Type of Submission: Paper
Total Number of Pages: 10
Title: Learning from Architects: Complementary Concept Mapping Approaches
Short running Title: Learning from Architects
Author: Dr. Remo Aslak Burkhard
Affiliation: ETH Zürich
Chair for Information Architecture
Wolfgang-Pauli-Str. 14
CH-8093 Zürich
Tel: +41 44 633 29 20
burkhard@arch.ethz.ch

Statement of exclusive submission: This paper is not currently under review by a journal or conference, nor will it be submitted to such within the next three months.

Learning from Architects: Complementary Concept Mapping Approaches

Abstract

The research scope in concept mapping research can be extended with the investigation of **complementary concept mapping approaches** which are visual representations that complement the classical node link diagrams from Novak. To do so, concept mapping researchers can draw inspiration from architects. This article presents four strategies of architects to map concepts. The analysis shows what concept mapping researchers can benefit from architects: First, from the practice of architects to use complementary visualizations, which is investigated in the research field of **Knowledge Visualization**; Second, from their practice to structure information, which is investigated in the research field of **Information Architecture**. Both research fields are relevant for concept mapping researchers that investigate new formal approaches that complement the concept mapping approach taken by Novak. Third, the article discusses examples of complementary concept maps in different business situations.

Keywords: Concept maps, complementary concept mapping approaches, knowledge visualization, information architecture, information visualization, case studies from business.

1. Introduction

The research scope in concept mapping research can be extended with the investigation of new visual representations that complement the classical node link diagrams from Novak and his group [1, 2]. This article claims that concept mapping research sticks too much to the formal visual representation of Novak and that it neglects to investigate additional and maybe better visual representations.

What is a concept map? Concept maps according to Novak and his group [1, 2] are diagrammatic representations to visually reference knowledge or to visualize relationships among concepts. A concept map generally consists of items (nodes) and relationships (links) among these items. The individual items are visualized as geometric shapes (e.g., rectangles, circles, ovals) connected by lines or arrows that are tagged with descriptions (e.g., "is-a", "part-of", "related-to"). Concept maps have their origin in constructivism, which states that prior knowledge is required to learn about new concepts. The technique has its roots in Novak [1] and Novak and Gowin [2], based on ideas of Ausubel [3], who stated that an individual's knowledge is mentally represented in a hierarchy of concepts. Novak concluded that learning involves the integration of new concepts into existing cognitive structures. Concept maps can be used for different purposes. Concept maps help represent a concept, a network of concepts, and information. More specifically, they help (1) explicate mental cognitive maps, (2) brainstorm, structure, or summarize content, (3) for sense making by illustrating overview and detail, (4) as visual interface to digital information repositories or multimedia databases, (5) for a shared understanding of a complex domain, (6) as cognitive aid for individual learning situations by enhancing memory, (7) for knowledge compression through the use of different levels of details regarding the information, etc.

For the above purposes other visual representations exist that complement node link diagrams. This article claims that concept mapping research neglects to investigate the complementary use of other concept mapping techniques. In this special issue, Eppler discusses in detail the difference among Concept Maps, Mind Maps, Conceptual Diagrams and Visual Metaphors and initiates a discussion on mixed-mode visualizations, or hybrid formats. This approach is based on the insight, that the combined, sequenced use of the four methods can provide benefits that go beyond the possibilities of each individual method alone. This article argues similarily that the complementary use of different visualizations and concept mapping techniques can lead to new insights in the concept mapping community. This article concentrates on the practice of architects to use complementary visualizations to map concepts. It proposes two competencies of architects: First, their practice to **communicate concepts** by using complementary visualizations which is investigated in Knowledge Visualization. Second, their practice to **structure information** which is investigated in Information Architecture. Both research fields provide relevant examples and approaches for concept mapping researchers. Therefore, both fields are introduced, defined, and sharpened. Finally, the article will discuss examples of the application of such new formal types of concept maps in business.

2. Related Work

This section discusses recent developments in concept mapping research and research that is based on the idea of Novak, but further developed.

The state of the art in concept mapping research is discussed in detail in the introduction to this special issue. Most of these scientists research how concept mapping can be used for large sets of data. Other recent developments concern technical, conceptual, and usability features, for example [4] and [5]. The study of the new developments shows that concept mapping researchers generally stick to one formal approach, the one taken by Novak. They do not systematically investigate new formal types. On the contrary: Åhlberg [6] classifies concept mapping techniques according to their formal appearance and proposes a limitation of the label "concept mapping" to approaches that are based on the writings of Novak and his research group.

Looking beyond the circle of concept mapping researchers we can identify researchers who adapt concept mapping to other domains. In computer science for example, formalized concept maps are used in software design. The so-called Unified Modeling Language (UML) offers conventions that help programmers illustrate the concept of new software applications and communicate it to non-expert programmers. In business studies various related diagrams can be found: Decision trees [7, 8] illustrate sequential decisions in a tree structure and link probabilities to the relations and future outcomes. Similarly, "logic trees" and "issue trees" are used for structuring and analyzing problems [9]. System dynamics illustrates cause-effect relationships with causal loops or circular causalities. System dynamics is known in different fields, such as strategic management [10, 11], forecasting [12], or product development [13]. Kaplan and Norton [14, 15] introduced a diagrammatic "strategy map" that visualizes indicators relevant to business and interrelationships among them. Another visual modeling technique is the rich picture approach [16], or cognitive mapping [17, 18].

As this special issue shows, concept mapping research is still vital and important. However, this article argues that the strategy of limiting the term concept map to one formally predefined type, as it is proposed by Åhlberg [6], will lead to further improvements but will miss the chance to find additional and maybe even better formal approaches, or to investigate the complementary use of different mapping techniques. Therefore, it is proposed to expand the scope of concept mapping research. The research agenda should include the investigation of new formal concept mapping approaches or the complementary use of existing mapping techniques.

3. Learning from Architects: Four Concept Mapping Strategies

Why can concept mapping researchers learn from architects? Because they are experts in conceptual thinking and visualizing concepts. A concept according to Novak is a mental image of a thing or object. Today the term concept is used differently in different domains. Generally, it is understood as an abstract idea or a mental symbol, often associated with a corresponding representation, such as in language or symbology. Architects use the term concept in various situations. They develop abstract concepts for new city districts, conceptual ideas for a new building, a conceptual process, or a mental model that helps relate relevant entities and illustrate interdependencies. That means, architects have not the same understanding of the term concept such as concept mapping researchers.

An example illustrates the usage of the term "concept" among architects: For the design of a new airport, architects do not only elaborate a *concept* for the "built" structures (e.g., buildings), they also elaborate *concepts* for "non-built" issues, such as a maintenance *concept*, a security *concept*, *concepts* for using rooms differently, a *concept* for short walking distances for passengers, a signalization *concept*, or a *concept* for integrating information systems in architecture. These examples show that for the design of a building, architects daily need to understand and assess concepts (i.e., conceptual ideas, conceptions, conceptual models) from different domains and to collaborate and negotiate with persons from different domains, such as engineers, security experts, local authorities, managers. The key to understanding the individual domain knowledge is communication. Here, the link to concept mapping research that structures abstract declarative domain knowledge is close. To understand, assess, and optimize information from all these different domains, architects **structure information,** and **visualize the information**. To do so, they use a variety of complementary visualizations. Next, four strategies of architects to visualize concepts, mental concepts, ideas, conceptions, conceptual ideas will be introduced.

A **first strategy** of architects is the use of **physical conceptual models to design physical spaces**. In the process of designing a new building, architects create physical objects that visualize potential geometries of a building. They call these artifacts conceptual models. These conceptual models can be constructed with cardboard, wood, plastic, or other materials. The purpose of these models is to improve the communication in a team, to enhance learning processes and to support controlling details plus the big picture. Physical conceptual models are therefore used for analytical purposes, for collaborative design, and for communication purposes. Therefore architects tend to create many different conceptual models. An example is the Office of Metropolitan Architecture (www.oma.nl) that exhibited a collection of 34 physical concept models that were used for the design of two libraries in Paris.

A **second strategy are digital models used to design a physical space**. This digital approach complements the physical objects and became possible with the introduction of computer aided architectural design (CAAD) techniques. Various software tools enable architects to construct a building in three dimensions on the computer. Similar to physical models these digital models make it possible to control spaces and interrelationship among structural elements. In contrast to physical models these digital models allow viewers to explore the structure from inside and to switch layers on or off.

A **third strategy are metaphors of physical spaces used to design virtual environments**. Such virtual environments are known from the movie industry (e.g., a simulated scene of a medieval castle for a movie), the gaming industry (e.g., a virtual building for a computer game), they are used for the management of buildings (e.g., a three-dimensional application for facility management), or user interfaces for the management, access, and exploration of data, such as financial data. The latter point is illustrated with an example: the 3D Trade Floor Visualization Application [19]. It is a real-time virtual model of the New York Stock Exchange trading environment designed by the architecture office Asymptote Architecture. The virtual model is based on the physically built trading floors of the New York Stock Exchange. The virtual environment allows users to view, monitor, and analyze information pertaining to the Stock Exchange's daily trading activity. This fully integrated environment allows users to survey portfolios and market data in a real-time computer based application. The interface makes it possible to fly through a virtual trading floor, to observe trading activities and to monitor the markets. The example improves understanding, exploration, and use by structuring the relevant domain knowledge of the New York Stock Exchange, illustrating relationships (e.g., between stocks, databases etc), motivating different users to explore the information system, supporting recall, and serving as cognitive aid.

A **fourth strategy are imaginary metaphors used to design a virtual environment**. Such virtual environments can be used for the interactive visualization of abstract, multivariate, or temporal data. Such a spatial structure of data makes it possible to analyze and cluster information. A good example which also illustrates the difference to the previous example is the concept of particle clouds that were used as a metaphor for creating a visual structure for time-varying data streams. Figure 1 shows the "Infoticle" application [20, 21] which is an exploratory information visualization application that allows users to analyze database content within an immersive virtual reality environment. Each data object (e.g., a financial value) is represented with a particle (a so-called "Infoticle") and placed in a three-dimensional space. In this space, forces that correspond to particular data values and rules, attract or repulse the Infoticles according to their data values. Looking at this three-dimensional system (Figure 1), users are able to recognize outliers and visual phenomena that help them gain new insight from the underlying data. This effect can be leveraged by using stereoscopic vision, where special glasses allow viewers to explore the data streams in three dimensions.

[ENTER FIGURE 1 ABOUT HERE]

The first two strategies are used by "traditional architects" to design a building. Concept mapping researchers can benefit from their practice to use visual representations to visualize concepts and conceptual ideas [22, 23], which is investigated in **Knowledge Visualization**. The latter two strategies are used by architects that expand their role to the digital space. Concept mapping researchers can benefit from their approaches to structure information. Their purpose is to improve access, understanding, and using information. The associated research field is called **Information Architecture**. Both fields are discussed next.

4. Linking Concept Mapping Research to Knowledge Visualization and Information Architecture

This section introduces two sources of inspiration and anchor points for concept mapping researchers that investigate the complementary use of mapping techniques: Knowledge Visualization and Information Architecture.

4.1 Linking Concept Mapping Research to Knowledge Visualization Research

The research field **Knowledge Visualization** [23-26] concentrates on the use of complementary visualizations in knowledge-intense processes, where knowledge has to be created or to be reconstructed by each individual. Knowledge Visualization research aims to (1) identify the related fields that investigate visual methods for the transfer and creation of knowledge, (2) integrate their insights into theoretical frameworks and models, (3) thus serves as a mediator among isolated fields, (4) relates these insights to predominant problems in different domains, such as business and science, (5) and finally invents novel visual approaches, where no suitable visualization technique could have been identified.

The Knowledge Visualization Framework identifies four perspectives that should be considered in knowledge-intense processes, such as the mapping of concepts. The perspectives are based on four questions: (1) What is the purpose of using a visualization method? (2) What type of knowledge needs to be visualized? (3) Who is being addressed? (4) What is the most appropriate visualization type? Answers to these questions lead to the Knowledge Visualization Framework [22, 24, 26] that is illustrated in Figure 2.

[ENTER FIGURE 2 ABOUT HERE]

4.1.1 The Function Type Perspective

The Function Type Perspective distinguishes different functions of visual representation for processing information based on research in perception and neuroscience [27-29]. Six functions with social, emotional, and cognitive functions are summarized in the CARMEN-Acronym [24]: **C**oordination: Visual representations help coordinate individuals in the communication process. **A**ttention: They get the attention by addressing emotions, to keep the attention, and to identify patterns, outliers, and trends. **R**ecall: They improve memorability, remembrance, and recall. **M**otivation: They inspire, motivate, energize, and activate viewers. **E**laboration: They foster the elaboration of knowledge in teams. **N**ew Insights: They support the creation of new insights by embedding details in context, showing relationships among objects, or by leading to a-ha effects.

4.1.2 The Knowledge Type Perspective

This perspective aims to identify the type of knowledge that needs to be transferred. Five types of knowledge that are grounded in the knowledge management literature [30] are distinguished: Know-what (Declarative knowledge, as facts), Know-how (procedural knowledge, as knowing how things are done), Know-why (experimental knowledge, as knowing why things occur which captures underlying cause-and-effect relationships and accommodates exceptions, adaptations, and unforeseen events), Know-where (orientational knowledge as knowing where information can be found), Know-who (individual knowledge, as knowing experts).

4.1.3 The Recipient Type Perspective

The Recipient Type Perspective aims to identify the target group and the context of the recipient. The recipient can be an individual, a team, an organization (one culture), or a network of subjects (different cultures). Knowing the context and the educational, emotional, and cultural background of the recipient/audience is essential to finding the most promising visualization type.

4.1.4 The Visualization Type Perspective

This perspective arranges the visualization methods into seven main groups that are derived from the practice of architects [22, 31]: Sketches, Diagrams, Images, Maps, Objects, Interactive Visualizations, Stories. (1) **Sketches** are atmospheric, and help quickly visualize a concept. They present key features, support reasoning and arguing, and allow room for own interpretations. (2) **Diagrams** are abstract, schematic representations used to explore structural relationships among parts by denoting functional relationship. Diagrams explain causal relationships, reduce the complexity to key issues, structure, and display relationships. (3) **Images** can be defined as, "*representations which are primarily concerned with impression, expression or realism*" Kemp [32]. An image can be a rendering, a photograph, or a painting. Images catch the attention, inspire, address emotions, improve recall, and initiate discussions. Images are instant and rapid, instructive, and they facilitate learning. Visual metaphors support recall, lead to a-ha effects, support reasoning and communication. (4) **Maps** represent individual elements (e.g., roads) in a global context (e.g., a city). Maps illustrate both overview and details, relationships among items, they structure information through spatial alignment and allow zoom-ins and easy access to information. Maps generally have a scale that determines the size of an object represented on the map in relation to its actual size. Some maps are not scaled, however, for example the tube map. The features on a map depend on the map's purpose: a road map displays roads, whereas a tube map shows the tube system. (5) **Objects** exploit the third dimension and are haptic. They help attract recipients (e.g., dinosaur in a science museum), support learning through constant presence, and allow the integration of digital interfaces. Objects in space are helpful, for example for information points, knowledge fairs, or exhibitions. (6) **Interactive visualizations** are computer-based visualizations that allow users to control, combine, and manipulate different types of information or media. Interactive Visualizations make it possible to access, explore, and make sense of different types of digital information. Interactive visualizations help fascinate people, enable interactive collaborations across time and space and make it possible to represent and explore complex data, or to create new insights. (7) **Stories and mental images** are imaginary and non-physical visualizations. Architects often imagine scenarios. These mental images help discuss the ideas and concepts by externalizing them with stories or verbalized thoughts. This section presented the seven main visualization types that architects use.

Concept mapping researchers early investigated different functions of concept maps (Function Type Perspective). Later they developed concept maps for different recipients (Recipient Type Perspective). Recently they started discussing the mapping of other knowledge types, such as "Know-who" (Knowledge Type Perspective). Examples were discussed in the introduction to this special issue. But what still remains is the systematic investigation of other visualization types (Visualization Type Perspective). Therefore they can benefit from knowledge visualization researchers.

4.2 Linking Concept mapping Research to Information Architecture Research

Concept mapping researchers can secondly benefit from the competencies of architects to structure information. This is the domain of information architects. An example has been introduced in Figure 1. Today, the term is vaguely defined and needs a sharper definition.

4.2.1 Definition

Information Architecture designs structures to organize, visualize, and access information in digital and physical environments. **Design** means inventing, implementing, and evaluating value creating solutions; **organize** means creating classifications and relations to make the information more usable; **visualize** means using different visual representation techniques for social, emotional, and cognitive functions and includes simulation and exploration techniques, **access** means identifying, retrieving, and filtering information to use the information; **digital environments** mean information repositories and virtual environments, **physical environments** mean a physical space or intelligent object.

4.2.2 Application areas in Information Architecture

Application areas are: (1) Design of value creating interfaces to information systems. (2) Design of virtual environments, buildings, structures. (3) Simulation of virtual and physical environments, buildings, structures, processes, and products for planning and evaluation purposes. (4) Integration of information carriers such as displays in products or buildings. (5) Management of all information associated with a building or product. These application areas can be extended.

4.2.3 Origins of Information Architecture

Origins date back to the Library of Alexandria in the 3rd century BC, where the librarian Callimachus created a catalogue for the effective organization and retrieval of information similar to the Dewey Decimal System invented by Melvil Dewey in the 1870ies. The Dewey Decimal System provides a dynamic structure for the organization of library collections. In 1975, Richard Saul Wurman introduced the word "Information Architect" for a person who structures information to make it more understandable. In 1976 he organized a conference under the name "The Architecture of Information". Later he wrote two books [33, 34]. At a similar time, certain web and interaction designers called themselves information architects which led to various books such as the book by Rosenfeld and Morville [35] in 1998. In 1999, Schmitt [36] used the term in a book about the basis and the future of Computer Aided Architecture Design (CAAD). This book was a cornerstone for architects who investigated virtual architecture, Information Architecture or architectures for information. At leading universities researchers began to design and model spatial structures and to connect them to data [37]. Information Architecture therefore has three roots. Based on the concept of Wurman, information architects concentrate more on communication tasks and try to make information more understandable, thus are close to information design and knowledge visualization. Based on the concept of Rosenfeld and Morville, information architects create interactive websites, thus are close to interaction design and human computer interaction research. And based on the concept of Schmitt, information architects create interactive spatial structures, thus are close to CAAD, simulation, and basic research.

4.2.4 Distinction from related fields

To understand Information Architecture, it is important to distinguish it from related fields such as Information Design, Information Visualization, and Knowledge Visualization.

What is the difference between **Information Architecture and Information Design**? Information design is the visual design and presentation of information. Information Architecture is the structuring of information, before information design. Both, works from Tufte [38-40] and Bertin [41], cornerstones in the documentation of the history of information design, concentrate more on printed media. In contrast, information architects concentrate more on digital technologies [21, 35-37]. Tufte points to the limitations of displaying complex information on digital screens.

As a consequence, Tufte offers only few strategies and examples for exploiting the novel digital technologies to make information clearer. This is not solely, but rather the territory of information architects and information visualization researchers. A field that is very close to Information Design is the vaguely defined field "Visual Communication". The term is strongly associated with design and art schools, and describes a variety of graphic design challenges, such as the design of a corporate identity and logo, the design of signs and signalizations (i.e. in an airport), the graphic design and careful choice of typographical elements, or the design of a novel visual language for a poster series, a marketing flyer, or the design of a book. Thus it can be seen as a synonym for information design.

What is the difference between **Information Architecture and Information Visualization**? Information visualization is defined as "... *the use of computer-supported, interactive, visual representations of abstract data to amplify cognition*" (Card, et al., 1999). The goals seem close to the goals of information architects. A starting point for the analysis of differences is the educational background of the researchers. Information visualization researchers are mostly computer scientists that specialize in visualization, graphics, user interface, or human computer interaction. Therefore information visualization applications are often analytical, technical environments with filtering techniques. They are often aiming at visualizing multivariate data. However, sometimes they lack in the aesthetic and intuitive qualities of the user interface. Information architects like Wurman and Schmitt have a background in architecture. They are more concerned about structuring information and the design of visual approaches as interface to digital information systems. Information Architecture applications are often appealing, spatial, interactive structures in time used for exploratory tasks. However, they often lack in interactive filtering and data manipulation techniques. In conclusion, distinguishing the field can be achieved by understanding the educational background, motivation, and goals, such as visualizing data to improve the analytical and exploratory tasks or structuring data (information visualization) to improve understanding and access to the data (information architecture).

What is the difference between **Information Architecture and Knowledge Visualization**? Knowledge Visualization investigates the use of complementary visualization techniques from all visualization domains that help in knowledge-intense processes. Knowledge Visualization researchers firstly collect the positive and negative aspects of the individual visualization methods in all visualization domains, secondly they concentrate on understanding specific contents, in order to thirdly apply the most suitable visualization technique to solve a specific problem. To do so, Knowledge Visualization researchers also investigate in analysis, and problem-solving methods and often have a background in business studies and business consulting practice.

This section introduced the two research fields Knowledge Visualization and Information Architecture as two relevant fields for concept mapping research. The next section will discuss three examples of complementary visualizations in different business contexts that aim at visualizing concepts, conceptual knowledge, or conceptual ideas.

5. Examples for Concept Mapping Approaches in Business

This section provides insight into projects where different customers had to map conceptual knowledge. The examples are relevant for scientists because they illustrate the need in business to map concepts and conceptual knowledge and the need for new visualization types. The three examples were created and implemented by a Knowledge Visualization Company (http://www.vasp.ch). The author is a partner in this company.

The **first example** is located in the information technology industry. An innovative IT-security company (open systems AG, www.open.ch) wanted to explain their global integrated security concept. The typical schematic IT diagrams, that looked similar to first generation concept maps, were too abstract for customers. They are appropriate for technical journals but do not help non-experts understand their concept. However, for marketing and sales purposes this is crucial. That is why a more appealing and more expressive structure for the concept of the global protection shield had to be developed. It was supposed to catch the attention and to illustrate the products (nodes represented as spheres) and interrelationships between products in the bigger context. The final structure (Figure 3) has a futuristic appearance and is available as an interactive animation, with a flythrough and stops at positions where the individual products are explained with overlaying text. The structure sticks to the memory of potential customers because it is both attractive and instructive. Consequence: concept mapping researchers might be inspired to start investigating node link diagrams in the third dimension and should consider the aesthetic quality of concept maps.

[ENTER FIGURE 3 ABOUT HERE]

The **second example** is located in the context of communicating the conceptual idea of a strategic project to different stakeholders. Science City is the vision and project for a new campus of the Swiss Federal Institute of Technology

(ETH) that consists of new *buildings* and *programs*. All recipients were able to imagine the *buildings*. But the challenge was to illustrate the *programs*, such as student exchange programs, public events, international relations, wireless access, or improved communication with the public. To explain the programs and how they interrelate, the Science City Map (Figure 4) was designed. It is a poster (2 by 5 meters) that conveys the programs and associative information. It combines different graphic elements, such as geographic maps, building plans, statistical information, text, arrows, hotspots, or fictitious stories. The map consists of three parts - a world map, a map of the new campus Science City, and a map of Zurich. Interrelations of the programs with the world or the city of Zurich are illustrated with pink lines that are tagged with short sentences (e.g., "a professor from the 'MIT' moves to Science City and initiates a new institute"). Next, the power of storytelling was used to describe – as a fictitious scenario – what the finished project could look like in 2011, and in what ways each stakeholder would benefit. These stories were easy to understand and motivated viewers to tell them to friends. The stories were added at the bottom of the poster, also linked with arrows to elements in the image to spatially locate the fictitious persons. The map was used as a physical poster in exhibitions and integrated into the website as a digital map, where one was able to click on individual elements. Interviews and observations of persons that studied the map in the exhibitions showed that the average reader studied the map between five and ten minutes. The individual short texts in the plan or the labeled lines were easy to read and gave viewers a deep understanding of the project on the whole. The spatial localization of the different ideas and concepts helped imagine what living in Science City could be like. Readers could see how different programmatic elements interrelate, which led to a-ha effects. Feedback from various persons indicated that the visualization motivated them and helped them build an individual mental model of the project. This allowed them to explain the project to others by telling stories.

Consequence: concept mapping researchers might be inspired to start developing **visually enriched concept maps** and to integrate complementary visualization techniques, such as story telling.

[ENTER FIGURE 4 ABOUT HERE]

In the **third example** a quality development process had to be communicated and established in an education centre for health care professions. Gantt charts and traditional project plans did not reach their goal. Therefore, the client was looking for a concept or knowledge map that complemented the Gantt chart. The "**Tube Map Visualization**"

(Figure 5) maps the whole project based on the visual metaphor of a tube map. In the Tube Map Visualization each tube line represents a target group and each station a milestone. The visualization was printed as a poster and located at prominent locations in the organization. The positive and negative aspects of the Tube Map Visualization and evaluations (e.g., a comparison of Tube Map projects with Gantt Charts) can be found in previous works [42-44]. The findings indicate that the Tube Map Visualization is a powerful metaphor to communicate a complex project when different groups of persons are involved. The employees considered the Tube Map Visualization useful because it provides an overview and detailed information in one image and because it initiates discussions and helps create a mental model for the abstract concept of a quality development process. An interactive version for the intranet was proposed to add more information (such as text or multimedia resources) for each milestone. But the printed posters at prominent locations seemed to catch more interest and attention because they lead to more discussions among the employees.

Consequence: even if the above examples are not exactely in the field of concept mapping and the understanding of concepts is closer to conceptual ideas or schemas, concept mappping researchers might get inspirations to start investigating the integration of visual metaphors into concept maps or the complementary use of different visualization techniques.

[ENTER FIGURE 5 ABOUT HERE]

All three examples point to the need among companies of using visualization techniques with the purpose to illustrate concepts or complex business related contents. The role of the designer is challenging, because she or he has to master **consulting and problem-solving tasks** on the one hand and **visualization skills** on the other hand. Only then it is possible to create significant added value for the customer. The examples illustrate the use of visually enriched maps, the integration of visual metaphors, and the use of different media.

5. Summary

This article claims that the scope of concept mapping research needs to be expanded to new formal approaches and the complementary use of visualization techniques. To do so, concept mapping researchers can learn from architects. First, from their practice to use complementary visualizations, which is investigated in **Knowledge Visualization**.

Second, from their practice to structure information, which is investigated in **Information Architecture**. Both research fields are a source of examples and theoretical anchor points for concept mapping research. Therefore both fields were introduced, defined, and sharpened through the distinction from related fields. Finally, three examples of concept mapping approaches in different business situations were discussed. In the process of implementing these solutions one assumption was confirmed: that customers are looking for new concept mapping approaches that combine ideas from different domains.

Acknowledgments

I want to thank Gerhard Schmitt, Andrew Vande Moere, Martin Eppler, Joseph Novak, Sigmar-Olaf Tergan, Tanja Keller, and Michael Meier for their valuable comments that helped me sharpen this article.

Figures

Figure 1. The Infoticle application uses a spatial metaphor of particle clouds to visualize abstract data (http://blue-c.ethz.ch)

FUNCTION TYPE	KNOWLEDGE TYPE	RECIPIENT TYPE	VISUALIZATION TYPE
Coordination	Know-what	Individual	Sketch
Attention	Know-how	Group	Diagram
Recall	Know-why	Organization	Image
Motivation	Know-where	Network	Map
Elaboration	Know-who		Object
New Insight			Interactive Visualization
			Story

Figure 2: The Knowledge Visualization Framework consists of four perspectives that need to be considered when creating visualizations that aim to transfer knowledge.

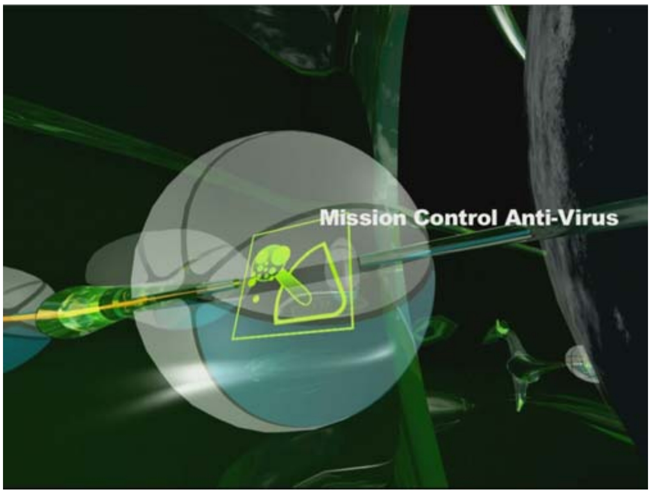

Figure 3: A three-dimensional visualization with nodes and links visualizes the abstract service of a global protection shield.

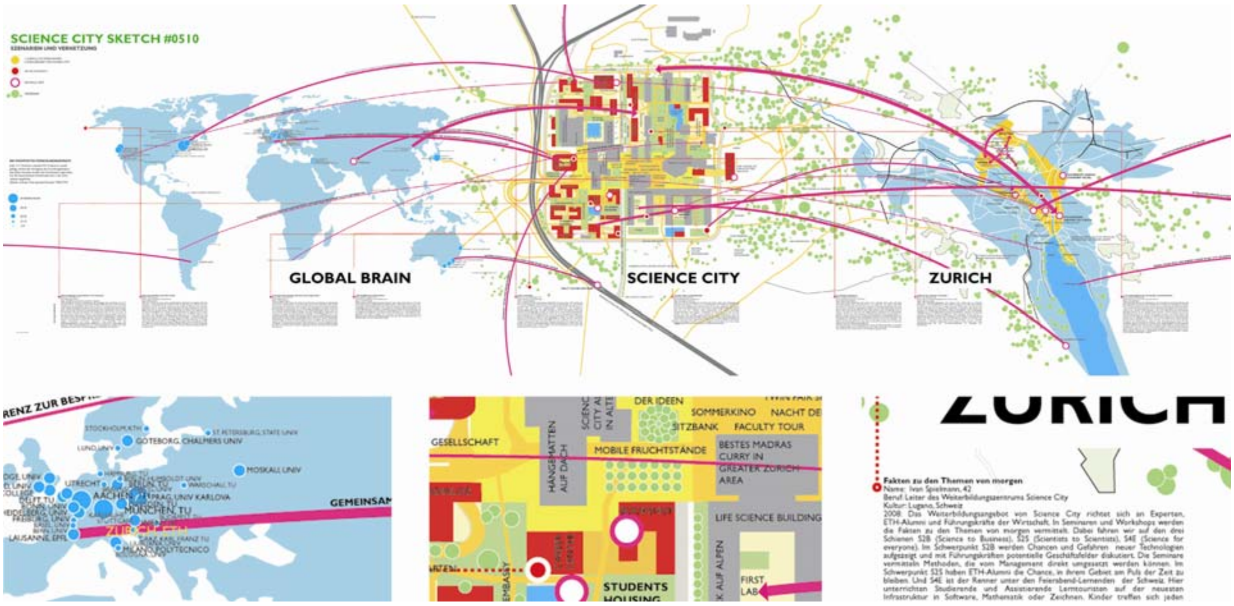

Figure 4. The Science City Map integrates storytelling techniques and various graphical elements.

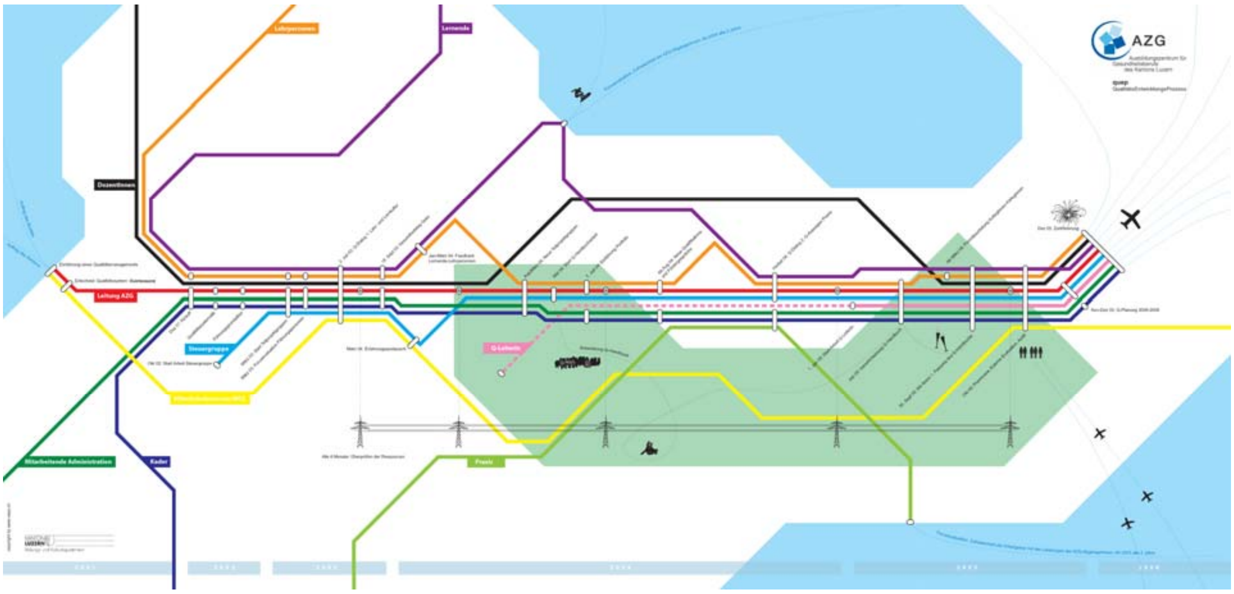

Figure 5. The tube map visualization (1,2 x 2,4 meter) presents an overview and details on a quality development project. Each line represents one target group, each station a project milestone. (http://www.vasp.ch)

References

1 Novak JD. Learning theory applied to the biology classroom. *The American Biology Teacher* 1980; **42**: 280-285.
2 Novak JD and Gowin DB, *Learning how to learn*. Cambridge University Press: Cambridge, 1984
3 Ausubel DP, *The psychology of meaningful verbal learning*. Grune & Stratton: New York, 1963
4 Alpert SR. Comprehensive Mapping of Knowledge and Information Resources: the Case of Webster, In: Tergan S-O and Keller T (Eds). *Knowledge and Information Visualization: Searching for Synergies. LNCS 3426*. Springer Verlag: Heidelberg. 2005. 208-227.
5 Tergan S-O and Keller T. Visualizing Knowledge and Information. An Introduction., In: Tergan S-O and Keller T (Eds). *Knowledge and Information Visualization: Searching for Synergies. LNCS 3426*. Springer-Verlag: Heidelberg. 2005. 1-23.
6 Åhlberg M. Varieties of concept mapping. *Concept maps: Theory, methodology, technology. Proceedings of the first international conference on concept mapping* 2004 (Pamplona, Spain), Universidad Pública de Navarra.
7 Neely JE and de Neufville R. Hybrid Real Options Valuation of Risky Product Development Projects. *International Journal of Technology, Policy and Management* 2001; **1**: 29-46.
8 Sharpe P and Keelin T. How Smithkline Beecham Makes Better Resource-Allocation Decisions. *Harvard Business Review* 1998; **76**: 45-57.
9 Rasiel EM and Friga PN, *The McKinsey Mind*. McGraw-Hill: New York, NY, 2002
10 Malik F, *Strategie des Managements komplexer Systeme: Ein Beitrag zur Management-Kybernetik evolutionärer Systeme*. Vol. 7te Auflage. Paul Haupt Verlag: Bern Stuttgart Wien, 2002
11 Lyneis JM. System Dynamics for Business Strategy: A Phased Approach. *System Dynamics Review* 1999(15): 37-70.
12 Lyneis JM. System Dynamics for Market Forecasting and Structural Analysis. *System Dynamics Review* 2000; **16**: 3-25.
13 Ford DN and Sterman JD. Dynamic Modeling of Product Development Processes. *System Dynamics Review* 1998; **14**: 31-68.
14 Kaplan RS and Norton DP, *Strategy Maps: Converting Intangible Assets into Tangible Outcomes*. Harvard Business School Press, 2004
15 Kaplan RS and Norton DP. Having Trouble with Your Strategy? Then Map It. *Harvard Business Review* 2000; **78**(5).
16 Monk A. The Rich Picture: A Tool for Reasoning About Work Context. *Interactions* 1998: 21-30.
17 Eden C. Analyzing Cognitive Maps to Help Structure Issues or Problems. *European Journal of Operational research* 2004; **159**: 673-686.
18 Eden C. Cognitive Mapping. *European Journal of Operational Research* 1988; **36**: 1-13.
19 Scanlon J. Ride the Dow. *Wired* 1999; **7th of June**.
20 Vande Moere A. Infoticles: Information Modeling in Immersive Environments. *Proceedings of the Sixth International Conference on Information Visualization* 2002 (London).
21 Vande Moere A, Mieusset KH, and Gross M. Visualizing Abstract Information using Motion Properties of Data-Driven Particles. *Conference on Visualization and Data Analysis 2004, IS&T/SPIE Symposium on Electronic Imaging 2004* 2004 (San Jose (CA)).
22 Burkhard R. Learning from Architects: The Difference between Knowledge Visualization and Information Visualization. *Eighth International Conference on Information Visualization (IV04)* 2004 (London, July).
23 Burkhard R, *Knowledge Visualization - The Use of Complementary Visual Representations for the Transfer of Knowledge. A Model, a Framework, and Four New Approaches. Ph.D. thesis*. 2005, Swiss Federal Institute of Technology (ETH): Zurich.
24 Eppler M and Burkhard R. Knowledge Visualization, In: Schwartz D (Ed). *Encyclopedia of Knowledge Management*. Idea Press: New York. 2005.
25 Chen C, *Mapping Scientific Frontiers: The Quest for Knowledge Visualization*. Springer: London, 2003; 244.
26 Burkhard R. Towards a Framework and a Model for Knowledge Visualization: Synergies between Information and Knowledge Visualization, In: Tergan S-O and Keller T (Eds). *Knowledge and information visualization: Searching for synergies. LNCS 3426*. Springer-Verlag: Heidelberg. 2005.
27 Farah MJ, *The Cognitive Neuroscience of Vision*. Fundamentals of Cognitive Neuroscience. Blackwell Publishers: Oxford, 2000; 380.
28 Ware C, *Information Visualization: Perception for Design*. Morgan Kaufmann: San Francisco (CA), 2000; 438.
29 Koffka K, *The Principles of Gestalt Psychology*. Lund Humphries: London, 1935; 720.
30 Alavi M and Leidner D. Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly* 2001; **25**(1): 107-136.
31 Burkhard R. Knowledge Visualization sagt mehr als tausend Worte. *io new management, Zeitschrift für Unternehmenswissenschaften und Führungspraxis* 2004(6): 56-58.
32 Kemp M, *Visualizations. The Nature Book of Art and Science*. University of California Press: Berkeley & Los Angeles, 2000
33 Wurman RS, *Information Anxiety 2*. QUE Books, 2000
34 Wurman RS, *Information Architects*. Graphis Inc: Zurich, 1996; 235.
35 Louis Rosenfeld PM, *Information Architecture for the World Wide Web*. O'Reilly & Associates, 1998
36 Schmitt G, *Information Architecture; Basis and Future of CAAD*. Birkhäuser: Basel, 1999

37 Engeli M, ed. *bits and spaces: architecture and computing for physical, virtual, hybrid realms*. Birkhäuser: Basel, Boston, Berlin, 2001
38 Tufte E, *The Visual Display of Quantitative Information.* Graphics Press: Cheshire, 1983
39 Tufte ER, *Envisioning Information*. Graphics Press: Cheshire (CT), 1990; 126.
40 Tufte ER, *Visual Explanations: Images and Quantities, Evidence and Narrative*. Graphics Press: Cheshire (CT), 1997; 156.
41 Bertin J, *Sémiologie Graphique*. 2nd ed. Gauthier-Villars: Paris, 1967
42 Burkhard R and Meier M. Tube Map: Evaluation of a Visual Metaphor for Interfunctional Communication of Complex Projects. *Proceedings of I-KNOW '04* 2004 (Graz, Austria, June 30 - July 2); 449-456.
43 Burkhard R and Meier M. Tube Map Visualization: Evaluation of a Novel Knowledge Visualization Application for the Transfer of Knowledge in Long-Term Projects*.* *Journal of Universal Computer Science* 2005; **11**(4): 473-494.
44 Burkhard R, et al. Knowledge Visualization: A Comparative Study between Project Tube Maps and Gantt Charts. *I-Know '05* 2005 (Graz, Austria).