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

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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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A. Okada et al. (eds.), *Knowledge Cartography: Software Tools and Mapping Techniques*, Advanced Information and Knowledge Processing,
DOI 10.1007/978-1-4471-6470-8_7,

many countries like the United Kingdom, the emphasis of the science curricula is shifting towards 'scientific literacy'. Teachers are now required to develop students' capabilities to engage with science-based technology and the socio-scientific issues they will encounter outside school, rather than just on grounding in knowledge or a preparation for a scientific career. This requires adopting an inquiry-based methodology, which provides students opportunity for self-expression and for coming to informed decisions. Inquiry-based learning aims to develop the skills of scientific thinking, so that learners can interpret evidence, weigh up technologies, make informed judgements, and argue their views. As scientific issues continue to dominate public policy that impacts our lives (e.g., food safety, environment, genetic engineering) citizens need to have the skills to assess the reliability of information, the soundness of arguments, and the ethical implications. In order to be "scientifically literate" students need to know how to put together arguments coherently (Hodson 2003). Teachers need to equip young teenagers with the ability to evaluate claims about science in the media.

Learning "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 for students. They find it difficult to apply their knowledge to construct scientific explanations. Recent studies show that many students are very poor at connecting data and theory in order to validate arguments (Kuhn 1991; Means and Voss 1996; Hogan and Maglienti 2001). Schwarz and Glassner (2003:232) observed that students do not know how to connect, to 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*".

Scientific argumentation skills do not come naturally. Kuhn's studies (1991) motivate the view that presenting controversial socio-scientific issues for debate in the classroom is not sufficient on its own to foster good argumentation skills (Kuhn 1991; Newton et al. 1999; Rider and Thomason, Chap. 6). Teachers need to assist students 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 et al. (2002) emphasise scientific reasoning is a special form of discourse that needs to be developed and appropriated by students through suitable tasks, and through "structuring and modelling". In order to help students scaffold scientific argumentation teachers need to show how to set out strong components and establish good connections.

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, students 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).

This study is the first in a long term research programme to investigate how approaches like dialogue mapping can augment students' scientific reasoning, and critical thinking more broadly. This exploratory work analyses the potential of using dialogue mapping to scaffold young students' scientific argumentation. In this context, by scaffolding we mean constructing scientific argumentation graphically through a step-by-step process. We are currently framing this inquiry in terms of the following general questions, each of which has many possible sub-issues:

- Scientific knowledge and mapping. As noted, the current interest in deliberation and argumentation that we see amongst researchers and practitioners is driven by the recognition that beyond a good understanding of the domain, students also need the skills of being able to communicate and critique in an appropriate way their own reasoning, and that of peers. This question focuses on 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 their own or a peer's speech or writing into a map lead to new insights? What is the effect of creating a dialogue map on derivative written and spoken presentations?
- Cartographic literacy. We know a lot from previous research about the cognitive skills of crafting good concept, dialogue and argument maps: it is hard work, but at its best is satisfying and fosters intellectual rigour. Which of these processes do students find easy or hard to attain, and can they be communicated in more age-appropriate, multimodal/media ways?
- The teacher's role. While highly motivated students 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 different ages? 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 students and staff tell us about the digital tools we are offering them?

We will see these themes emerging as we analyse the case studies, and will revisit them in turn in our discussion. In Sect. 7.2, we introduce the idea of using diagrammatic representations to support the acquisition of scientific reasoning skills in secondary schools. Section 7.3 motivates the use of Dialogue Mapping as an approach, based on the hypothesis that its success in non-educational contexts may be transferable to gifted teenage students in the science classroom. In order to ensure quality of scientific argumentation, we introduce an "evidenced based dialogue mapping" approach, which integrates dialogue mapping with Toulmin's model of a scientific argument. In Sect. 7.4, we present the methodology applied to this research, which comprises a set of inquiry-based learning activities for applying dialogue mapping to arguing and writing in science, data collected and criteria for analysing extracts. Through three case studies, we describe students' achievements and difficulties in constructing scientific arguments. Section 7.5 presents our findings and our future work.

7.2 Could Argumentative Maps Be Useful for Secondary School?

Clearly, no simplistic statements can be made about the merits of different media, ontologies and notations, since they each exert their own influence, and interact strongly with factors such as the learner's domain expertise, fluency with the tools, familiarity with each other, and the way in which their activity is designed (Veerman 2003). However, based on some chapters in this volume, appropriately designed and deployed mapping tools can aid learning: to make sense of internet information (Zeiliger), clarify reasoning (Rider & Thomason), develop conceptual understanding (Novak & Canas; Mariott & Torres), foster critical thinking (Reed & Rowe), collaborative inquiry and affordances of different representations for learning (Suthers).

As a practitioner working on science education for gifted school students, O'Brien (2003:70) concludes that argument maps offer:

- a permanent record of thinking on a topic that contributes to a debate;
- clarity and rigour in thinking by improving the sharing of knowledge in a group leading to a deeper understanding of issues;
- efficient ways to present overviews indicating boundaries of current knowledge or debating in complex argumentation to another student;
- better decision making by ensuring that a higher proportion of relevant considerations are taken into account.

Specifically, in science education, there are studies using graphic representations to help students argue in science in high school and higher education. For instance, Schwarz and Glassner (2003) analysed argumentation as a central form of literacy with high school students in physics. Suthers (Chap. 1) investigated scientific argumentation for collaborative inquiry with undergraduate students in physics. In the literature, several researchers have developed argumentation with younger students, but without computer support (i.e. Driver et al. 2000; Hogan and Maglienti 2001; Jaubert and Rebiere 2005; Manson and Boscolo 2000; Means and Voss 1996; Ratcliffe 1997).

This is the first work to explore the potential of using a particular approach called Dialogue Mapping for young secondary school students to construct their scientific arguments. Children and teenagers frequently argue in home and at school, asking questions, giving answers and reasons for and against. They also have to give counterarguments to refute other's opinions. The components of their argumentative conversation – questions, answers, pros, cons, comments and conclusions – are similar to those used to represent dialogue maps, as described next.

7.3 Adapting Dialogue Mapping for Scientific Arguing

Dialogue mapping is a knowledge mapping technique developed 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 – 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 that grow with the conversation (Conklin and Begeman 1988). Extended by Compendium visual hypermedia tool, this technique has been applied in organisations and companies by researchers, training facilitators, consultants and team leaders in support of collaborative sensemaking (Selvin, Chap. 11). Given the success of Compendium in these sectors, and the growing need to begin instilling argumentation literacy at an early age (with a specific interest in science), the question arises: Could dialogue mapping be equally useful in the classroom, to help students argue scientifically?

In order to show how dialogue mapping can be used to represent the process of arguing, we selected this example below, which collates responses posted online at the summer school where students were asked: "what makes a good scientific argument?".

Teacher: What do you think makes a good scientific argument?
Kim: It must include questions, answers and explanations of the reason why.
Sara: Statistics are very useful and gives readers an idea of amount or what you are talking about
Beth: Evidence and strong pros and cons and a good topic to base the argument on
John: A good scientific argument consists of a good question, a good strong fact with an even better argument!
Peter: An argument showing both sides fairly with evidence for them and some biased comments for the side that you support but be careful youdon't contradict yourself
Alex: A logical, well thought out statement that works in putting your thought across in a few concise sentences
Tina: Keep arguing and go over all evidence and always confirm it.
However, nether be biased and expect to be surprised, not all discoveries are predictable.
Lucy: The more facts the better

Extract 00 Responses from Totally Wild Science Course in Moodle

In these maps, the Compendium icons were used to represent questions (question node), answers (answer node), arguments (pro node), counterarguments (con node) and data (note node). As we can see, this map could have different representations, depending on the interpretation of the group and mapper. If the discussion in Extract 00 was Dialogue Mapped by a beginner, they might capture contributions more or less as they were uttered, and linked to reflect the temporal sequence. However, Dialogue Mapping at its best helps to clarify the key Issues, thus illuminating how the other contributions relate to these in the form of Ideas responding to those Issues, and the relative Pros and Cons of each Idea in that context (Fig. 7.1). The emphasis thus shifts from chronological structure to logical structure. The challenge is how teacher intervention, software tools and practice can effect this shift in students, from naturalistic reasoning/discourse to conceptual reconstruction.

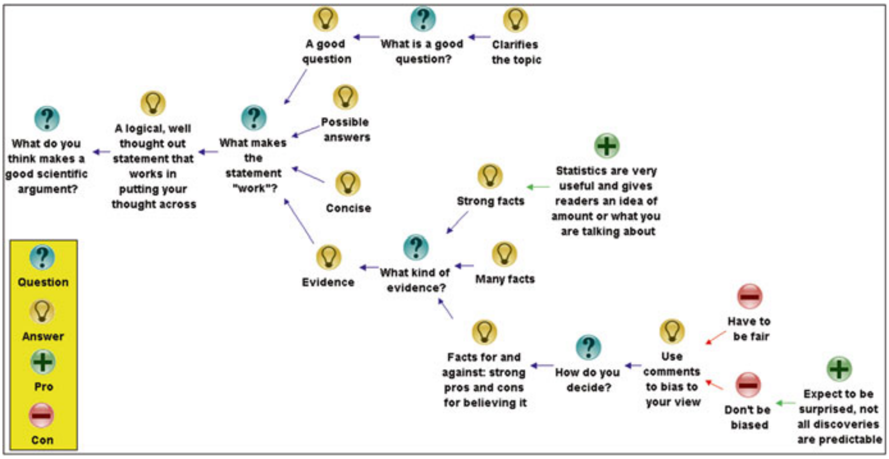


Fig. 7.1 Dialogue map in Compendium (tool described in Chap. 17 by Sierhuis and Buckingham Shum)

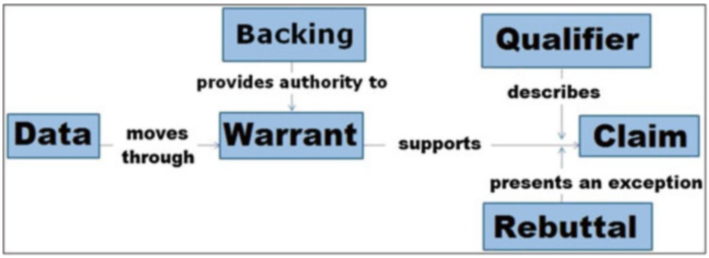


Fig. 7.2 Toulmin argumentation scheme

While IBIS provides a relatively intuitive language, as we discuss next, it is missing a key element central to scientific argumentation: evidence.

7.3.1 Evidenced-Based Dialogue Maps

In scientific reasoning, it is important that the students can ground their claims in scientific concepts instead of 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.

In order to represent the components of a scientific argument for teachers, Simon et al. (2002) adopt the well known Toulmin (1958) model (shown in Fig. 7.2; also discussed in Chap. 8 by Rowe and Reed; and Carr 2003). In their research, the Toulmin approach was applied for teachers to guide students in structuring their argumentation scientifically and assessing the quality of their argumentation.

Fig. 7.3 Evidenced-based dialogue map

Toulmin's model can be re-expressed in dialogue mapping's IBIS language as shown in Fig. 7.3 (Carr 2003). 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*, etc.).

In Toulmin form, there are six basic components of an argumentative move:

1. Claim: is the position on the issue and the essence of the argument. This represents the arguer's conclusion.
2. Data: i.e. initial grounds for the argument and evidence that can be accepted as factually true. This can be based on facts, events, examples and statistics.
3. Warrant: evidence used to support the connection between the data and the claim. It can be "authoritative" based on a reference by an expert; "motivational" based on convictions or "substantive" based on example, classification, generalization or cause and consequence. In science, the quality of the warrant is based on scientific concepts (substantive) rather than own convictions (motivational).
4. Rebuttal: This states the exceptions to the claim and is an exception to the truthfulness of the argument. It illustrates instances where the argument may not be true.
5. Qualifier: This states the "strength" of the claim. It represents the validity of an argument and indicates the context or circumstances where the argument is "true".
6. Backing: A source of authority for the warrant.

However, in this study we selected only four components of Toulmin's model – claim, warrant, rebuttal and data. These were considered by the science teacher to be the most relevant elements for students to incorporate into a scientific argument and a simple approach to scaffold their arguing skills.

Figure 7.3 shows the scientific argument structure created in Compendium which we call as "evidenced-based dialogue map". The connections between these components are not exactly as Toulmin's model. It is a simple structure for scientific explanations, whose a claim should be connected to one or more warrants, rebuttals and data in order to demonstrated the evidence for the claim. Considering the vocabulary of these 12–13 years old students, these four components refer to answers, pros, cons and data (shown in Extract 00).

In this context, we examine whether Compendium helps students write scientific arguments. Our hypothesis is that it does so by scaffolding the task, breaking down the process into a series of more manageable and visualisable steps for students:

1. Represent initial reasoning in the form of a map, using Compendium's icons to show the parts of the argument visually.

2. Use these visualised components to elicit further existing knowledge, and add this to the map.
3. Assess the strengths and weaknesses of the reasoning, by seeing if the claims are backed up with enough evidence.
4. Once the reasoning is strengthened, to transform the map into a linear text-based argument.

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

7.4 Methodology: Constructing Scientific Arguments in Compendium

7.4.1 Context: A Science Summer School

In this research, we observed 20 "gifted and talented" students who volunteered to attend a summer course "Totally Wild Science" during their school holiday in 2006. "Gifted and talented" is a term used in the United Kingdom for students who are in the top 10 % of the national average based on their performance in formative assessment and test scores. The educational science consultant who organised this course with the educational committee of Canterbury Christ Church University selected 12–13 year-old teenagers, from different schools in the United Kingdom, based on an essay that described why they wanted to take this course and why they were very good at learning science.

"Totally Wild Science" was a science course organised around three topical themes: Forensic Science, Space, and Environment, with the aim of engaging students to develop their science learning skills. The main approach of this course was to use a great variety of learning projects in the science and computer laboratory, virtual learning environments and events such as trips and workshops with scientists. The main aspect of this course was to help them apply their own knowledge in projects in order to develop their scientific skills, rather than teaching new science concepts.

This research focused on the Environment project: "Global Warming – what do you think will happen in the future?" We developed a set of activities using dialogue maps about global warming with the science teacher. The tasks were published in the Moodle virtual learning environment, which was used to support collaborative learning. Students recorded their discussion and dialogue maps in a Moodle Forum (threaded discussion tool). They also posted their essays based on their dialogue maps. During this process, they described their progress and reflected on their difficulties and improvement. Compendium was introduced by the author, who demonstrated how the discussion between the science teacher and students could be recorded by dragging and dropping Compendium icons: questions, answers, pro, cons and notes. Some examples (similar to Fig. 7.1) were presented to illustrate a

Fig. 7.4 This picture illustrates a student working with Compendium (*left*), dragging into her map the results of web image searches (*right*)

dialogue mapping structure. The science teacher explained the importance of organising scientific arguments through these icons. Each answer should be connected to pros, cons and data. He showed some examples of maps based on Fig. 7.3.

Although students were using Moodle and Compendium for the first time, they did not encounter difficulties in manipulating these tools. Dragging and dropping information from the web and Moodle into Compendium (illustrated by Fig. 7.8) was straightforward. This level of digital literacy enabled us to start the project with new tools with a brief introduction (Fig. 7.4).

7.4.2 Inquiry Based Learning Activities

In this *Global Warming* project we organised seven activities (Table 7.1) related to confirmation/verification inquiry (see Table 7.2).

Five inquiry skills areas are described by the US National Research Council (2000):

- engaging by scientifically oriented questions
- giving priority to evidence in responding to questions
- formulating explanations from evidence
- connecting explanations to scientific knowledge
- communicating and justifying scientific explanations to others

Tafoya et al. (1980) suggested four kinds of inquiry-based learning based on different levels of student autonomy (Table 7.1). The first level is the ***confirmation/verification inquiry*** in which students are provided with questions, procedures (method) and results in order to practice the inquiry based learning approach. The second level is ***structured inquiry***, in which students are provided with questions

Table 7.1 Inquiry based Learning activities – using dialogue mapping for arguing and writing about global warming

Inquiry-based learning activity	Tools
"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 a reason. 2. What do you think makes a good scientific argument?	Moodle – Forum I
"Writing about Global Warming": Elaborate a composition in pairs about "What will be the impact of Global Warming (crops, diseases, ecosystem, water or weather)?". Share it in the forum discussion	Moodle – Forum II
"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"	Compendium, Moodle – Forum III
"Mapping data from the web": Enrich the map with significant information from the internet and prepare a better argumentation structure	Compendium, Internet, Moodle – Forum IV
"Editing and improving map": Improve scientific arguments in the map by using teacher's feedback and focussing on the strongest idea	Compendium
"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	Compendium, Word, Moodle – Forum V
"Reflecting on writing from maps": Share your opinion about your learning, the use of Compendium and dialogue mapping applied to writing	Moodle – Forum VI

and procedure; they, however, generate an explanation supported by the evidence they have collected. The third level is the ***guided inquiry***, where the question is still provided by the teacher and students design the procedure (method) to test their question and the resulting explanations with guidance or mentoring support. The fourth and highest level of inquiry is ***open inquiry***, where students have the opportunity to act like scientists, deriving questions, designing and carrying out investigations as well as communicating their results. This level requires experienced scientific reasoning and domain competences from students.

The inquiry skills described in Table 7.2 show a detailed version of the five skill areas related to the each of four levels of inquiry. These twenty skills were adapted from the table inquiry grid for teaching towards student skills presented by Bodzin and Beerer (2003).

The inquiry based learning activities of the Global Warming project, which focus on confirmation/verification level, aim to introduce students to the experience of conducting investigations with teacher's guided support for:

- Reflecting on the questions provided by teacher, materials, or other source
- Analyzing given data to select evidence with directed support
- Applying provided evidence to formulate explanation with directed support
- Selecting possible connections to clarify explanations with directed support
- Applying given steps and procedures for scientific communication

Table 7.2 Meta-levels of inquiry skills – table adapted by Okada based on Bodzin and Beerer (2003) and NRC (2012)

	Inquiry skill area				
Level of inquiry	1. Scientifically orientated questions	2. Priority to evidence	3. Explanations from evidence	4. Explanation connected to knowledge	5. Communicate and justify
1. Confirmation/verification	Engaging in questioning provided by teacher, materials, or other source	Analyzing given data to select evidence with directed support	Applying provided evidence to formulate explanation with directed support	Selecting possible connections to clarify explanations with directed support	Applying given steps and procedures for scientific communication
2. Structured inquiry	Sharpening or clarifying question provided by teacher, materials, or other source	Analyzing given data to select evidence	Selecting possible ways to use evidence with directed support to formulate explanation	Selecting possible connections to clarify explanations	Selecting broad guidelines to use sharpen communication
3. Guided inquiry	Selecting among given questions and posing new scientific questions with guided support	Collecting certain data with guided support for what constitutes evidence	Formulating explanations from evidence with guided support	Linking areas and sources of scientific knowledge to clarify explanations	Communicating explanations based on scientific reasoning with guided support
4. Open inquiry	Posing a scientific question	Determining what constitutes evidence, and collecting evidence	Formulating explanations after summarizing evidence	Examining independently other resources and forming the links to explanations	Forming reasonable and logical argument to communicate explanations

Table 7.3 Criteria for analysing level of arguing

Level of argumentation	Description
(1) no argument	Only claims
(2) weak	Claims and (weak) warrant (based on convictions)
(3) simple	Claims, (weak) warrants and rebuttals or data
(4) strong	Good Claims, good warrants, rebuttals/ data

Table 7.4 Criteria for analysing level of writing

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

7.4.3 Data Focus for This Study

The method of this qualitative research was case studies involving qualitative analysis. We collected discussions, maps, writing and notes posted by students and the teacher in Moodle, which served not only as a collaborative learning environment but also as a data archive for subsequent analysis. 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 writings); (2) detailed examination of each pair of students who worked together analysing what they have produced (3 maps, 4 messages and 2 writings), (3) deep study of three cases which were selected because they were distinctive, as defined by Tables 7.3 and 7.4.

7.4.4 Criteria for Analysing the Extracts

Based on the Toulmin argument scheme, we described four levels of argumentation and writing. These two tables were used as a reference to guide the case studies analysis.

We present data from three pairs of students for range of sources, since they represented different outcomes. Like the rest of the class, these six teenagers did not enjoy writing in science. None of them had problems in using Compendium, although they encountered difficulties in dialogue mapping which we will describe.

Case A analysed data from students who had difficulties in writing and arguing. Their writing in science was considered "weak" by the science teacher; because they did not apply enough science concepts and their arguments were based on personal convictions. The level of argumentation dropped in their first map (from level 2 to level 1), then it gradually improved (from level 1 to level 3). Their final

Table 7.5 Level of argumentation and writing of three pairs of students

Case	Student	Forum 2 1st writing	Forum 2 Arguing	Forum 3 1st Map	Forum 4 2nd Map	Forum 2 3rd Map	Forum 5 Final writing	Would you use maps?
A	Alan	Weak	(2)	(1)	(2)	(3)	Ok	No
	Alex							Maybe
B	Beth	Very weak	(1)	(2)	(3)	(4)	Good	Probably not
	Ben							Yes
C	Chris	Good	(4)	(2)	(3)	(4)	Very good	Yes
	Carl							Yes

essay showed that mapping did not help them construct significant arguments. Although it contributed to making their writing clearer – level "ok", their argumentation were not strong because they did not present enough data nor counterarguments. Here, we focus on analysing their difficulties.

Case B analysed data from students with poor skills for writing and arguing. Their first writing before mapping was classified as "very weak" with no arguments. In their maps, the level of argumentation gradually increased (from level 2 to level 4). At the end, their composition from maps was significantly improved -"good". They included data and counterarguments, but they were not able to include science concepts to ground every claim. Here, we focus on analysing their achievements.

Case C analysed students who were good at arguing and writing, but presented initial difficulties in mapping. At the beginning of their project mapping was neither easy nor useful for them. Their level of argumentation dropped from 4 (in their writing) to 2 (in their first map). During the mapping activities, their scientific arguments were gradually improved (from level 2 to level 4). At the end, they were also able to present significant improvements in their writing, which was considered "very good". Here we focus on mapping skills for constructing scientific arguments.

Table 7.5 summarises the level of argumentation and writing based on Tables 7.3 and 7.4 during their inquiry-based learning activities. In forum 2, they recorded their initial writing. In forum 3, they created their first map. In forum 4, they improved their map by bringing data from the web. In forum 5, they prepared the final version of their map, exported to web outline and from a sequential list of components they elaborated their writing.

7.4.5 Case A

In Extract A.1, two students who worked together explain why they don't like writing in science. For Alan, writing is "*painful*" and for Alex, "*it helps for revision but is boring*". Both were able to provide a reasonable answer to "*what makes a good scientific argument*". They also constructed an argument about the future of the UK in the event of global warming.

Teacher: How much do you like writing in science? (1= not at all, 3=OK, 5=I really like it). Alan: Not at all. Because I get cramp in my wrist easily, so it is actually painful to write large amounts by hand. Alex: OK. It helps for revision but getsa bit boring. It is more fact than fiction. It is more remembering than imagining. Teacher: What do you think makes a good scientific argument? Alan: A good scientific argument consists of a good question with a good strong fact with an even better argument! Alex: A theory and logical, well thought out statement that works in putting your thought across in a few concise sentences.

Extract A.1 from the Forum I – Reflecting on writing in science

Extract A.2 shows these students' writing. Their answer was based on a long sentence, which presented their ideas, argument and a short science explanation.

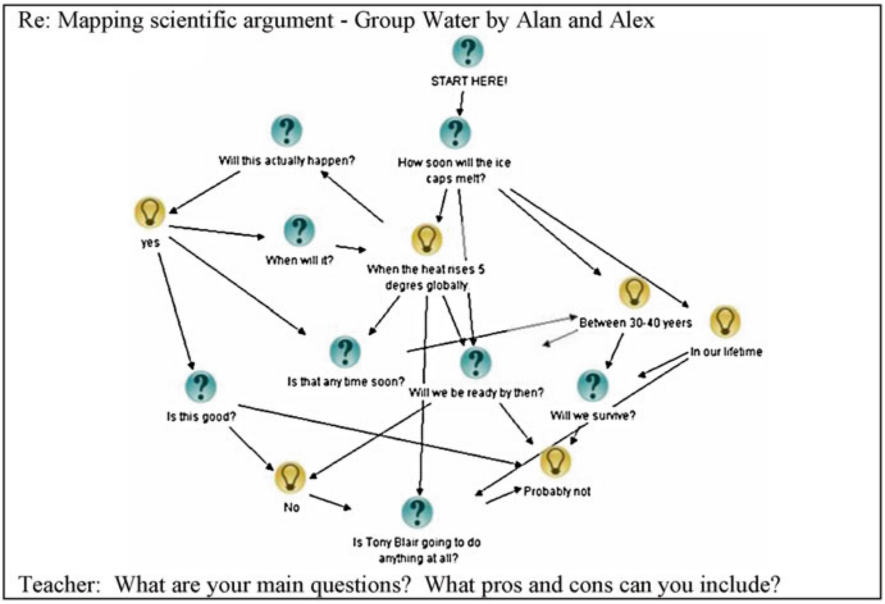
Teacher: Write down for your topic: What you think will happen in the future in the UK? Re: Writing about Global Warming -Group Water by Alan and Alex.
If the ice caps do melt and the product of the melting (the water) goes into the sea (which it will) it will make the water levels rise dramatically and flood villages, towns, cities and maybe even small countries! Shocking(!) The reasons for these ideas are really just logic. Teacher: Why will water levels rise dramatically if the ice caps melt?

Extract A.2 from the Forum II – Writing about global warming

In order to analyse the level of argumentation of these students' writing, the author created the map below (Fig. 7.5) in Compendium. By interpreting their answers graphically based on Toulmins' model, we can see that they included a claim, a warrant and one piece of data. The level of this argumentation is 2. They were able to connect warrant and a concept to support their claim, but they were not able to apply knowledge scientifically. They presented strong conviction "(*which it will*)" to support their answer, but they did not provide enough justification. The argument is sound in structure. However, they were not able to explain how ice caps melt would make the water levels rise "*dramatically*". They did not include data showing the risk of flooding in the UK nor any rebuttals.

Fig. 7.5 Map created in Compendium based on Toulmin's models

Extract A3 shows the first dialogue map this pair created in Compendium. They generated eight questions and six short answers. Although their questions were very relevant and imaginative, their answers were very short ("*yes*", "*no*", "*probably not*") and there were no arguments.

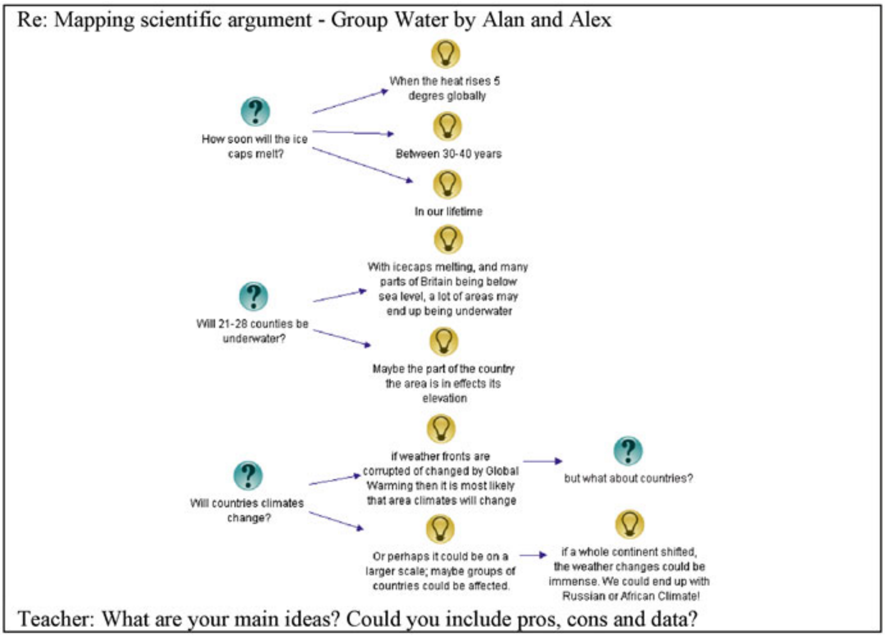


Extract A.3 from the Forum III – Mapping scientific arguments

For these students, writing an argument in the discussion forum was quick, but representing an argument graphically was very hard. They spent a long time, and they were not able to structure clearly their reasoning. Reading the content of this mapping is a little distracting, and it is easy to be lost. In this intricate structure, connecting pros, cons and data for each answer is more difficult because the information is not well organised spatially. The level of their argumentation in this map is 1 – weak claims (e.g. "*yes*", "*in our lifetime*", "*between 30–40 years*",…) and no arguments (neither pros nor cons). Comparing the argumentation in their writing (Extract A.2) to their first map, the quality dropped from level 2 to level 1. Looking at their short answers, it is hard to identify "*well thought out statements*", because they are incomplete sentences. These few words only make sense if we read the questions, but each answer addressed several questions.

In this case, Compendium functioned as a brainstorming medium which helped them to generate several interesting questions about implications for policy and action. They were able to go through a rich process of questioning. As Alex mentioned "*a good scientific argument consists of a good question*". However they were not able to connect warrants, rebuttals and data in their map. In this case, the challenge for teachers is to help students find ways to reorganise their map. Students who are not good visual thinkers and not familiar with mapping techniques will need more support for establishing good connections between components.

Extract A.4 shows their map after teachers support. The students improved the structure and they were able to construct scientific claims through full sentences. This new structure suggests a sign of substantial cognitive change. This process is not quick; they spent a long time restructuring their map. In this activity, ‘Mapping data from the web’, they did not access the internet because they were focussed on disentangling their ‘intricate web’ and clarifying their thinking. They deleted many nodes; some of them were excluded accidentally (as described in Extract A.6).

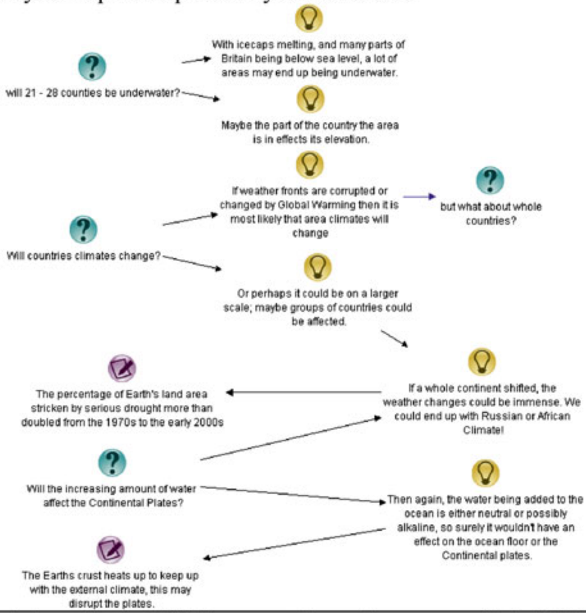


Extract A.4 from the Forum IV – Mapping data from the web

As we can see in the Extract A.4, although the structure of their map is better, the level of argumentation was not significantly improved. They made some progress on the content of their claims, but the quality of their arguments in this new map is similar to their initial writing. Their warrants are not based on accurate knowledge. They did not give any evidence to support their arguments. Their argument is based on common sense knowledge (melting ice increases the volume of water) but if the ice is floating on the sea, the level of water will not rise. If they are talking about ice from land, then it will rise. From the science perspective it would be important to ask what science concepts ground their ideas, for instance, why would “*the whole continent shift*”? They tried to create arguments, but based on ‘logic’ and suppositions. They did not support their claims with warrants based on science concepts, rebuttals or data.

Extract A.5 presents their final map and composition. In the map, we can notice their difficulties again in organising the structure of nodes, in choosing icons and making connections. The arrows, again, were represented in different directions.

Re: Writing from your map - Group Water by Alan and Alex



"Will 21-28 counties be underwater? With icecaps melting, and many parts of Britain being below sea level, a lot of areas may end up being underwater. Maybe the part of the country the area is in affects its elevation.
Will countries climates change? If weather fronts are corrupted or changed by Global Warming then it is most likely that area climates will change. It could be on a larger scale. Maybe groups of countries could be affected. If a whole continent shifted, the weather changes could be immense. We could end up with Russian or African Climate! The percentage of Earth's land area stricken by serious drought more than doubled from the 1970s to the early 2000s.
Will the increasing amount of water affect the Continental Plates? Then again, the water being added to the ocean is either neutral or possibly alkaline, so surely it wouldn't have an effect on the ocean floor or the Continental plates. The Earths crust heats up to keep up with the external climate, this may disrupt the plates.

Extract A.5 from the Forum V – Writing from your map

In their second paragraph, they came up with a series of plausible claims, but rarely included relevant data, and did not establish a relationship between the claim (e.g. "*If a whole continent shifted, the weather changes could be immense*") and the evidence (e.g. "*The percentage of Earth's land area stricken by serious drought more than doubled from the 1970s to the early 2000s*"). In their third paragraph, the argument is good, but the science knowledge (suggesting that climate change might alter the structure of the Earth's tectonic plates) does not make sense. Their argumentation did not improve significantly comparing the initial writing (level 2) with their final composition (level 3). There are more sentences organised in better sequences, they could visualise their strongest ideas, but they did not develop the quality of arguments, they were not able to identify where they should connect more evidence. They did not add strong warrants, rebuttals and enough data. There were no strong connections based on science concepts between their claims.

Extract A.6 shows students confirming that mapping was not significant to construct arguments. "*The map doesn't make things any easier*". "*A written explanation can be clearer*" than a graphical representation of argumentation. For these students, "*it is easier to just think through an argument than make one on compendium*". About mapping for writing, Alan states "*The map doesn't make things any easier*". For Alex mapping "*makes writing quick and efficient, but some good detail can be lost.*"

Teacher: How useful do you think maps are for constructing scientific arguments? Give reasons.
Alan: Little use. For me it is easier to just think through an argument than make one on Compendium.
Alex: Good, but a written explanation can be clearer
Teacher: Did you find any problems during the process of mapping?
Alan: It was a little bit fiddly, and I accidentally deleted things a few times.
Alex: Not really
Teacher: Would you use a map in future? If so, say why?
Alan: No. Alex: Maybe, it depends on what it would be used for
Teacher: Overall, does the map make the process of writing any easier? Why?
Alan: The map doesn't make things any easier.
Alex: It briefs things. that makes it quick and efficient but some good detail can be lost

Extract A.6 from the Forum VI – Reflecting on writing from maps

In summary, the students turned dialogue mapping into a 'brainstorm of questions'. Constructively, the students generated several new interesting issues, but their argumentation remained poor. A good question is often a good starting point for creating a scientific argument: incisive issues can presumably only help scientific inquiry. However, in the process of brainstorming in the 'blank canvas' of Compendium – one of students' difficulties was to organise icons and arrows on the screen. A strong visual template could probably help them develop their scientific arguments.

Selvin (Chap. 11) points out that practitioners (Compendium users) need important skills for constructing good dialogue maps. Rider and Thomason (Chap. 6) show the importance of developing lots of argument maps to create good argumentation. Students need to learn how to structure all issues properly in the map to avoid a confusing layout. If students create an intricate web of ideas, than teachers need to help them disentangle it, because the more complex is the format of their map, the more difficult will be editing and improving it. It is important to teach how to establish good sequences and connections between components. At the same time it is good to have initially the flexibility to allow students shape their reasoning by creating nodes and connections without feeling attached to a particularly structure.

7.4.6 Case B

Case B shows quite structured mapping, which helped students generate evidence-based claims. Their maps provided visual guidance for them to identify for which claims they could develop arguments using their existing knowledge, and which they could not.

Extract B.1 presents this pair of students 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.

Teacher: How much do you like writing in science? (1= not at all, 3=OK, 5=I really like it). Beth: 2. Because I hardly ever do it and I always get stuck for an answer Ben: 3. Writing is ok for me. I don't mind writing and sometimes it can be good, but doing it fully and properly is V. Tedious and Tiresome Teacher: What you think makes a good scientific argument? Beth: Evidence and strong pros and cons and a good topic to base the argument on. Ben: I think that good sturdy evidence is obviously the basis to a strong conclusion and also to try and disprove any other theories by any means possible

Extract B.1 from the Forum I –"Reflecting on writing in science"

In Extract B.2, we can see their text posted in the 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: What you think will happen in the future in the UK? Re: Writing about Global Warming-Group Ecosystem by Beth and Ben
Impacts on nature. Disappearance of many wetlands and extinction of some species.

Extract B.2 from the Forum II – Writing about global warming

Figure 7.6 shows a map created by the author to represent the level of argumentation of these students' writing. Based on Toulmin's model, we can see that all components are claims. They did not present any warrant, data or rebuttals. Their level of arguing and writing is very weak (level 1).

Extract B.3 shows their first dialogue map in Compendium. They generated a question, two answers, a pro and a con. Interestingly, for each answer, 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. Looking at their map, it was possible for the teacher to see immediately from the 'placeholder' Pro and Con nodes with question marks where they lacked information, and what role they saw this playing in their analysis (that is, how information fragments could become contextualised knowledge). By looking at the text of each node, the science teacher could also identify problematic assumptions in their argumentation (e.g. if it gets colder there will be no sun) and pose follow-on questions (Extract B.3).

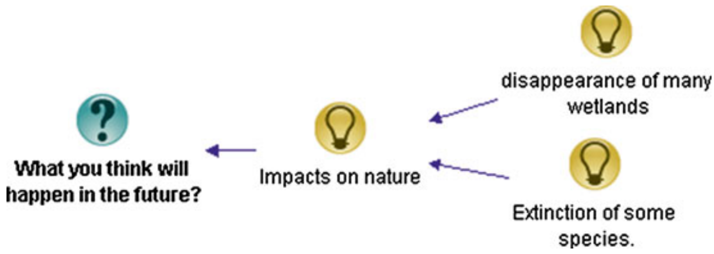
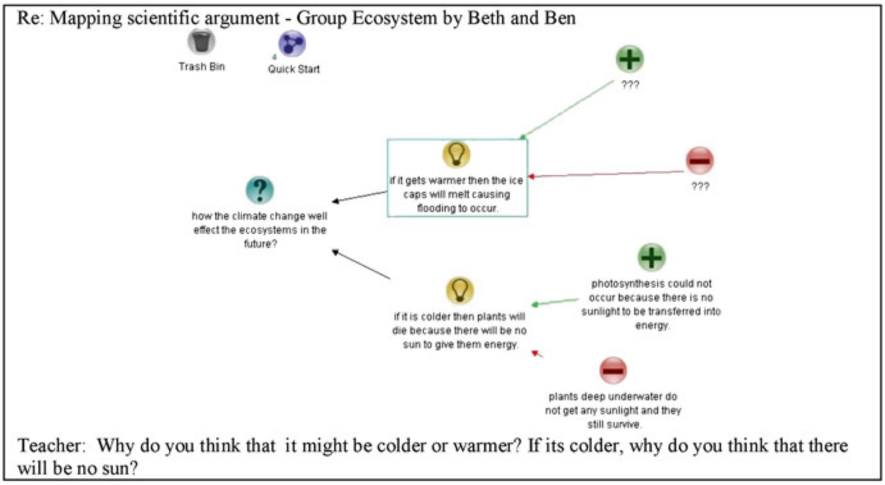


Fig. 7.6 Map created in Compendium based on Toulmin's models



Extract B.3 from the Forum III – Mapping scientific arguments

In order to analyse the level of argumentation embedded in their dialogue map, we examined each component directly from their Compendium map. They represented two claims using proper sentences but they were not able to establish good connections. Their level of argumentation in their first map (2) is better in the map than in their writing (1) because they included 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 on their own convictions. Their map suggests that they do not have 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 enough 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.

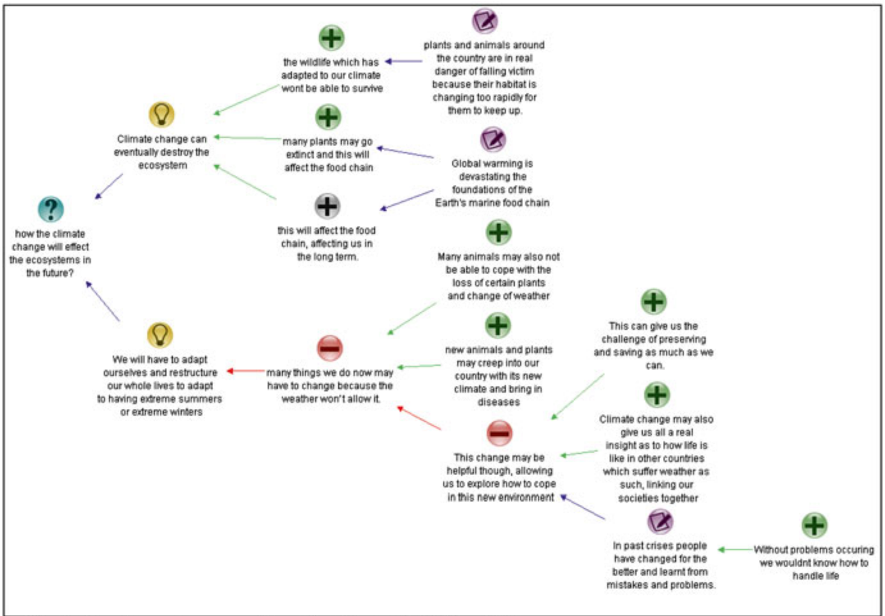
Extract B.4 shows their maps extended with data from two websites during the activity to map data from the web. Students brought two notes from the internet. Mapping the web was neither easy nor fast. For them, bringing data into the map did not mean simply dragging and dropping sentences into Compendium. 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 questions (Extract B.3) to improve their two initial ideas, they selected two new pieces of information that helped them elaborate three arguments around a new answer.

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.

Extract B.4 from the Forum IV – Mapping data from the web

Extract B.5 shows their map edited after comments from teacher. From this map they elaborated their writing. Comparing this map with their previous one, their main change was focussing on their strongest answer by bringing more arguments, counterarguments and notes. The part of the map that 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 be better if they had added more science concepts rather than personal opinion.



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."

Extract B.5 from the Forum V – Writing from your map

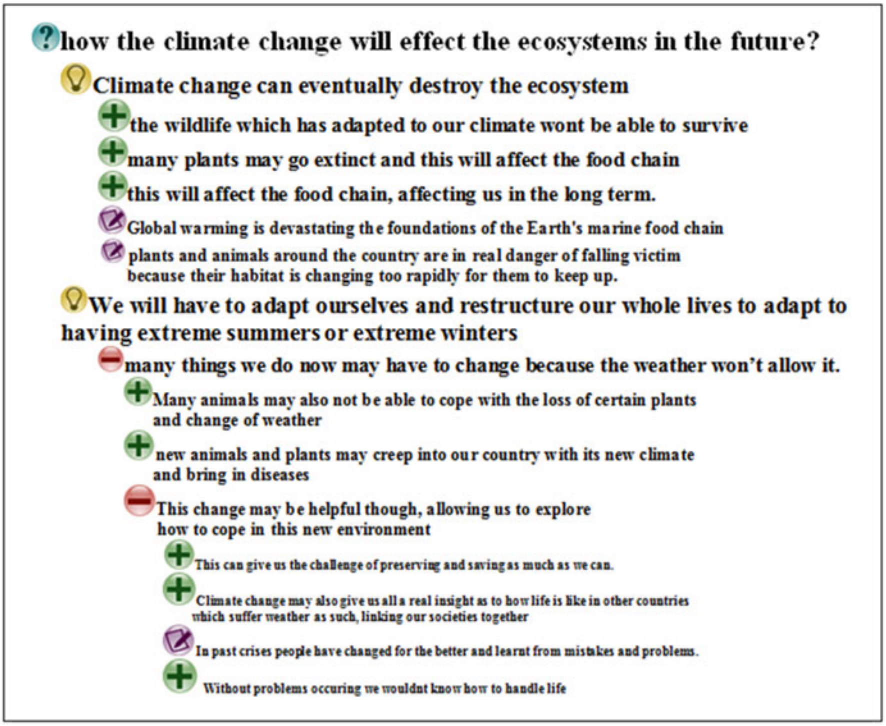


Fig. 7.7 List of topics generated by Compendium as a "web outline"

Figure 7.7 shows how Compendium was useful for students to structure their writing from their map. They exported it using the Web Outline View option which linearises the map into an indented list of nodes. They then edited the outline into more flowing prose.

Extract B.6 shows how the students viewed this process. 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 considered "*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: "*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, they considered "*fairly easy*", "*it was fine*". The "*few problems*" was "*along the way like whether the nodes were right*". The tool was easy, but the mapping was hard!

Teacher: How useful do you think maps are for constructing scientific arguments?
Beth: OK. They help prove up your point in an scientific argument. However, it takes a LONG time.
Ben: They are very good because they help you to think of many ideas connect them and not miss anything out then you can construct a good fair BALANCED scientific argument (s.p) by using all of the nodes you have created and linking them all together with words.
Teacher: Did you find any problems during the process of mapping?
Beth: I encountered a few problems like whether the nodes were right, but other than that it was fine.
Ben: No it was fairly easy
Teacher: Would you use a map in future? If so, say why?
Beth: I probably wouldn't because it took a bit too much time.
Ben: I think i would because it is an easy way to sum up ideas for a report.
Teacher: Overall, does the mapmake theprocess of writing any easier? Why?
Beth: It does. Everything is there easy to read, not in your head where it may slip away.
Ben: I think it does because it has all the information you need in the shortest formation possible. It is kind of like a sophisticated mind map. I AM DEAD.

Extract B.6 from the Forum VI – Reflecting on writing from maps

In summary, for these students, the process of thinking about the nodes is not trivial, nor quick. It takes a "*LONG time*" and one student declares at the end "*I am dead*". 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?". If the students can be engaged in this process of thinking, and of course supported by their colleagues and particularly by the teacher, then this analysis illustrates how dialogue mapping can serve as a new kind of scaffold for improving scientific argumentation. 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 students can be engaged in all these kinds of questions, then thinking about "the nodes", means thinking about the components of a scientific argumentation. Questioning "whether the nodes are right", means questioning if their scientific reasoning is right.

Dialogue mapping, from the perspective of these students, functions as a "*sophisticated*" strategy for argumentation. By visualising "*all the information they need in the shortest form possible"* they were able to use the most significant components to construct "*a good fair BALANCED scientific argument*". Dialogue mapping can also be an "*easy way to sum up ideas for a report*."

7.4.7 Case C

Case C presents another role for dialogue maps, "self assessment". Once students are able to visualise their arguments through the right icons, they can recognise easily what part 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". This kind of "formative assessment" – feeding back information to the learner about their understanding – is widely recognised as a major factor in enhancing achievement.

In Extract C.1, this pair of students explained that writing is neither as fun 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.

Teacher: How much do you like writing in science? (1= not at all, 3=OK, 5=I really like it). Give a reason Chris: 3. Because you can get want you want to say across quite easily, but presentations to people you know are easier Carl: 2. It is boring, I have more funin practical. Teacher: What you think makes a good scientific argument? Chris: EVIDENCE!! you need evidence to back up your ideas and arguments otherwise you dont have a very good case. Finally you need to be able to argueboth sides of a case Carl: A good scientific argument puts across what you mean simply and clearly, keeps attention and is not to complicated, but does not leave out important logic steps (it shows your thinking well).

Extract C.1 from the Forum I –Reflecting on writing in science

Extract C.2 shows their writing with a good science argument. Their text was based on two short paragraphs, in few well-connected sentences. This text not only presents a good claim grounded in pros, cons and data, but also they were able to bring some science concepts to ground their answer.

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. Of course, if you take into account the cause of global warming, pollution, you have even more problems. Pollution causes eye and lung diseases.

Extract C.2 from the Forum II – Writing about global warming

Figure 7.8 shows a map created by the author to represent the level of argumentation embedded in the students' writing. Based on Toulmin's model, we can see that they included the main components to ground their claim: claim, rebuttal, pros and "evidence to back up their ideas". The level of their argumentation and writing are very good.

Extract C.3 shows their first dialogue map in Compendium. They generated more questions and more claims. They extracted the different issues from their initial statements, and opened up discussion about them. They also described some science concepts giving more details. 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 of science argument, then the maps would be better. As they had difficulty in choosing the icons, they can not visualise what part could be improved. They represented all of them as answers in three linear sequences as if they were writing, which suggests that, in fact, they could have written these arguments without creating the map.

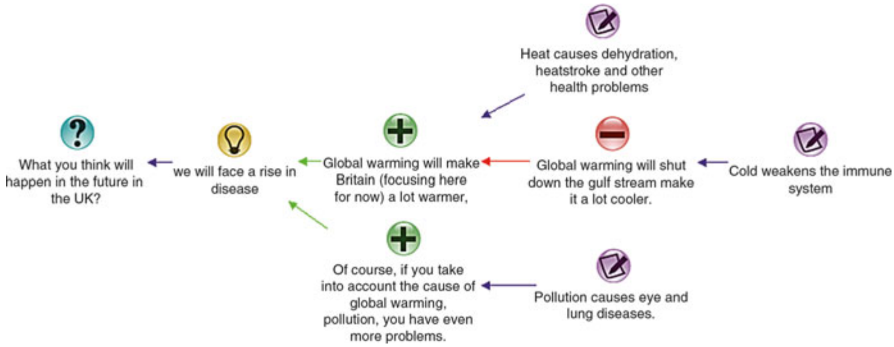
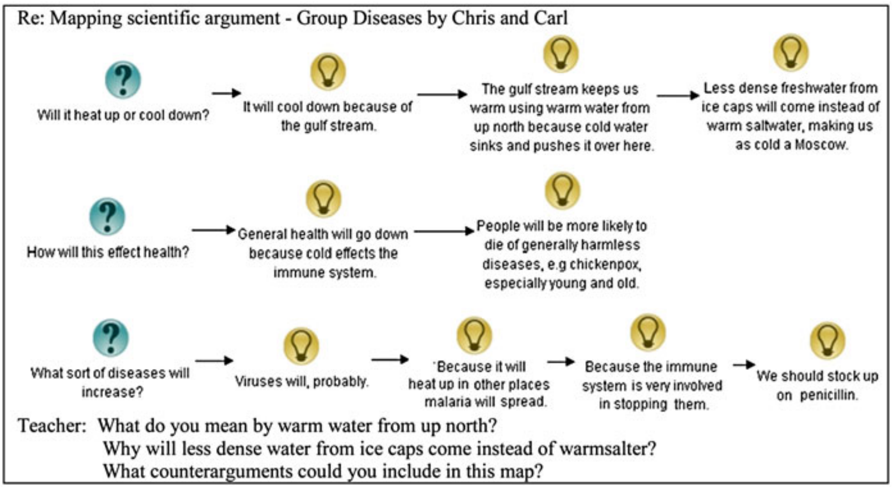


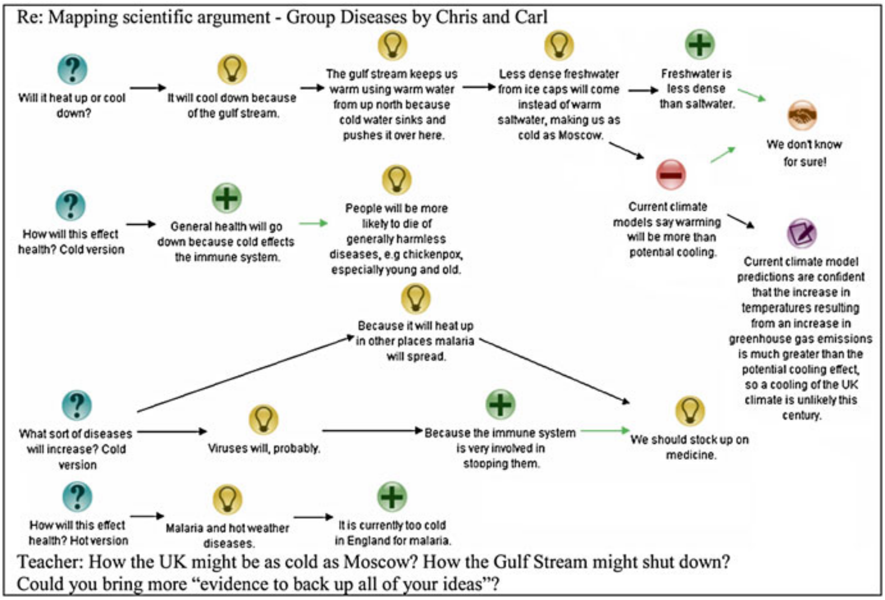
Fig. 7.8 Map created in Compendium based on Toulmin's model

Extract C.3 shows students 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.



Extract C.3 from the Forum III – Mapping scientific arguments

Extract C.4 represents their map with information from the web. They added more data, questions and arguments. They also represented the components 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 answers and pros.

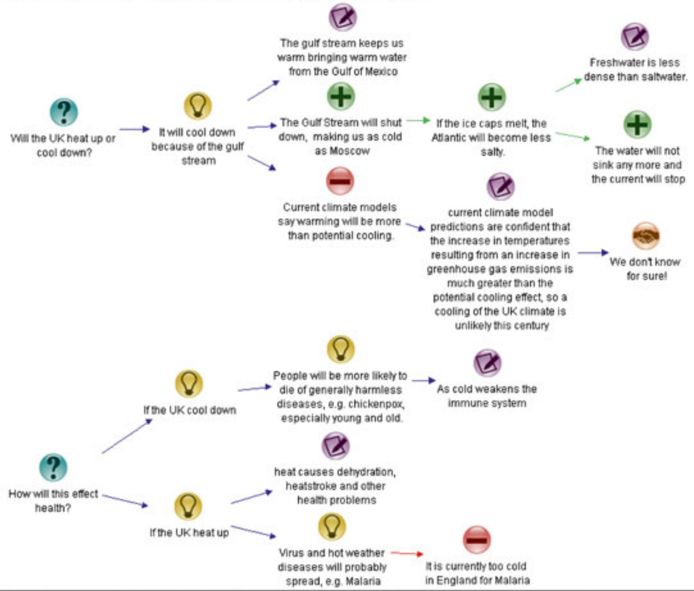


Extract C.4 from the Forum IV – Mapping data from the web

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, not as linear as the previous map. However, their arguments in this map were not as well integrated as in their writing (Fig. 7.10) where we could see all of their arguments connected to data. In the writing Extract C.2, as they mentioned, they were "focussed" on the main idea ("Britain, a lot warmer") and they brought more components to ground that claim (Fig. 7.7). In the map in Extract C.4, they raised more questions and open more statements, but they weren't able to put their arguments together in order to construct a good argumentation.

Extract C.5 presents their final map and writing. After the teacher's feedback and explanation about the Compendium icons, students were able to improve their map significantly. With better understanding 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



"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."

Extract C.5 from the Forum V – Writing from your map

They used the icons more systematically to express the roles played by each node:

- "Note" to represent facts, concepts and data. These are their evidence, which means statements that can be considered acceptable as truth based on science. Normally they are presented with present tense verbs.
- "Answer" to indicate their main claims which address their questions. As their questions refer to the future, these sentences are in the simple future tense.
- "Pro" to show their arguments. This can also be in the future, but their function is to support or explain their main answer.
- "Con" to introduce exceptions, opposite ideas, statements against.

Once they were able to use the icons properly, they really 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 beginning they said that their focus was on “it will be warmer”, then after better explanation, they changed to “it might be colder”.

As they were able to construct strong argumentation on their map, and clear structure, it was easier for them to edit all the nodes from the map into a good composition. As they could clarify their understanding about the Gulf Stream, they could present better explanation in the composition which made it better than the previous writing. They were also able to visualise better what was their main proposition and describe it clearer on the text.

Extract C.6 shows how these students reflected as mapping for writing. Both of them considered it useful. They presented several reasons: “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.”

Although they considered it difficult to export and import maps in Moodle, they really showed interest in using mapping again. They also presented interesting reasons: “Writing from mapping “is more fun”, “Argument is more logical and ordered”, “It makes the whole thing a lot quicker”. They could also identify significant benefits such as “it would also be easier for a teacher to mark my ideas”.

Teacher: How useful do you think maps are for constructing scientific arguments?
Chris: 4 It's reasonably good because it helped me to sort out my ideas and arguments and make my points clearer and easier to understand. I presume it would also be easier for a teacher to mark my ideas.
Carl: 5. It was a really good tool to sort out your ideas with and was very effective. It also helps you to think through the facts and how they affect your arguments.
Teacher: Did you find any problems during the process of mapping?
Chris: The only problem I found was that the process of saving the maps, opening, exporting etc. was very complicated and I would not be able to do it by memory, I would need the whole process written down for me to do it by
Carl: Importing and exporting were quite tricky and it would be easier if you could just save and copy and paste the text.
Teacher: Would you use a map in future? If so, say why?
Chris: I might use the map in the future because it makes writing easier for me to do personally and for other people to understand. Overall it makes life a lot easier for everyone and it is definitely a very useful
Carl: Of course, but I wish saving the work was easier.
Teacher: Overall, does the map make the process of writing any easier? Why?
Chris: You can get down the basic ideas and link them together, making connections and then edit the same text, which makes the whole thing a lot quicker because you can actually use the notes you make.
Carl: yes its more fun. I find when it comes to writing up an essay that my argument is more logical and ordered.

Extract C.6 from the Forum VI – Reflecting on writing from maps

In summary, we observed in case C that when students present good 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 assessing their understanding. As students need to support their position in the map through connections, maps can reveal possible misunderstandings that their writing can not. Once students, through teachers' feedback, are able to clarify their connections, then they can enrich their argumentation and improve significantly their writing. Then, maps work as a tool for “sorting out their ideas and arguments”. Their “arguments are more logical and ordered” and their “points are clearer and easier to understand”.

7.5 Discussion: Returning to Our Research Questions

Encouraged by the success of Compendium-enabled dialogue mapping in non-educational contexts, we have presented the first step in our efforts to investigate its potential as a cognitive discipline, within a structured digital medium, to foster school students' scientific argumentation. We now discuss the preliminary answers that we can give to our opening research questions, based on the analyses of student pairs A-C.

7.5.1 Scientific Knowledge and Mapping

In our case study pairs, we saw examples of superficially well-structured maps with poor argumentation, and of poorly structured maps with good argumentation embedded in the labels of nodes. We saw how the visual language of IBIS can provide a template, for instance, cueing students that at least one Pro and Con are expected to be linked to each Position, even if they are not yet sure what these should be. We saw that the maps added depth to searching the Web: students may be seeking a specific kind of data to complete a map, or when unexpectedly encountering a potentially relevant page, they must now reflect on how to link it in coherently to their narrative.

Reviewing this work, O'Brien (personal communication) stated "mapping has its strength in that the students can determine for themselves the links that make the knowledge intelligible, through conceptual bridges they can make in their own minds, and in this way their inquiry-based learning skills are greatly enhanced. For these students, this allows them to develop strong strategies for learning like chunking, and skills to develop thinking in depth" (Okada and Buckingham Shum 2008).

7.5.2 Scientific Writing and Mapping

The students we worked with clearly did not see writing as particularly enjoyable or central to science. It is likely that this naïve separation between what might be paraphrased as "doing the real science" versus "merely communicating it" is widely shared in the general public, but is directly challenged by the work we briefly reviewed at the start, in which science is constituted by its different discourses, which in turn actively shape the work that is undertaken. Sociological theories aside, we have the intensely practical task of raising a generation who want, and have the skills, to engage in public debate about science-related dilemmas. Pragmatics confronts us with the task of teaching students how to argue and reason critically, and convincing them that how and why scientists argue is deeply interwoven with what experiments they do and what can be concluded from them.

Since we are all schooled in writing prose from an early age, it is no surprise that writing essays or posting comments to a discussion forum came more easily to the students than mapping. This will always be the 'path of least resistance' – but as all teachers and researchers know to their cost, fluency with the language and the fluidity of the digital medium can simply serve as a channel for unfocused verbiage. As historians of orality, literacy and digital media note, greater resistance in an information environment can foster greater reflection before ideas are committed (Ong 2002; Heim 1987).

We have described 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 students 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. A closer analysis is needed to investigate specific questions about how graphical connections in a mapping language relate to appropriate use of connectives in prose (Okada 2009).

Moving in the other direction, we translated students' prose into maps for analytical purposes, but there were no activities that specifically scaffolded this, e.g. through teaching the systematic annotation of texts, as is supported more directly by tools such as Araucaria (Chap. 8). Again, it is an open question as to whether young teenagers can be taught this, in the way that Reed et al. have worked with university undergraduates.

7.5.3 Cartographic Literacy

Prior work has documented the intellectual work involved in constructing dialogue and argument maps. The cognitive tasks include parsing the flow of ideas at an appropriate granularity, assigning a node type (icon), labelling them succinctly, and connecting them with meaningful links to an appropriate node. Doing this in real time to capture a discussion in the graphical IBIS language is a specific skill that Conklin (2006) terms Dialogue Mapping, which includes a collection of heuristics for recognising different kinds of conversations and creating coherent, balanced maps. Selvin (Chap. 11) takes this even further, examining expert performance when formal modelling and multimedia assets are added to the mix. In sum, like any advanced intellectual or artistic discipline (as cartography surely is), one starts simple, but there is great scope for mastery and beauty.

To a practised dialogue mapper's eye, the students' 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 student (and staff) motivation to use 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 students' maps (or, indeed, any dialogue map) highlights that there are no hard rules. 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, Answer, 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's role.

7.5.4 The Teacher's Role

In any context, teachers must provide appropriately constrained activities in which students can accomplish meaningful work. Knowledge cartography's process-orientation can provide a 'window' into the workings of students' minds by showing the intellectual moves they are making more clearly than when it is embedded in prose. As one student 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 students 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 students 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 students could use to assess the quality of dialogue maps, adapting the work of Conklin and Selvin on the practitioner skillset to capture the heuristics in engaging, memorable ways.

7.5.5 Software Design

We have discussed at some length the nature of the resistance that a diagrammatic language like graphical IBIS presents to the expression of ideas. In contrast, the mechanics of driving Compendium were unproblematic, with students comfortable with a familiar direct manipulation user interface for dragging, dropping and linking nodes and websites. Greatest problems were encountered in exporting maps to outlines, and sharing maps via the Moodle web environment, a process that has been streamlined since this summer school: Compendium now has a custom Moodle export that integrates HTML Maps, Outlines and XML data versions, which can be uploaded as one file for processing by Moodle.

Of most interest to us is the match between how students give form to their thinking, and how this can be gradually structured, 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. Central to Compendium's design has been a focus on avoiding "premature commitment" to inappropriate structure, and other key cognitive dimensions that determine the fluidity of tools for thought (Green 1989; 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, establishing a visual language that makes tangible important intellectual lenses that we want to instill.

To summarise, we might pull together the above threads in a vision as follows. We want to reach the point where students 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 all say the same thing? (=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?).

7.6 Future Work 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. This chapter has discussed the results of a pilot investigation introducing it into a secondary school context, specifically in response to growing concern over students' poor scientific reasoning skills.

We have explained the relationship of scientific argumentation and Dialogue Mapping, and presented qualitative analysis of three 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 to improve students' critical thinking and argumentation skills in contemporary socio-scientific debates and Inquiry-Based Learning Projects.

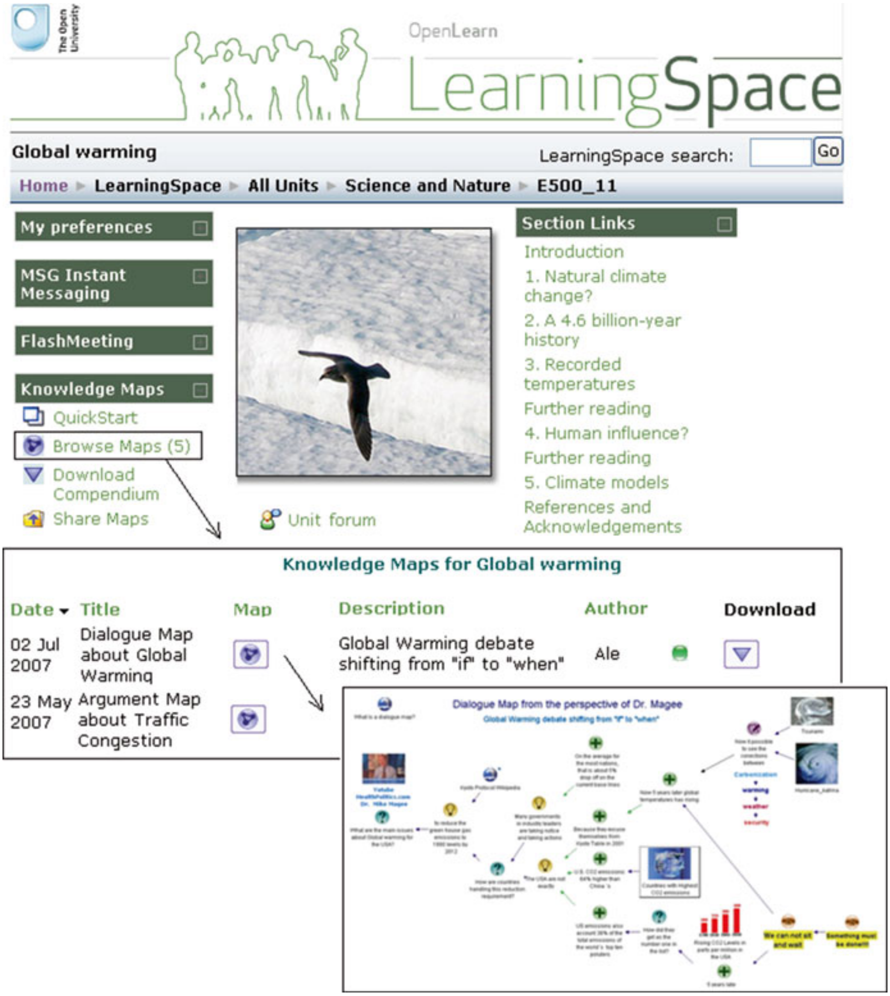


Fig. 7.9 OpenLearn project was developed based on Moodle, which integrates Compendium knowledge maps (http://openlearn.open.ac.uk)

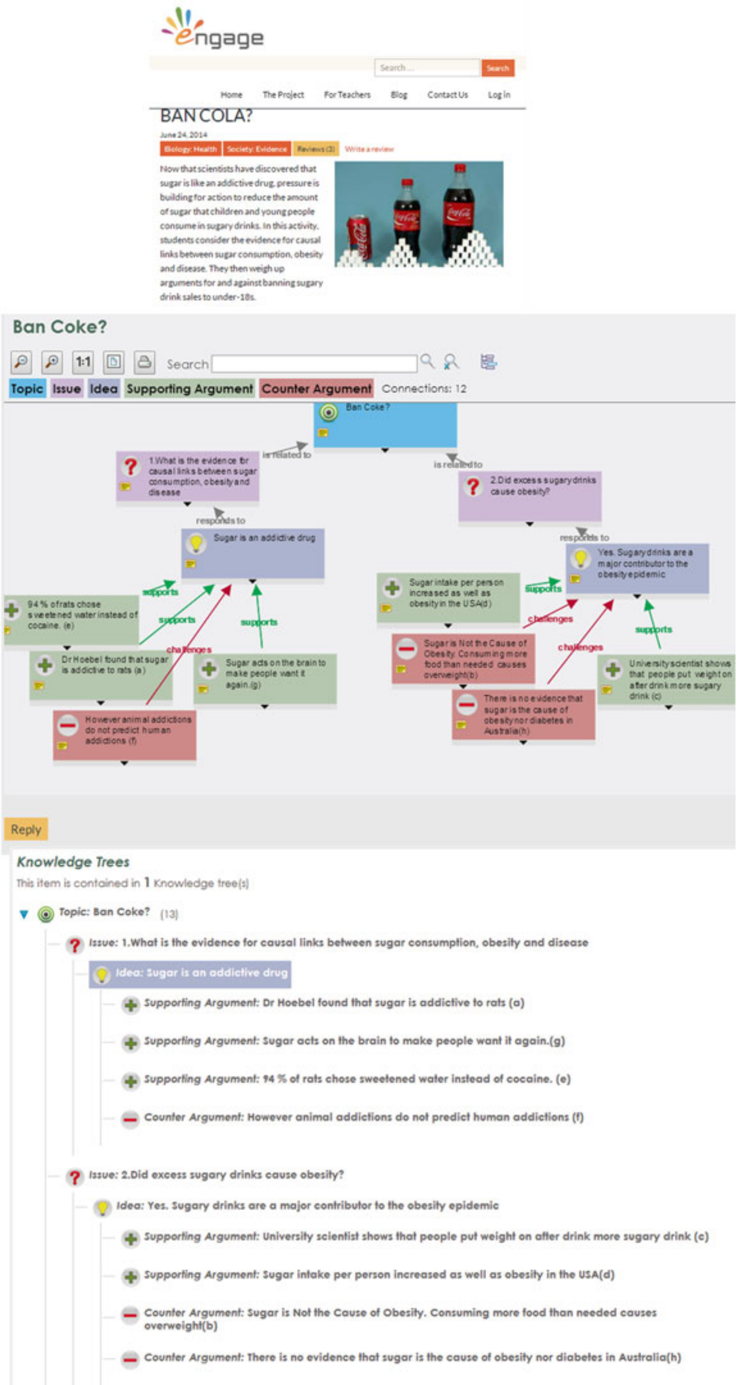
Our objective in terms of professional development is to foster a community of practice (in the OpenLearn project – Fig. 7.9, weSPOT project – Fig. 7.10 and ENGAGE project – Fig. 7.11) amongst educators and researchers (and perhaps even students), with its own focused workshops, online discussions and the sharing of curriculum ideas (Okada 2013; Okada et al. 2014).

OpenLearn project, a large scale online environment that makes a selection of higher education learning resources freely available via the internet. OpenLearn, which is supported by William and Flora Hewlett Foundation, in the 2 year period of its existence has released over 5,400 learning hours of the OU's distance learning

Fig. 7.10 weSPOT project was developed based on ELGG, which integrates Mobile Data Collection, Learning Analytics and Reflection Environment as well as Mindmeister knowledge maps (http://inquiry.wespot.net)

resources for free access and modification by learners and educators under the Creative Commons license. It also offers the knowledge mapping tool: Compendium for visual thinking, used to connect ideas, concepts, arguments, websites and documents. Co-learners can create, upload and download maps (Fig. 7.9).

The weSPOT project (Working Environment with Social, Personal and Open Technologies) focuses on propagating scientific inquiry as the approach for developing scientific literacy through different scenarios related to formal, non-formal and informal contexts. Its aim is to provide learners with the ability to build their own inquiry-based learning space, enriched with social and collaborative features. Smart support tools can be used for orchestrating inquiry workflows, argumentative mapping, mobile apps, learning analytics and social collaboration on scientific inquiry. Learners can interact with their peers and discuss their inquiry projects, receive and provide feedback, mentor each other, thus develop meaningful social


engage
Search
Home
The Project
For Teachers
Blog
Contact Us
Log in
BAN COLA?
June 24, 2014
Biology: Health
Society: Evidence
Reviews (3)
Write a review
Now that scientists have discovered that sugar is like an addictive drug, pressure is building for action to reduce the amount of sugar that children and young people consume in sugary drinks. In this activity, students consider the evidence for causal links between sugar consumption, obesity and disease. They then weigh up arguments for and against banning sugary drink sales to under-18s.
Ban Coke?
Search
Topic
Issue
Idea
Supporting Argument
Counter Argument
Connections: 12
Ban Coke?
is related to
1.What is the evidence for causal links between sugar consumption, obesity and disease
2.Did excess sugary drinks cause obesity?
responds to
Sugar is an addictive drug
Yes. Sugary drinks are a major contributor to the obesity epidemic
supports
challenges
94 % of rats chose sweetened water instead of cocaine. (e)
Dr Hoebel found that sugar is addictive to rats (a)
Sugar acts on the brain to make people want it again.(g)
However animal addictions do not predict human addictions (f)
Sugar intake per person increased as well as obesity in the USA(d)
Sugar is Not the Cause of Obesity. Consuming more food than needed causes overweight(b)
There is no evidence that sugar is the cause of obesity nor diabetes in Australia(h)
University scientist shows that people put weight on after drink more sugary drink (c)
Reply
Knowledge Trees
This item is contained in 1 Knowledge tree(s)
Topic: Ban Coke? (13)
Issue: 1.What is the evidence for causal links between sugar consumption, obesity and disease
Idea: Sugar is an addictive drug
Supporting Argument: Dr Hoebel found that sugar is addictive to rats (a)
Supporting Argument: Sugar acts on the brain to make people want it again.(g)
Supporting Argument: 94 % of rats chose sweetened water instead of cocaine. (e)
Counter Argument: However animal addictions do not predict human addictions (f)
Issue: 2.Did excess sugary drinks cause obesity?
Idea: Yes. Sugary drinks are a major contributor to the obesity epidemic
Supporting Argument: University scientist shows that people put weight on after drink more sugary drink (c)
Supporting Argument: Sugar intake per person increased as well as obesity in the USA(d)
Counter Argument: Sugar is Not the Cause of Obesity. Consuming more food than needed causes overweight(b)
Counter Argument: There is no evidence that sugar is the cause of obesity nor diabetes in Australia(h)

networks that will help and motivate them in their collaborative inquiry projects. Co-learners can create collective maps together and develop scientific reasoning collaboratively (Fig 7.10).

Further studies will also integrate the European project ENGAGE (Equipping the Next Generation for Active Engagement in Science) whose aim is to help educators develop the beliefs, knowledge and practice for RRI (Responsible Research and Innovation). This project also focuses on adopting inquiry based methodology to provide learners opportunity for coming to informed decisions through scientific argumentation and awareness of important Socio-ethical issues. Co-learners can also share their individual or collective maps as well as their scientific explanations (Fig. 7.11).

We welcome contact from all who would like to participate in such a network (Colearn.open.ac.uk/maps).

Acknowledgments I am grateful to *Pat O'Brien* from the P&S Consultancy, whose work has been used by the National Academy for Gifted and Talented students in science and the National Learning Science Centre, for his very helpful feedback. I am grateful to *Tony Sherborne* from the Sheffield Hallam University, the author and coordinator of the Totally Wild Science Summer Course, for the opportunity to start this research. I am grateful to colleagues at the Open University: *Karen Littleton* from the Centre for Research in Education and Educational Technology for her significant comments, *Simon Buckingham Shum* and *Michelle Bachler* (both from the Knowledge Media Institute) for technical support.

weSPOT project is funded by European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement N° 31849.

ENGAGE project is funded by European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement N° 612269.

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Fig. 7.11 ENGAGE project is a new platform in development, which will integrate OER, MOOC, and Learning Analytics Partnership broker system through a knowledge hub. *Its aims are to* embed RRI in the curriculum through IBL and to provide:
Scientific argumentation tools for teachers trainers
Open learning materials in RRI in different languages
Video Library of RRI pedagogies
MOOC's online courses
Brokering System for school-scientist partnerships
Learning Analytics Tools to collect student opinions remotely

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