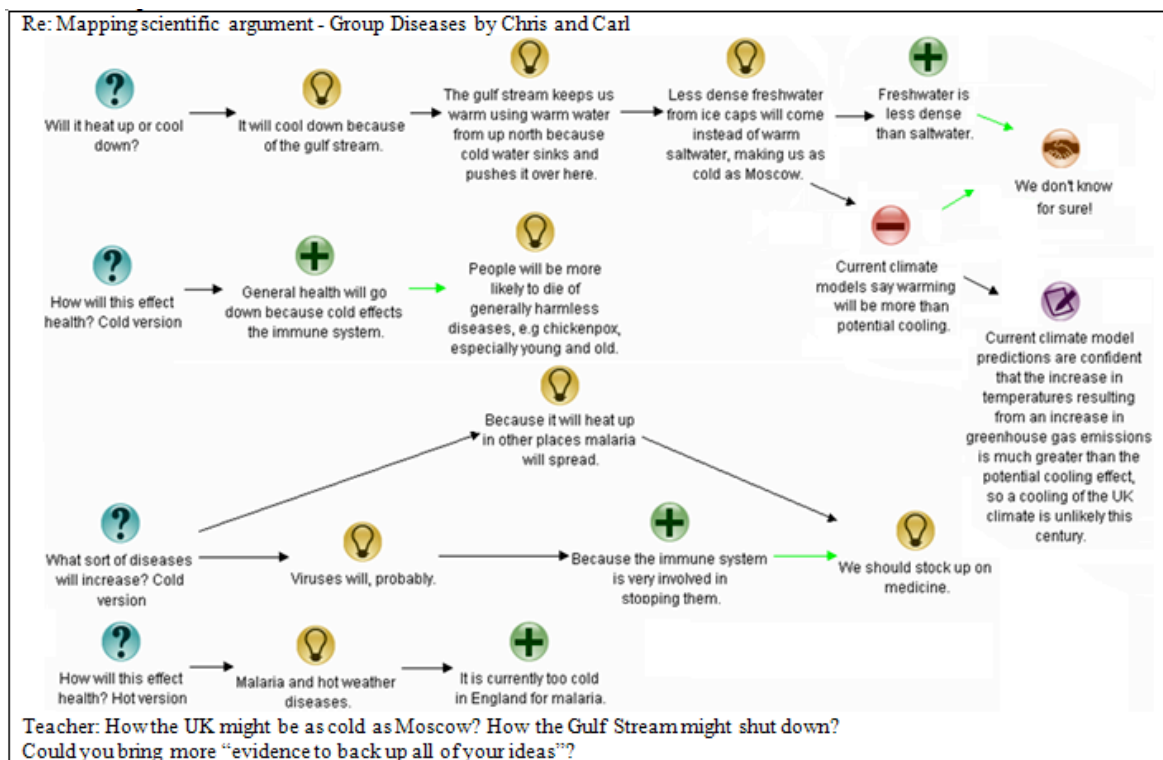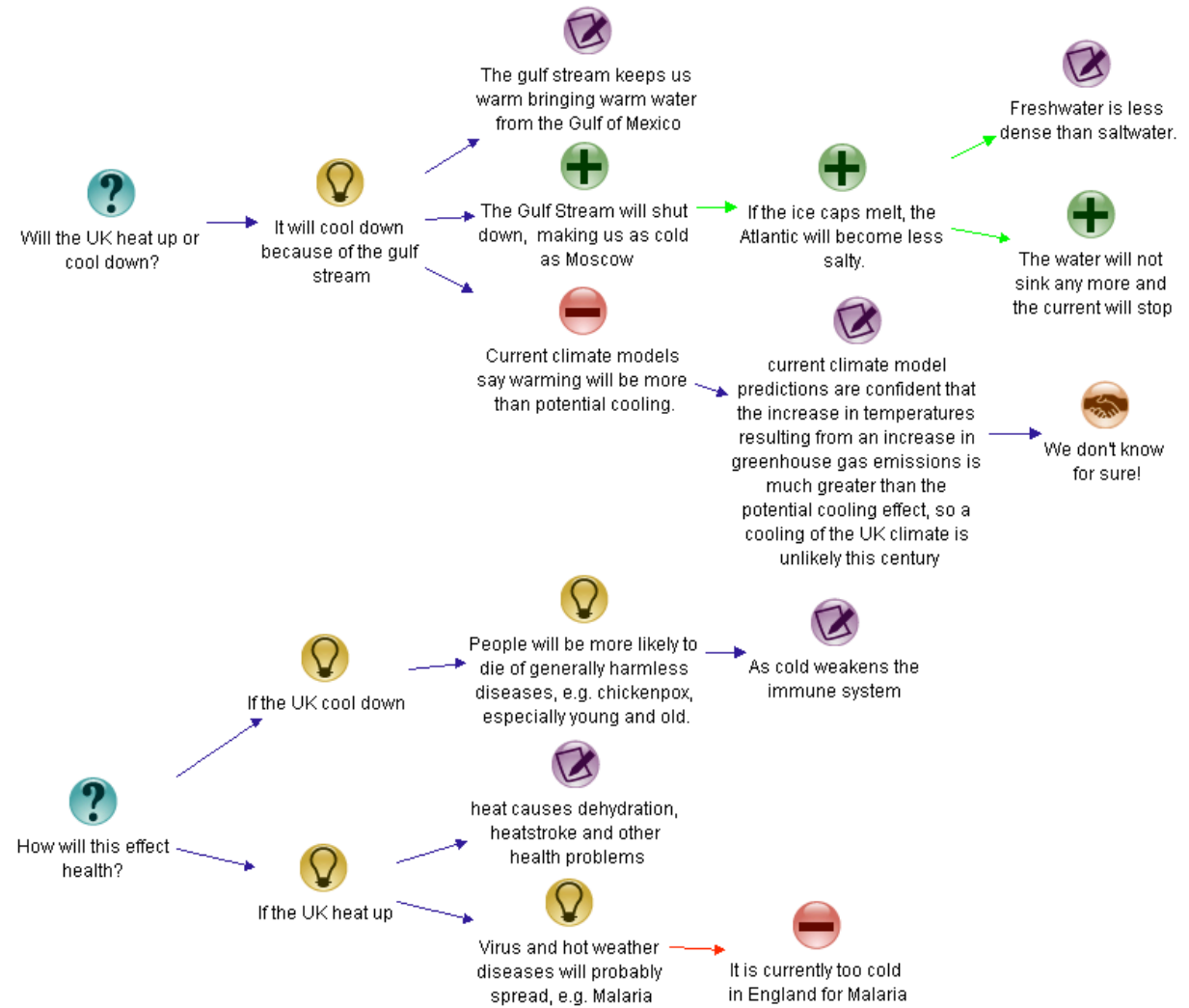
Figure 15 from the Forum IV – "Mapping data from the web"

The level of argumentation in their mapping improved. However, it is not possible to conclude that mapping helped them to construct better arguments. They established good connections, which were not as linear as the previous map. However, their arguments in this map were not as well integrated as in their writing (Figure 13 – first map) where we could see all of their arguments connected to data. In the prose of Figure 12, as they mentioned, they were "focussed" on the main idea ("Britain, a lot warmer") and they brought more components to ground that claim . In the map in Figure 15, they raised more questions and open more statements, but they were not able to inter-connect their arguments.

Figure 16 presents their final map and writing. Following the teacher's feedback and explanation about Compendium icons, pupils were able to improve their map significantly. With better understanding of how to to visualise the components of their map, they were able to assess their strengths and limitations; and construct better arguments.

Re: Writing from your map – *Diseases* Group by Chris and Carl

The gulf stream keeps us warm bringing warm water from the Gulf of Mexico

Freshwater is less dense than saltwater.

Will the UK heat up or cool down?

It will cool down because of the gulf stream

The Gulf Stream will shut down, making us as cold as Moscow

If the ice caps melt, the Atlantic will become less salty.

The water will not sink any more and the current will stop

Current climate models say warming will be more than potential cooling.

current climate model predictions are confident that the increase in temperatures resulting from an increase in greenhouse gas emissions is much greater than the potential cooling effect, so a cooling of the UK climate is unlikely this century

We don't know for sure!

If the UK cool down

People will be more likely to die of generally harmless diseases, e.g. chickenpox, especially young and old.

As cold weakens the immune system

How will this effect health?

heat causes dehydration, heatstroke and other health problems

If the UK heat up

Virus and hot weather diseases will probably spread, e.g. Malaria

It is currently too cold in England for Malaria

"We think that the UK might cool down because of the gulf stream. The gulf stream keeps us warm bringing warm water from the Gulf of Mexico but the gulf stream might shut down, making us as cold as Moscow. This is because if the ice caps melt, the north Atlantic will become less salty. Freshwater is less dense than salt water so salt water normally would sink allowing the freshwater to pass above it. But if the water becomes less salty, the water will not sink anymore and the current will stop making the UK cool down rather than heat up.
However, current climate models say warming will be more than potential cooling. Current climate model predictions are confident that the increase in temperatures resulting from an increase in greenhouse gas emissions is much greater than the potential cooling effect, so a cooling of the UK climate is unlikely this century. We don't know for sure!
How will this effect health? If the UK cool down, people will be more likely to die of generally harmless diseases, e.g. chickenpox, especially young and old because cold weakens the immune system. If the UK heat up, heat causes dehydration, heatstroke and other health problems. Virus and hot weather diseases will probably spread, e.g. Malaria. However, it is currently too cold in England for Malaria."

Figure 16 from the Forum V – Writing from your map

The pupils are now using the icons more systematically to express the roles played by each idea:

- **Data** notes to represent facts, concepts and data. These are their evidence: statements that can be considered acceptable as truth based on science. Normally they are expressed in the present tense.
- **Ideas** to indicate their main claims in response to the Questions. As their questions refer to the future, these sentences are in the simple future tense.
- **Pros** to show supporting arguments. This can also be in the future, but their function is to support or explain their main Idea.
- **Cons** to introduce exceptions and other kinds of opposing arguments.

Once they were able to use the icons properly, they improved their map with better and more consistent explanation of the Gulf Stream. They also had a clearer visualisation about what their main viewpoint was, in order to support and challenge it. At the start they said that their focus was on "it will be warmer", but after better explanation, they changed to "it might be colder".

Figure 17 shows how Compendium was useful for these pupils to structure their writing from their map. They exported it using the Web Outline View option which linearises the map into an indented outline of nodes. They then edited the outline into more flowing prose.
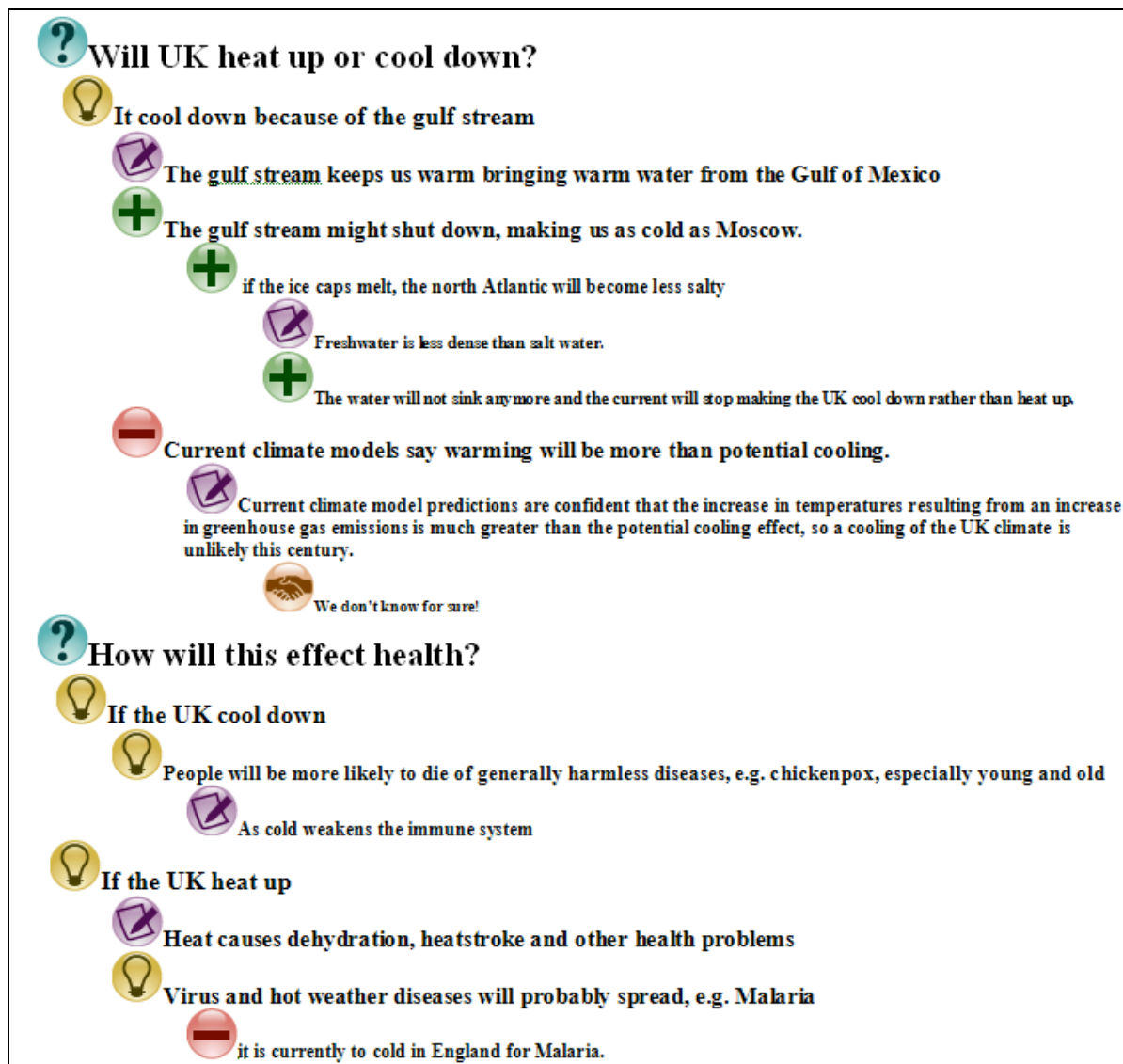
Figure 17 – Outline headings generated by Compendium from the map

The final discussion forum shows how these pupils reflected on mapping for writing. Both of them considered it useful: *"helped me to sort out my ideas and arguments"*, *"make my points clearer and easier to understand"*, *"It also helps you to think through the facts and how they affect your arguments."* They also volunteered the following advantages: *"Writing from mapping "is more fun"*, *"Argument is more logical and ordered"*, *"It makes the whole thing a lot quicker"*. Interestingly, they also recognised that they received better feedback from the teacher: *"it would also be easier for a teacher to mark my ideas"*.

In summary, we observed in Case B that when pupils demonstrate sound knowledge and arguments in their initial writing, maps can acts as a tool for seeing whether they were able to apply their knowledge and formatively assess their understanding. As pupils need to support their position in the map through connections, maps can reveal possible misunderstandings that their writing can not. Once pupils, through teachers' feedback, are able to clarify their connections, then they can enrich their argumentation and improve significantly their writing.

**5. Discussion (1): revisiting our research questions**

Encouraged by the success of Compendium-enabled Dialogue Mapping in non-educational contexts (e.g. knowledge management and information analysis), we have presented the first step in our efforts to investigate its potential as a cognitive discipline, within a structured digital medium, to help teacher-researchers investigate their school pupils' scientific argumentation. We now discuss the preliminary answers that we can give to our opening research questions, based on the analyses. We then draw some conclusions about Evidence-based Dialogue Mapping as an argumentation research method.

**Scientific knowledge and mapping**

In our case studies, we saw examples that Evidenced-based Dialogue Maps helped the science teacher-researcher visualise well-structured maps with poor argumentation, and of poorly structured maps with good argumentation embedded in the labels of nodes. Our findings showed that the visual language of IBIS can provide a template, for instance, cueing teachers and pupils that at least one Pro and Con are expected to be linked to each Idea, even if they are not yet sure what these should be. We saw that the maps were a useful tool to analyse whether information from the Web added coherence and depth to pupils' scientific argumentation, because the visual language requires pupils to make explicit what role they see information resources playing in their reasoning.

**Scientific writing and mapping**

We have analysed some of the translations that we observed from maps to prose, with some indicative results that a good IBIS tree structure in a map assisted the subsequent linearisation task by generating a coherent document outline. Sometimes pupils wrote maps in anticipation of conversion to prose, using connectives in node labels, while others added them after, in order to translate the nodes and links into more flowing prose. The relationship between the linear structure of texts and the logical structure of argument must be more fully explored. For instance, a closer analysis is needed to investigate how semantic, graphical connections in maps relate to the use of connectives in derivative prose.

**Cartographic literacy (both researchers and pupils)**

To a practised Dialogue Mapper's eye, many of the pupils' maps leave much to be desired in terms of form and content, but these are equivalent to the first stammering phrases in a new language. The question is to what extent Dialogue Mapping can add value even at this stage, in order to maintain pupil (and staff) motivation to try this new way of reading and writing ideas. Our case studies provide qualitative indicators that we take to be promising, although the story is clearly not straightforward.

The tasks of parsing one's thoughts into discrete nodes, and classifying with appropriate icons, are possibly the most demanding, and examination of the pupils' maps (or, indeed, any Dialogue Map) highlights that there are no hard rules (as we emphasised with our own maps in Figure 13). Whether a node is considered objectively reported Data or a personal Idea varies;

whether an idea is a Pro/Con or an Idea depends on how the root Question is framed. Whether a complex idea is left as one node or decomposed into constituents is again context dependent. The point is that concepts such as Problem, Idea, Data, Evidence are merely roles that elements play in discourse. At one moment, an idea is an unproblematic assumption, folded into a Question. That same idea may become an explicit Idea node somewhere else, or a Pro/Con. Pedagogically, this is of course an extremely complex point to teach any teenager, but this abstract concept is made tangible in Dialogue Mapping through the icons: the message is implicit in the visual language, if taught correctly. This brings us to the teacher-researcher's interventions and learning activities.

**Pedagogical interventions and learning activities**

In any context, teachers must provide appropriately constrained activities in which pupils can accomplish meaningful work. Knowledge cartography's process-orientation can provide a 'window' into the workings of teacher-researchers specifically when they can visualise pupils' minds through their maps, which show the intellectual moves they are making more clearly than when they are embedded in prose. As one pupil commented, mapping makes it easier for the teacher to mark the work, and we saw a key role for teachers to provoke thinking by asking specific questions about maps. The science teacher working on the summer school commented, *"Dialogue Mapping can function as a teaching aid if this mapping technique is applied in a context of a project with a set of activities, where pupils can rethink their mapping, get feedback and improve it"*.

In terms of Dialogue Mapping, this translated in a number of ways, including drawing attention to a specific part of the map that lacks clarity (*"what are your key ideas?"*) or needs elaboration *("where are the counter-arguments?")*; focusing pupils on substantiating reasoning with evidence from the Web; as well as domain knowledge checks *("why will melted ice raise water levels?")*. We see huge scope for developing a 'battery' of checks that both teachers and pupils could use to assess the quality of Dialogue Maps, adapting work on the practitioner skillset such as Conklin (2006) and Selvin (2008), to devise engaging, memorable heuristics.

**Software design**

Central to our inquiry is the challenge of providing media for pupils to give form to their thinking, and gradually structure it, moving from an inchoate collection of thoughts equivalent to a sheet of sticky-notes, into a deliberation map that can be judged rigorous by scientific and argumentation standards. Compendium's design has been strongly shaped by a focus on avoiding "premature commitment" to inappropriate structure, and other key *cognitive dimensions* that determine the fluidity of tools for thought (Cognitive Dimensions, 2007). We saw in the case studies the value of permitting freeform layouts of nodes, but also the danger that this low constraint condition can provide 'enough rope to hang yourself' with spaghetti link structures. We are concluding that predefined visual patterns in the form of reusable templates could have an important role to play in seeding maps with useful structures.

To summarise, our vision might be framed as follows. We want to reach the point where pupils and teachers feel as confident with knowledge cartography as they do with other digital tools, and where the visual schemes provide an intuitive way to build and critique reasoning using the cartographic language of colour and space, e.g. *Where's the purple?* (there's no

data); *Where's the red?* (there are no counter-arguments); *Why do these nodes repeat each other?* (there may be a clearer structure to this map which groups these nodes together more elegantly); *Where's the root node?* (what's the core issue at stake?); *Why are these nodes out here on the edge?* (are they irrelevant to the rest of the argument, or are you missing an important question that will bring them in?).


## 6. Discussion (2): Evidence-based Dialogue Maps as an argumentation research method

Research methods are normally, from the perspectives of researchers, separate from any methods used by those whom they study. In contrast, in the participatory action research approach reported here, we are using Evidence-based Dialogue Mapping as researchers to analyse whether the very same method in the hands of pupils helps them to behave like researchers engaged in scientific reasoning, and in the hands of teachers, could be an assessment tool. The approach is thus serving as a 'tool for thought' for all stakeholders. We have sought from this pilot work to understand the kind of analysis that this reflexive approach permits, but recognise the tensions that are set up. Let us briefly consider some of the pragmatic factors that must be negotiated.

We have emphasised that, as with its spatial analogue, knowledge cartography of this sort is never neutral. Depending on perspective, different maps can be constructed by a researcher from the same transcript (as with any codification system), and different students will construct different maps from the same resources. Maps are refined as the mapper's understanding develops around the domain (scientific knowledge), and their mapping (cartographic literacy) develops. We therefore see instances where scientific reasoning may be sound but Dialogue Maps expressing that reasoning may be poor (e.g. compared to pupils' greater fluency with prose). Alternatively, a Dialogue Map may have superficially good form which disguises flawed scientific reasoning in the unclear use of links, or in the detail of the nodes.

This representational flexibility does not leave us in interpretive chaos, however, for several reasons:

- Firstly, for the reasons laid out above, we are led to conclude that, as with many other approaches to assessing complex reasoning, assessment by teachers or researchers is unlikely to be as simple as uncritically counting the numbers of different node types that are created: qualitative analysis is required. This complicates, but does not undermine, our objective (validated to a degree by the empirical evidence reported), that knowledge maps of this sort make thinking visible, providing insight into reasoning.
- Secondly, in contrast to most participants whose argumentation is studied by researchers, Dialogue Mappers (and users of other discourse mapping approaches) are already engaged in a greater level of argumentative reconstruction than with other symbol systems. This not only slows them down (sometimes to their frustration, but also hopefully to their benefit), but provides an outsider (whether a pupil peer, a teacher or a researcher) with a 'head start' when it comes to understanding what is going on — if they also have the literacy to read the visual language. We have shown

that, even with brief training, novice pupils are able to construct maps that enable a teacher to provide rapid, helpful feedback which the pupils value.

- Thirdly, we are not left in analytical chaos by the interpretive license inherent in Dialogue Mapping: there is a disciplined craft (Conklin, 2006) to constructing 'good' maps that researchers (and pupils and teachers) can learn; we have sought to show that we as researchers can be systematic in how we rate pupils' argumentation whether in prose or maps, and self-aware as we construct our own maps from pupil transcripts. Once teachers or researchers agree on a coding scheme and conventions for mapping, the resulting systematicity provides greater confidence in quantitative and purely structural measures of map quality as a reflection of underlying scientific quality.

This work raises an important question concerning the expressive power of the IBIS language. While any deliberative process can be mapped in IBIS as a series of Questions, Ideas, etc., it is clear that it cannot adequately express all argumentation in all fields of discourse: one has only to consider the complexity and variety of rhetorical devices in different disciplines, and the different notations developed in argumentation theory and computational argumentation, to see its limitations. A more modest ambition is to demonstrate that Evidence-based Dialogue Mapping can, with minor extensions, express most forms of deliberation necessary at primary, and possibly secondary, level school science. To take a specific example, Evidence-based Dialogue Mapping does not deal well with chains of Pros and Cons supporting/challenging other Pros and Cons: it becomes hard to understand the display. We have already found it necessary to enrich the visual language, drawing from related work in argument mapping (e.g. Appendix 1; Buckingham Shum, 2007; Buckingham Shum and Okada, 2008).

## 7. Summary and conclusion

Dialogue Mapping is a relatively mature knowledge cartography approach, with an established user community, technical base and codified training, with demonstrable value outside education in many organisational sectors. This paper has discussed the results of a pilot investigation introducing it into a secondary school context, specifically in response to growing concern over pupils' poor scientific reasoning skills.

We have explored the relationship of scientific argumentation to Dialogue Mapping, and presented qualitative analysis of two case studies from a UK summer school for teenagers aged 12-13 years. We aim to continue investigating the research questions introduced above with respect to how Dialogue Mapping and Argument Mapping can be used as a teaching-research tool to improve pupils' critical thinking and argumentation skills in contemporary socio-scientific debates.

Our objective in terms of professional development is to foster a community of practice amongst educators and researchers (and perhaps even pupils), with its own focused workshops, map-exchange websites, and online discussions for sharing curriculum ideas. We welcome contact from all who would like to participate in such a network.

## Acknowledgements

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**Appendix 1: Vertical layout of an Evidence-based Dialogue Map**

A researcher (second author) analysing the work of Case B pupils. This example illustrates not only the vertical 'bottom-up' layout as an alternative to the horizontal left-right layout shown in other examples, but also the use of intermediate Questions as an organising device to clarify the structure of the reasoning. Compare this to other maps in Case B.