Preface

The eyes are not responsible when the mind does the seeing.

Publilius Syrus (85–43 BC)

Maps are one of the oldest forms of human communication. Map-making, like painting, pre-dates both number systems and written language. Primitive peoples made maps to orientate themselves in both the living environment and the spiritual worlds. Mapping enabled them to transcend the limitations of private, individual representations of terrain in order to augment group planning, reasoning and memory. Shared, visual representations opened new possibilities for focusing collective attention, re-living the past, envisaging new scenarios, coordinating actions and making decisions.

Maps mediate the inner mental world and outer physical world. They help us make sense of the universe at different scales, from galaxies to DNA, and connect the abstract with the concrete by overlaying meanings onto that world, from astrological deities to signatures for diseases. They help us remember what is important, and explore possible configurations of the unknown. Cartography – the discipline and art of making maps – has of course evolved radically. From stone, wood and animal skins, we now wield software tools that control maps as views generated from live data feeds, with flexible layering and annotation.[1]

"Foundational concept, fragmented thinking, line of argument, blue skies research, peripheral work": we spatialise the world of ideas all the time with such expressions. *Maps* can be used to make such configurations tangible, whether sketched on a napkin or modelled in software. In this book we bring together many of the leading researchers and practitioners who are creating and evaluating such software for mapping intellectual worlds. We see these as new tools for reading and writing in an age of information overload, when we need to extract and construct meaningful configurations, around which we can tell different kinds of narrative.

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[1] Our sister volume in this series, *The Geospatial Web*, explores the convergence of spatial data, mapping tools and the social web (Scharl and Tochtermann, 2006).

For a visual generation of children who have never known a world without ubiquitous information networks, we might hypothesise that knowledge maps could have particular attraction as portals into the world of ideas. Moreover, *the network* is not only dominant when we think about our social and technical infrastructures, but almost an ontological stance in postmodernity, where we hold our viewpoints to be precisely that: always partial and contextualised. Weaving connections between nodes in the network is the most flexible way to bring ideas and information into locally coherent relationships with each other, knowing that there is always another viewpoint on the validity of these patterns. Modelled in software, the vision is that intellectual continents, islands and borders can be invoked and dissolved at different scales, as required.

Knowledge Cartography can be defined as:

- the art, craft, science, design and engineering of different *genres of map* to describe intellectual landscapes – answering the question *how can we create knowledge maps?*
- and the study of *cartographic practices* in both beginners and experts as they make and use such maps – answering the question *how effective are knowledge maps for different kinds of users?*

The particular focus of the authors in this volume is on *sensemaking*: the process by which externalising one's understanding clarifies one's own grasp of the situation, as well as communicates it to others – literally, the *making* of *sense* (Weick 1995: p. 4). While "sense" can be expressed in many ways (non-verbally in gesture, facial expression and dance, and in prose, speech, statistics, film, etc.), knowledge cartography as construed here places particular emphasis on digital representations of connected ideas, specifically designed to:

  I. *Clarify the intellectual moves and commitments at different levels.* (e.g. Which concepts are seen as more abstract? What relationships are legitimate? What are the key issues? What evidence is being appealed to?)
 II. *Incorporate further contributions from others, whether in agreement or not.* The map is not closed, but rather has affordances designed to make it easy for others to extend and restructure it.
III. *Provoke, mediate, capture and improve constructive discourse.* This is central to sensemaking in unfamiliar or contested domains, in which the primary challenge is to construct plausible narratives about how the world was, is, or might be, often in the absence of complete, unambiguous data.

Our intention with this book is to provide a report on the state of the art from leaders in their respective fields, identify the important challenges as they are currently seen in this relatively young field, and inspire readers to test and extend the techniques described – hopefully, to think more critically and creatively. Many of the tools described are not sitting in research labs, but are finding application in diverse walks of life, with active communities of practice. These communities represent the readership we hope for: learners, educators, and researchers in all fields, policy analysts, scenario planners, knowledge managers and team facilitators. We hope that

practitioners will find new perspectives and tools to expand their repertoire, while researchers will find rich enough conceptual grounding for further scholarship.

Genres of Knowledge Maps

A range of mapping techniques and support tools has evolved, shaped by the problems being tackled, the skill of mappers, and the sophistication of software available. We briefly characterise below the main genres of map. The appendix summarises at a glance which mapping approaches and software tools are presented in each chapter.

Mind Mapping was developed by Tony Buzan in the early 1970s when he published his popular book *Use Your Head.* Mind Mapping requires the user to map keywords, sentences and pictures radiating from a central idea. The relatively low constraints on how elements can be labelled or linked makes it well suited for visual notetaking and brainstorming (Fig. 1).

Concept Mapping was developed by Joseph Novak around 1972, based on Ausubel's theory that meaningful learning only takes place when new concepts are connected to what is already known. Concept maps are hierarchical trees, in which concepts are connected with labelled, graphical links, most general at the top. Novak and many others have reported empirical evidence of the effectiveness of this technique, with an international conference dedicated to the approach (Fig. 2).
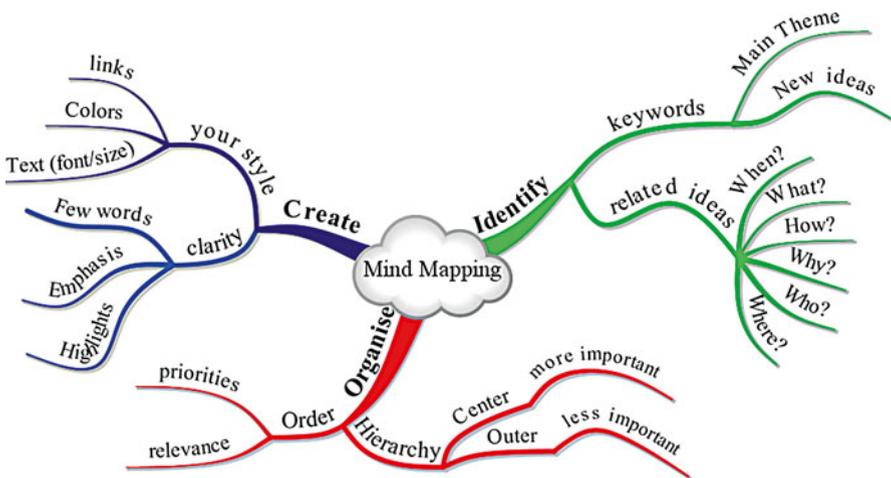

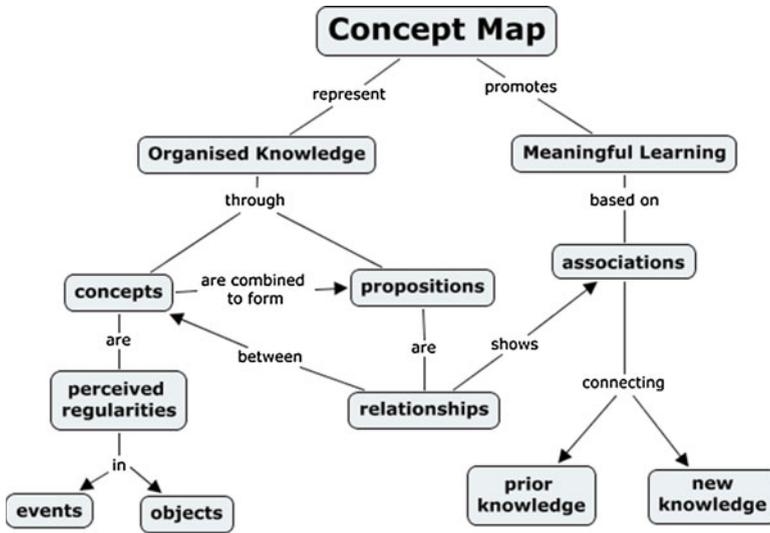**Fig. 1** Mind Map created with iMindmap

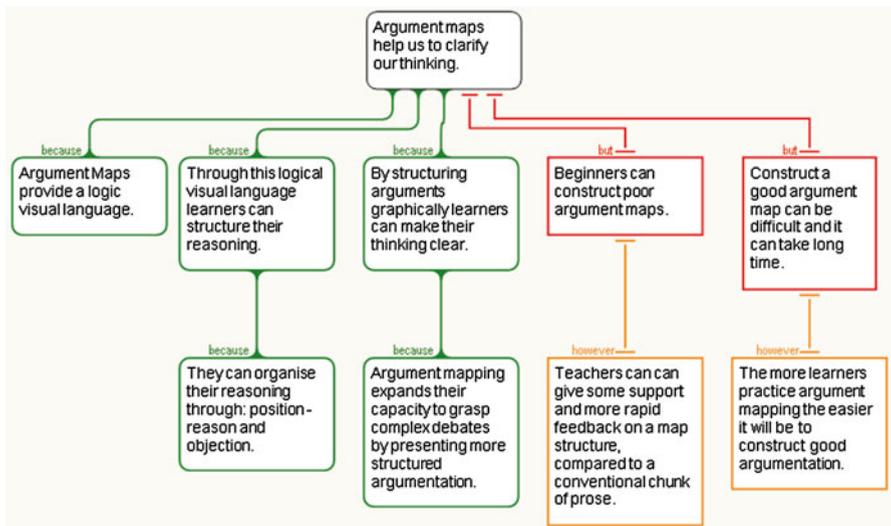**Fig. 2** Concept Map created with CMap Tools

Fig. 3 Argument Map created with Rationale

Argument and Evidence Mapping was first proposed by J. H. Wigmore in the early 1900s to help in the teaching and analysis of court cases. The objective is to expose the structure of an argument, in particular how evidence is being used, in order to clarify the status of the debate. Still used in legal education today, the idea has been extended, formalised (and reinvented) in many ways (Buckingham Shum 2003; Reed et al. 2007), but all focused on elements such as *Claims, Evidence, Premises* and supporting/challenging relations (Fig. 3).
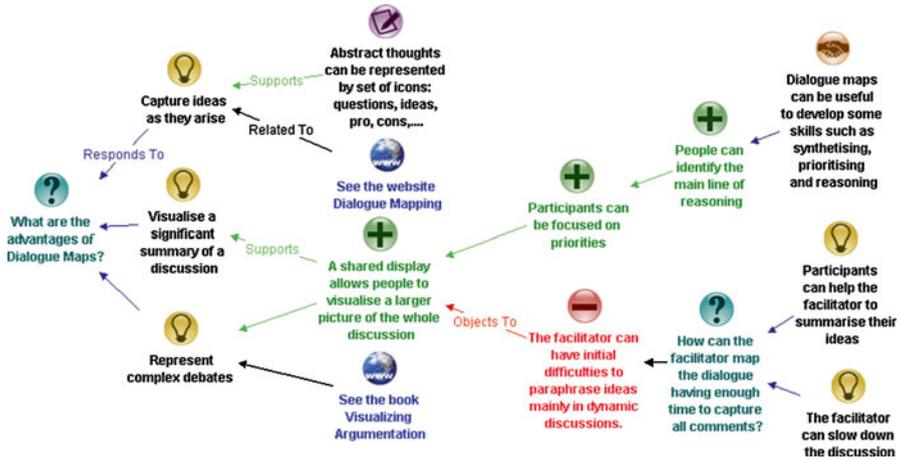
Fig. 4   Issue Map created with Compendium

Issue Mapping derives from the "Issue-Based Information System" (IBIS) developed by Horst Rittel in the 1970s to scaffold groups tackling "wicked" socio-technical problems. IBIS structures deliberation by connecting *Issues, Positions and Arguments* in consistent ways, which can be rendered as textual outlines and graphical maps. "Dialogue Mapping" was developed by Conklin (2006) for using IBIS in meetings, extended as "Conversational Modelling" by Selvin and Sierhuis (1999) to integrate formal modelling and interoperability with other tools (Fig. 4).

Web Mapping appeared as a result of the rapid growth of the internet. Software tools provide a way for users to capture, position, iconify, link and annotate hyperlinks in a visual space as they navigate, creating a richer trail which comes to have more personal meaning than a simple bookmark list (Fig. 5).

Thinking Maps as defined by Hyerle (Chapter 4) contrasts all of the above with a set of abstract visual conventions designed to support core cognitive skills. Hyerle's eight graphic primitives (expressing basic reasoning about, e.g. *causality, sequence, whole-part*) are designed to be combined to express higher order reasoning (e.g. *metaphor, induction, systems dynamics*) (Fig. 6).

Finally, a note on what we might term **Visual Specification Languages**, which are designed for software interpretation by imposing constraints on how links and often nodes are labelled and combined. This is a huge field in its own right, with schemes such as Unified Modeling Language (UML) supporting user communities far larger than any of the others listed here, plus innumerable other notations and tools that exploit the power of visualization for modelling processes, ontologies and organizations. These are not, however, heavily represented in this book (though see Chapters 17 [Sierhuis] and 22 [Basque]) for the simple reason that this book's interest in sensemaking focuses on the analytical work required at the upstream phases in problem solving, or in domains where formal modelling is contentious because of the assumptions it requires. Once the problem, assumptions and solution criteria are agreed and bounded, there is a clearer cost/benefit tradeoff for detailed modelling.
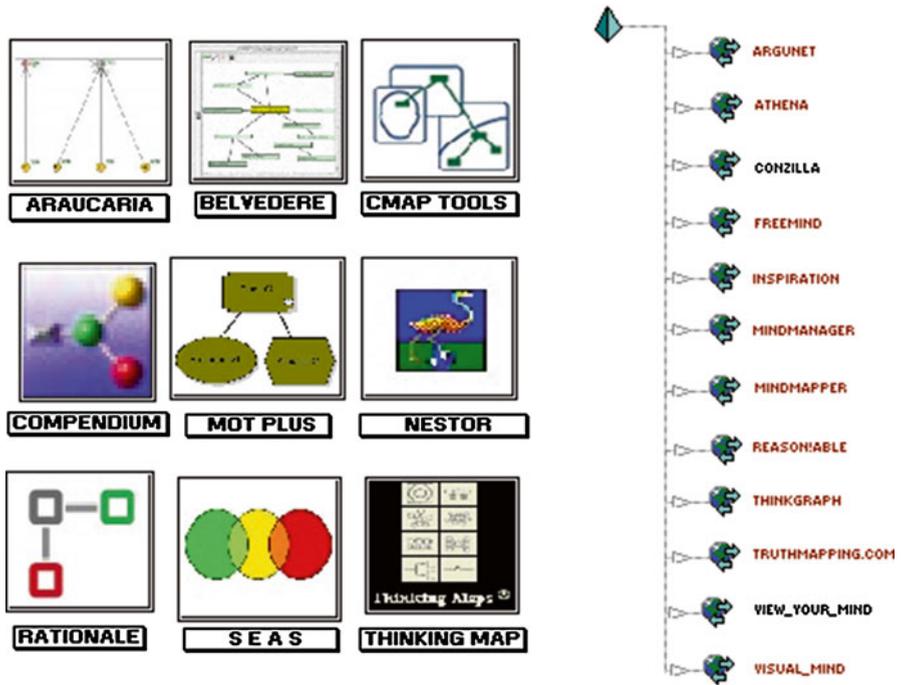
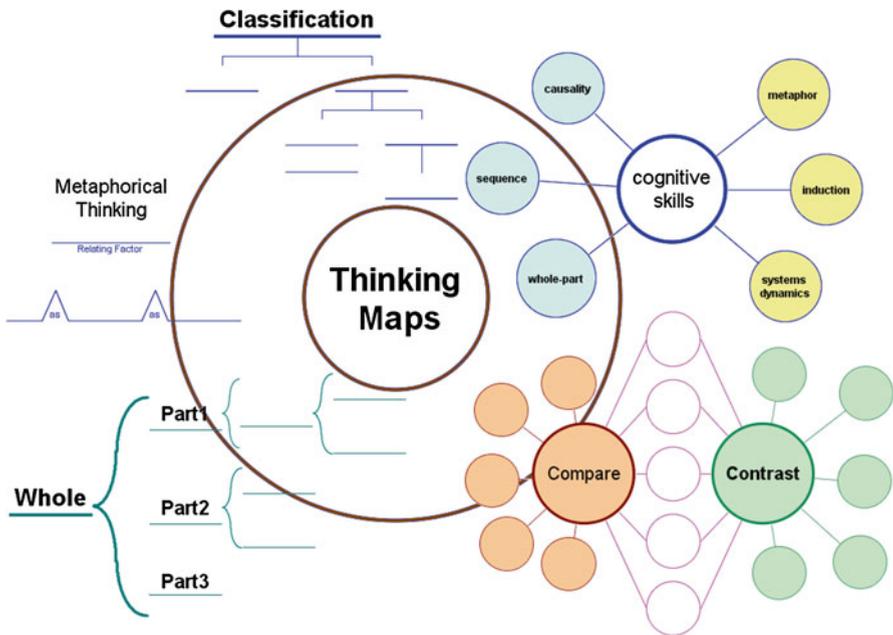**Fig. 5** Web Map about mapping tools with Nestor Web Cartographer

Fig. 6 Thinking Maps created with Thinking Maps © tool

Overview of the Book

This book has 22 chapters organised in two parts, defined by whether the primary application is in formal learning or the workplace. However, while this distinction reflects two large audiences, readers will find ideas cross-fertilising healthily between chapters. The first half, *Knowledge Maps for Learning and Teaching*, focuses on applications in schools and universities. We start with tools for learners, opening with a literature survey, followed by examples of different approaches (concept mapping, information mapping; argument mapping). Attention then turns to the kinds of maps that educators need. In the second half we broaden the scope to *Knowledge Maps for Information Analysis and Knowledge Management*, examining the role that these tools are playing in professional communities – but with great relevance also to more formal learning contexts. We start with an analysis of the knowledge cartographer's skillset, followed by case studies around issue mapping and reflective practitioners documenting the most effective ways to map.

1. Suthers, in "**Empirical Studies of the Value of Conceptually Explicit Notations in Collaborative Learning**", reports on a series of studies which show that differences of notations or representational biases can lead to differences in processes of collaborative inquiry. The studies span face-to-face, synchronous online and asynchronous online media in both classroom and laboratory settings.

2. Canas and Novak present "**Concept Mapping Using CmapTools to Enhance Meaningful Learning**". After briefly introducing the pioneering concept mapping approach and CmapTools software, they provide an update to what is probably the world's largest systematic deployment of concept mapping, the "Proyecto Conéctate al Conocimiento" in Panama, reflecting on their experiences introducing concept mapping in hundreds of schools to enhance meaningful learning.

3. Marriott and Torres, in "**Enhancing Collaborative and Meaningful Language Learning Through Concept Mapping**" describe how concept mapping can help develop students' reading, writing and oral skills as part of a blended methodology for language teaching called LAPLI. Their research was first implemented with a group of pre-service students studying for a degree in English and Portuguese languages at the Catholic University of Parana (PUCPR) in Brazil.

4. Hyerle, in "**Thinking Maps®: A Visual Language for Learning**", summarises a graphical language comprising eight cognitive maps called Thinking Maps® and Thinking Maps® Software. These tools have been used from early grades to college courses to foster cognitive development and content learning, across all disciplines.

5. Zeiliger and Esnault, in "**The Constructivist Mapping of Internet Information at Work with Nestor**", present the Nestor Web Cartographer software and the constructivist approach to mapping Internet information. They analyze a case study in Lyon School of Management (EM LYON), to show how the features of the software, such as a hybrid representational system, visual widgets and collaboration, help in constructing formalised knowledge.

6. Rider and Thomason, in "**Cognitive and Pedagogical benefits of Argument Mapping: L.A.M.P. Guides the Way to Better Thinking**", show that in dedicated Critical Thinking courses "Lots of Argument Mapping Practice" (LAMP) using a software tool like *Rationale* considerably improves students' critical thinking skills. They present preliminary evidence and discussion concerning how LAMP confers these benefits, and call for proper experimental and educational research.

7. Okada, in "**Scaffolding School Students' Scientific Argumentation in Inquiry-Based Learning with Evidence Maps**", reports pilot work investigating the potential of Evidence-based Dialogue Mapping to foster young teenagers' scientific argumentation. Her study comprises multiple data sources: pupils' maps in Compendium, their writings in science and reflective comments about the uses of mapping for writing. Her qualitative analysis highlights the diversity of ways, both successful and unsuccessful, in which dialogue mapping was used by these young teenagers to write scientific explanations.

8. Rowe and Reed, in "**Argument Diagramming: The Araucaria Project**", describe the software package Araucaria, which allows textual arguments to be annotated to create argument diagrams conforming to different schemes such as Toulmin or Wigmore diagrams. Since each of these diagramming techniques was devised for a particular domain or argumentation, they discuss some of the issues involved in translating between the schemes.

9. Sherborne, in his chapter "**Mapping the Curriculum: How Concept Maps can Improve the Effectiveness of Course Development**", argues that "curriculum development" is a process that naturally lends itself to visualisation through concept mapping. He reviews the evidence for how mapping can help curriculum developers and teachers, by promoting more collaborative, learner-centric designs.

10. Conole, in "**Using Compendium as a Tool to Support the Design of Learning Activities**", reports work to help multimedia designers and university academics create and share e-learning activities, by creating a visual language for learning design patterns. She discusses how learning activities can be represented, and how the maps provide a mechanism supporting decision making in creating new activities.

11. Opening the second half, Selvin, in "**Performing Knowledge Art: Understanding Collaborative Cartography**", focuses on the special skills and considerations involved in constructing knowledge maps with and for groups. He provides concepts and frameworks useful in analysing collaborative practice, illustrating them with a case study.

12. Culmsee and Awati, in "**The Map and the Territory: A Practitioner Perspective on Knowledge Cartography**", provide a practical perspective of knowledge cartography by drawing on an approach that has been developed and refined through the lead author's experiences in facilitating workshops in diverse professional domains. The discussion focuses on the importance of developing a feel for conversational patterns and for understanding the kinds of questions that enable insights to emerge from dialogue, leading to an emergent design approach that combines the methods of knowledge cartography with other facilitation and problem solving techniques in a "fit-for-situation" manner.

13. Buckingham Shum and Okada, in "**Knowledge Cartography for Controversies: The Iraq Debate**", use the debate around the invasion of Iraq to demonstrate a knowledge mapping methodology to extract key ideas from source materials, in order to classify and connect them within and across a set of perspectives. They reflect on the value of this approach, and how it can be extended with finer-grained argument mapping techniques.

14. Groetker, in "**Visualized Problem Structuring for Stakeholder Consultations**", presents a process model for asynchronous stakeholder consultations with visualized problem structuring in the form of argument mapping. The consultations deal with matters of policy advice in the field of science, technology and society, with a focus on bioethics and business ethics.

15. De Liddo, in "**Enhancing Discussion Forums with Combined Argument and Social Network Analytics**", uses the manual annotation of an extensive comment forum on nuclear power to demonstrate how sensemaking of online debate can be improved with argument and social network maps. She proposes insights on the affordances of effective online discussion tools, and envisaging future research scenarios to enhance online dialogue with social network and discourse analytics.

16. Ohl, in "**Computer Supported Argument Visualisation: Modelling in Consultative Democracy Around Wicked Problems**", presents a case study where a mapping methodology supported the analysis and representation of the discourse surrounding the draft South East Queensland Regional Plan Consultation. He argues that argument mapping can help deliver the transparency and accountability required in participatory democracy.

17. Sierhuis and Buckingham Shum, in "**Human-Agent Knowledge Cartography for e-Science: NASA Field Trials at the Mars Desert Research Station**", describe the sociotechnical embedding of a knowledge cartography approach (Conversational Modelling) within a prototype e-science work system. They demonstrate how human and agent plans, data, multimedia documents, metadata, discussions, interpretations and arguments can be mapped in an integrated manner, and successfully deployed in field trials which simulated aspects of mission workload pressure.

18. Hogan, Harney and Broome, in "**Integrating Argument Mapping with Systems Thinking Tools: Advancing Applied Systems Science**", describe an approach to knowledge cartography that seeks to overcome three independent human limitations which impede our ability to resolve complex problems: poor critical thinking skills, no clear methodology to facilitate group coherence, consensus design and collective action, and limited computational capacities. Building on Warfield's vision for applied systems sciences, we outline a new systems science tool which currently combines two thought structuring methodologies: argument mapping for critical thinking, and interactive management for system design.

19. Scharl et al., in "**Visualizing Knowledge Along Semantic and Geographic Dimensions: A Web Intelligence Platform to Explore Climate Change Coverage** ", presents the Media Watch on Climate Change, a publicly available Web intelligence portal that collects, aggregates and visualizes large archives of digital content from multiple stakeholder groups (documents and user comments from news media, blogs, user-generated content from Facebook, Twitter and YouTube, corporate and NGO Web sites, and a range of other sources).

20. Lowrance et al., in "**Template-Based Structured Argumentation**", present a semi-automated approach to evidential reasoning, which uses template-based structured argumentation. These graphical depictions convey lines of reasoning, from evidence through to conclusions. Their structured arguments are based on a hierarchy of questions (a tree) that is used to assess a situation. This hierarchy of questions is called the argument template (as opposed to the argument, which answers the questions posed by a template).

21. Vasconcelos, in "**An Experience of the Use of the Cognitive Mapping Method in Qualitative Research**", analyzes concept mapping as a tool for supporting qualitative research, particularly to carry out literature reviews, concept analysis and qualitative data examination. He uses his own experience in applying CmapTools software to understand the concept of partnership.

22. Basque et al., in "**Collaborative Knowledge Modelling with a Graphical Knowledge Representation Tool MOT: A Strategy to Support the Transfer of Expertise in Organizations**", present a strategy for collaborative knowledge modelling between experts and novices in order to support the transfer of expertise within organisations. They use an object-typed knowledge modelling software tool called MOT, to elaborate knowledge models in small groups composed of experienced and less experienced employees.

Towards Human-Machine Knowledge Cartography

To summarise, *Knowledge Cartography* is a specific form of information visualization, seeking to represent spatially intellectual worlds that have no intrinsic spatial properties. We have emphasised the challenge of helping analysts craft maps of information resources, concepts, issues, ideas and arguments as an intrinsic part of their *personal and collective sensemaking*. As with all artistry and craft, the *process and product* should interweave: the discipline required to craft a good map should clarify thinking and discourse in a way that augments the analytic task at hand, and the emerging map should in turn provoke further reflection on the rigour of the analysis. We are interested in mapping the structure of *physical phenomena* (e.g. a biological process), of *intellectual artifacts* (e.g. a curriculum), and *intellectual processes* of inquiry (e.g. a meeting discussion, or a scientific or public debate).

This orientation complements the work that has emerged in Domain Visualization within the information retrieval community, and Meeting Capture from the multimedia analysis community. In Domain Visualization (e.g. Chen 2003; Shiffrin and Börner 2004), "maps of science" are generated from the analysis of text corpora and related scientometric indices (e.g. co-citation patterns in literature databases), with the analyst then able to tune parameters to expose meaningful patterns (e.g. emerging research fronts, turning points in the literature), and interactively navigate the visualization as they browse trails of interest. In Meeting Capture research (e.g. the

European AMI and US CALO Projects), the analogous goal is to extract significant moments from audio and video meeting records (e.g. decisions; action items; disagreements), including generating argument maps (e.g. Rienks et al. 2006) in order to index the meeting and support follow-on activity.

We envisage that human and machine knowledge mapping will eventually converge. Software agents will work continuously in the background and on demand, generating maps and alerts that expose potentially significant patterns in discussions and publications (e.g. term clusters, hub nodes, pivotal papers, emerging research fronts, supporting/challenging evidence, candidate solutions). Analysts will assess, further annotate, and add new interpretive layers. While some of the authors in this book focus on mapping domains where objective, "hard" science data can be used to decide whether a map is correct or not, other authors are interested in how maps can support modes of interpretation and discourse across "softer" disciplines within the arts and humanities, and for teams confronted with wicked problems in policy deliberation and strategic planning, where there is no single, knowable solution.

The layers that analysts will add to machine generated maps will, therefore, also reflect the community's deliberations – whether in meetings or the literature – adding important connections and summaries that are not in the source documents/datasets. Human and machine mapping should be synergistic. Machines will play a critical role by filtering the data ocean, extracting increasingly higher level patterns, and acting on those semi-autonomously. People will, however, sense connections between experiences and ideas, and constantly read new connotations into their physical and information environments, in ways that are hard to imagine in machines. Crafting maps by hand will, in this view, continue to be an important discipline for sensemaking, even as our tools expand exponentially in computational power.

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We are confronted today by ever more complex challenges at community, national and global levels. As we learn almost daily of new, unexpected connections between natural and designed phenomena, we have to find ways to teach these rich, multilayered webs to our children. More than ever, we need to find ways to build common ground between diverse groups as they seek to make sense of the past, the immediate challenges of the present, and possible future. It would trivialise the dilemmas we face to declare a technological silver bullet. However, we cautiously propose that rigour and artistry in Knowledge Cartography has a significant role to play in shaping how stakeholders, young and old, learn to think, listen and debate.

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Appendix: Mapping Approaches and Software by Chapter

Chapter		Tool	Technique	Use context
Part 1: Knowledge maps for learning and teaching				
01	Empirical Studies of the value of Conceptually Explicit Notations in Collaborative Learning	Belvedere	Argument mapping	Undergraduate science
02	Concept Mapping Using CmapTools to Enhance Meaningful Learning	CmapTools	Concept mapping	Schools
03	Enhancing Collaborative and Meaningful Languages Learning Through Concept Mapping	CmapTools	Concept mapping	Undergraduate language
04	Thinking Maps®: A Visual Language for Learning	Thinking Maps	Thinking maps	Schools
05	The Constructivist Mapping of Internet Information at Work with Nestor	Nestor	Web mapping	Web learners
06	Cognitive and Pedagogical Benefits of Argument Mapping: L.A.M.P. Guides the Way to Better Thinking	Rationale	Argument mapping	Undergraduate Philosophy
07	Scaffolding School Students' Scientific Argumentation in Inquiry-Based Learning with Evidence Maps	Compendium MindMeister, LiteMap	Dialogue mapping	Schools
08	Argument Diagramming: The Araucaria Project	Araucaria	Argument mapping	Undergraduate philosophy
09	Mapping the Curriculum: How Concept Maps Can Improve the Effectiveness of Course Development	CmapTools Mind Manager	Concept mapping, mind mapping	Schools
10	Using Compendium as a Tool to Support the Design of Learning Activities	Compendium	Mind mapping	Learning designers
Part 2: Knowledge maps for information analysis and knowledge management				
11	Performing Knowledge Art: Understanding Collaborative Cartography	Compendium	Conversational modelling	e-Science and other mission operations

Chapter		Tool	Technique	Use context
12	The Map and the Territory: A Practitioner Perspective on Knowledge Cartography	Compendium	Conversational modelling	Facilitation and problem solving in diverse professional domains
13	Knowledge Cartography for Controversies: The Iraq Debate	Compendium	Dialogue mapping	Policy analysis
14	Visualized Problem Structuring for Stakeholder Consultations	XMind VUE Compendium Mindmeister Argunet Argument Browser Rationale	Argument mapping	Participation design for policy advice in the field of science, technology and society
15	Enhancing Discussion Forums with Combined Argument and Social Network Analytics	Cohere	Conversational modelling	**e-Science for** social network and discourse analytics
16	Computer Supported Argument Visualisation: Modelling in Consultative Democracy Around Wicked Problems	Compendium	Modelling mapping	Government public consultation
17	Human-Agent Knowledge Cartography for e-Science: NASA Field Trials at the Mars Desert Research Station	Compendium	Conversational modelling	e-Science for space exploration
18	Integrating Argument Mapping with Systems Thinking Tools: Advancing Applied Systems Science	Argument mapping support tools IM software application SPSS, Statmodel ENSIM, Powersim	Argument mapping	e-Science for business and educational settings
19	Visualizing Knowledge Along Semantic and Geographic Dimensions: A Web Intelligence Platform to Explore Climate Change Coverage	MWCC Media Watch on Climate Change	Semantic and geographic mapping	e-Science for climate-related issues

(continued)

Chapter		Tool	Technique	Use context
20	Template-Based Structured Argumentation	SEAS	Evidence mapping	Intelligence and other evidence analysis
21	An Experience of the Use of the Cognitive Mapping Method in Qualitative Research	CmapTools	Concept mapping	Postgraduate research
22	Collaborative Knowledge Modelling with a Graphical Knowledge Representation Tool MOT: A Strategy to Support the Transfer of Expertise in Organizations	MOT	Conceptual modelling	Organizational knowledge sharing

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