DESIGNING THE INTERACTIVE KNOWLEDGE WORKBENCH

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Session L-2

Abstract

Communication challenges associated with globalization, iterative organizational restructuring and the specialization of knowledge require a new form of supporting dialogues. While intelligent digital platforms provide the capabilities to process, present and transmit information in an ever increasing number of ways, coherence and comprehensibility are frequently lost due to changes in the applied methods for knowledge processing and the format in which results are presented. The underlying fragmentation of the reasoning and communication process reduces the transparency of how decisions have emerged and therefore the ability of recipients to make sense of the resulting message.

This paper proposes to merge different design concepts to transform software into a platform termed the *knowledge workbench* which would aid in simultaneously generating and communicating insights. By defining principal design dimensions and presenting concrete functional characteristics associated with these, it attempts to provide specific guidelines which contribute to improving software-mediated knowledge dialogues. The findings from the theoretical framework are supported by implementations in practice which provide evidence that the developed design principles are increasingly reflected by the functional profile of commercial applications. As a conclusion, it is suggested that the digital knowledge workbench could serve as an ideal complement to the art of thinking and conversation.

Keywords: knowledge communication, visualization, man-machine interface, cognitive tools, analytical applications.

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1 Introduction

The communication challenge. Today's organizations face a number of serious communication challenges. First, the rapid expansion of available information, access channels and representation formats leave decision-makers with a sense of having only an insufficient grasp of what is important to know. Second, both private and public institutions are undergoing significant structural change at an ever faster pace. This puts them under growing pressure to adapt and explain their underlying reasoning to an increasingly unsettled constituency. Third, in a similar sense that globalization is diluting traditional patterns of spatial and cultural coherence, specialization is more and more contributing to a fragmentation of communities previously accustomed to applying a common language using similar sets of values and methods (Bohm, 1996). While the need to communicate seems greater than ever due to the asymmetries in what is understood, we witness a loss in confidence regarding the ability to act and converse intelligently within this complex environment. The observed symptoms range from high degrees of friction during implementation due to wheel reinventions, lack of buy-in and alignment to misunderstandings, alienation or a general retreat from participation (Sprinkart and Gottwald, 2003; Nefiodow, 2001).

The role of technology. At the same time, there has been a massive development of technological capabilities to deal with some of these challenges. The internet, company intranets and central data bases provide an unprecedented infrastructural base for the transmission of large amounts of information transcending traditional organizational barriers. Ever more sophisticated applications populate the nodes of this tremendous network serving a highly differentiated set of demands. The platforms provide a number of advantages: Digital storage makes the contained data ubiquitously accessible, image creation, navigation capabilities and the variation of content allow for a user-guided and transparent exploration of the represented knowledge space. The applied software solutions may be categorized as either analysis-focussed (business intelligence applications in the widest sense) or communication-focussed (software for presentation, collaboration or data exchange) with the implicit notion that one should first attempt to solve a problem and then proceed to communicate the results.

Crossing the chasm. It seems as though this fragmented approach may no longer serve the demands of an organization which finds itself in a state of continuous adaptation and conversation. All analyses applied in problem-solving are tightly interlinked with communication processes, be it between a group of people or between an individidual and a machine-based application. In each phase, different players are involved with different objectives and applying their own set of tools for analysis and communication ranging from flip charts and sticky pads to written documents, ERP-reports and PowerPoint. To illustrate this point, Fig. 1 shows an idealized planning cycle involving critical problem-solving and communication tasks with the participating parties. The "bubbles" represent typical tasks associated with the principal strategic phases "awareness", "analysis" and "action" developed by Noorderhaven (1995). The inner rings each stand for an involved party (depicted by flags) and the arrows represent typical "hand-over" points between parties involving some kind of communication. At each of these points – exemplarily representing the entirety of interfaces – there is a change of the working platform due to the shift in which aspect of the problem is being addressed, potentially causing a significant loss in coherence and transparency.

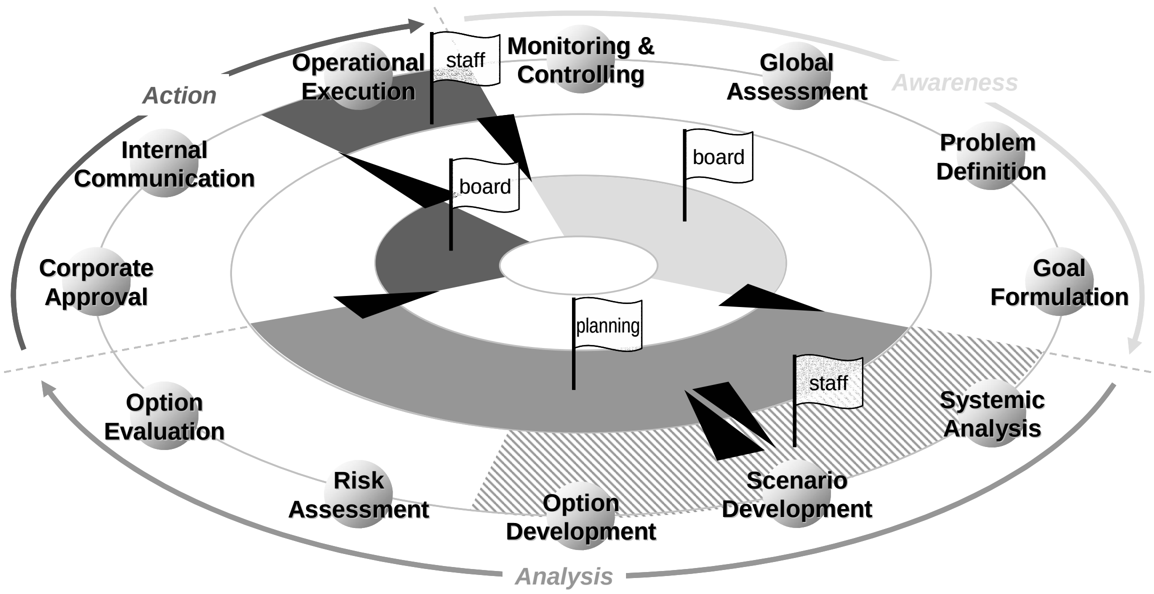

Fig. 1. Prototypical planning and communication cycle in an organization

Enabling digital knowledge dialogues. This indicates that there is no solution to a problem without the message in which it is embedded, they must be seen as two sides of the same coin. The objective of this paper is to propose a framework for designing a digital dialogue platform which helps to generate insights by simultaneously providing decision support and communication capabilities. The fusion of these functions should help reduce friction losses at the interface points of a problem-solving process, thereby improving the contiguity of the delivered content and transparency of decisions. In order to optimally utilize the perceived advantages of software and mitigate its deficits compared to dialogues between humans, specific design guidelines are developed in the following section.

2 Theory – Design Principles for a Knowledge Workbench

As was argued above, most knowledge generation processes involve some kind of dialogue. This removal of the traditional distinction between problem-solving and communication also becomes visible in recent developments of commercial software: analytical applications have moved towards improving graphical presentation features (e.g. diagram generation, control cockpits) and communication processes have become increasingly digitized supported by a growing number of analytical functions (e.g. search, statistics, embedded processors).

The fusion of associated requirements delivers the design framework (cp. Kennedy et al., 1996). In the following section it is argued that the framework is dominated by three design principles (cp. Fig. 2):

The organization of knowledge provides the logic.
The visualization of knowledge creates the image.
The interaction with content provides the basis for cognitive adoption.

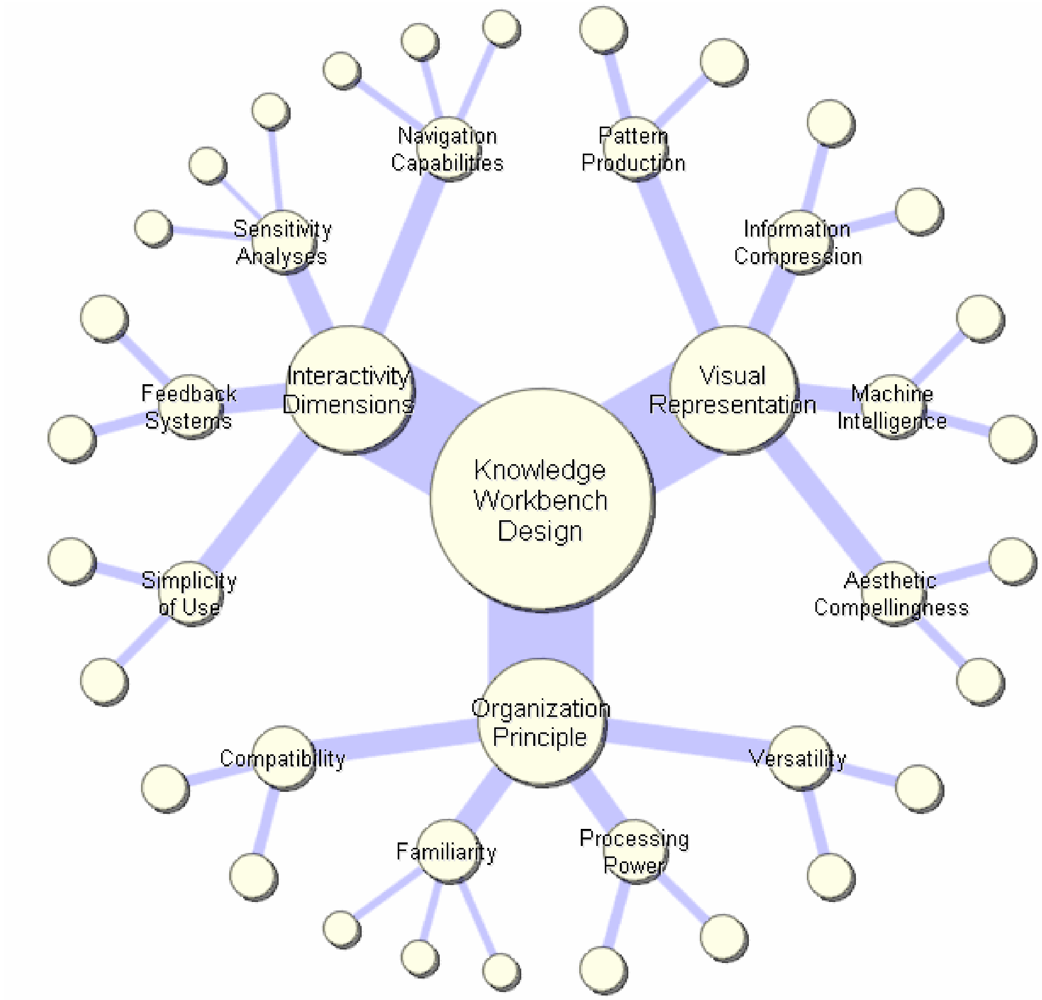

Fig. 2. Overview of design principles for an interactive knowledge workbench

2.1 Providing the Logic: The Organization Principle

The role of organization principles. Inquiries are guided by a specific set of expected answers. The organization principle describes the underlying logic used for structuring the knowledge pertaining to these inquiries. This logic determines which characteristic features of knowledge building blocks and the relationships between them are captured in which format in order to match the type of question asked. The characteristics together with the rules applied for evaluation represent the basis for further processing the provided inputs. Since the requirements vary according to the kind of inquiry it is necessary to differentiate between distinct types of knowledge structures[1]:

Categorial structures emerge from answering questions of the type "Where does this belong?" The knowledge universe is divided into classes and each concept can be localized in this space based on its characteristics and rules of attribution. From this, a classification is generated which also serves as a prerequisite for further processing using one or more of the organization principles described below (e.g. by providing a distinction between problems, goals, measures, events etc.). Document management systems and web portals follow the classification concept which serve the organization of access to different kinds of information.

Associative structures result from answering questions of the type „What is this similar to?" where similarities between elements are captured based on predefined feature vectors. These logical relationships form an essential base for statistical analyses or may be transformed into spatial representations. A group of elements with high correspondence in its features is termed a cluster. Search engines use the similarity concept to generate a ranked list of documents based on their correspondence with a search term and in so-called knowledge maps the similarity of search terms is depicted in multi-dimensional topologies (cp. Eppler, 1997; Schütt, 1999).

Normative structures emerge from responses to questions of the type "Why are we doing this?" and represent value systems. They inform about what is important, how much and why it is important and are defined in terms of visions, mission statements, goals, indicators or similar value factors. The relationships between these factors typically create a hierarchical membership structure where parts contribute to a whole. From knowledge about value structures preferences and contradictions in objectives may be derived. An exemplary representative of this structure format is the Balanced

[1] The semantic network represents a generic structure which may contain all of the organization principles described below.

Scorecard which goes back to Kaplan and Norton (1996) and today is widely applied in numerous enterprises.

Inferential structures result from answering questions of the type „Which impact does this have" or reversely, "Why is this so?" and describe causal dependencies. Contrary to associative relations, a direction of impact is defined between one or more input variables and an output variable representing an "if-then" relationship. Depending on the model applied these serve as predictions about impacts of changes in the current state (the values of the input variables are known), as explanations of the current state (the value of the output variable is known) or help to identify feedback loops. Typical representatives based on this structure format are econometric and structural equation models as well as system dynamic simulations and Bayesian Networks.

Procedural structures emerge from responses to questions of the type „How do we do this?" where elements of a problem representation are brought into a chronological sequence. Since any action is tied to the linearity of time, planning and implementation of a solution are based on procedural knowledge. Similarly, for processing a problem machines always require a procedural translation in form of an execution sequence. Each object in such a process represents an event, a task or a decision and the relations between objects determine a processing sequence which is linked to temporal or logical conditions. Flow charts and business process models follow the logic of this structure format.

Design principles. The most important software design criteria associated with the logical dimension are summarized in Fig. 3.

Fig. 3. Design criteria associated with the logical dimension

Compatibility: A typical assumption met in problem-solving is that "if you have a hammer every problem looks like a nail". Therefore, first and foremost a digital platform must provide a compatible framework for dealing with the question at hand. A framework is considered adequate for the information provider (sender) if it accepts the relevant problem-specific inputs and for the information seeker (recipient) if it allows to process his problem-specific query. Furthermore, an adequate *resolution bandwidth* must be provided. For example, understanding the mechanics of a detailed financial plan requires different representation structures than communicating financial policies to laymen.

Familiarity: For communication to work it is necessary that sender and recipient are familiar with and utilize a common "symbol system". According to Salomon (1994) such a system is defined by the constituent symbols and prescriptive or conventional rules connecting these (syntactic component) as well as a reference system (semantic component). Over centuries we have become familiar with the use of spoken and written language as *the* means for knowledge transfer. But the recent rapid adaptation to the use of tools such as spreadsheets and business diagrams for everyday communication illustrates that due to technological advances other forms of symbol systems are likely to become part of our natural symbol repertoire. The resulting competence may be generated at different levels: *Output interpretation* ("fact seeker") generally requires the lowest degree of familiarity, the *provision of inputs* ("template filler") a higher and understanding the underlying processing *engine* ("analyst") the highest degree of familiarity.

Processing power: The processing of data represents the "core competence" of software. Similar to the capabilities of the human brain, software-based methods may be used to generate new organization patterns from existing pieces of knowledge. The objective followed with transforming isolated information bits into a new coherent structure is to produce new constellations which may be more comprehensible for the recipient. For example, processors serve to create a logical organization of elements in space (e.g. structuring, mapping), to make a selection (e.g. summary, optimization) or to generate sequences of events (e.g. simulation). The greater the *sophistication* of a processor, the more efficiently or accurately it is able to compute a requested result from a set of predefined inputs. The greater the *variety* of processor operations, the greater the number of result patterns which may be generated from the same set of input data.

Versatility: There is a natural tension between specialty and versatility functions of a tool. Specialization aims at ensuring the optimal handling of a detail problem. At the same time, it may contribute to the fragmentation of a complete problem-solving process because of necessary changes in the required platforms. *Extensibility* or "horizontal versatility" provides the capability to use the existing structure as a basis for different organization principles. It corresponds to a natural behavior in speech where we easily move from a value discussion to one about means, scenarios or process. For software applications, this migration between formats may constitute a serious challenge because it is not possible to entirely formalize a complete problem-solving process with all of its reasoning components without losing the "fuzzy edge" humans have over machines. A "vertical versatility" allows the *variation of frameworks* within which the software is applied. This in essence mirrors the capacity of using the same platform for specification and analysis (problem-solving) on the one hand and presentation of results (communication) on the other which is also tightly linked to the user interface design (cp. section 2.3).

2.2 Creating the Image: The Visual Representation

The role of visualization. The human cognitive system reveals weaknesses in processing complex information due to limited working memory capacity (Baddeley, 1990; Halford et al., 1998). However, when the visual-spatial system is engaged, knowledge structures are more easily comprehended and efficiently processed. There is substantial empirical evidence that visual representations are superior vehicles for fostering the understanding of relations, patterns and causality which are required for building knowledge structures (e.g. Larkin and Simon, 1987; Paivio, 1991; Glenberg and Langston, 1992; Bauer and Johnson-Laird, 1993; Novick and Hemlo, 1994; Day, 1988, Kindfeld, 1993/1994; Novick, 2001).

The reason for this empirically validated increase in effectiveness lies in the characteristics of the visual system itself. Images support the establishment of knowledge structures because the visual perception itself is a recognitional, insight-driven process. It is known that perception is more than a passive image creation, it is an active search and construction process which generates a stable reference to the environment from comparatively unsystematic input data (Neisser, 1974). The representation codes used in images therefore reproduce not an outer reality but rather describe these search and construction processes in an abbreviated form (Sprinkart, 1992).

The concept of an organization principle which generates knowledge structures from the features and relationships between their constituent building blocks may also be transferred to visual representations. An effective visual translation is rooted in optimally synchronizing logical and symbolic organization principles.

Design principles. The most important software design criteria associated with the visual dimension are summarized in Fig. 4.

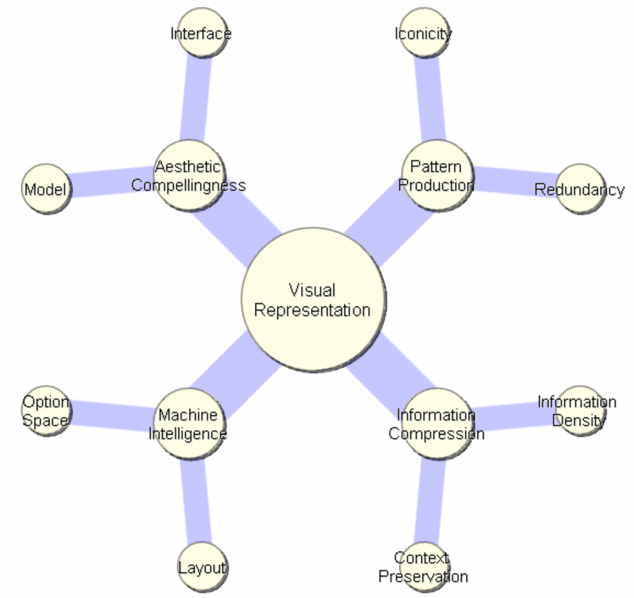

Fig. 4. Design criteria associated with the visual dimension

Pattern production: The most important function of visual representations in knowledge communication is to produce patterns which in turn prompt specific kinds of insights by the recipients. The ability of the human cognitive system to discern such contiguity from pieces of information – without having been provided with clear pattern search criteria which machines need – is a true sense-making capability. It is of tremendous value in terms of leveraging the recipient's existing experience in order to understand and handle something new (Margolis, 1987; Kuhlen, 2001) and for providing intuitive access to structural not just superficial characteristics of a problem (Holyoak, 1985). Producing meaningful patterns is not a task which can be prescribed. But their emergence may be facilitated by ensuring the *iconicity* of used symbols – e.g., node and link images mirror the function they represent – and generating structures which lead to compelling visual metaphors – e.g. a tree with leaves and branches representing a hierarchical value system (Eppler 2004) – which help to mirror the underlying logical organization (see also Preim 1999, Thaller 2002, Raskin 2001, Eppler 2004 for the use of metaphors).

Due to the multiplicity of features associated with each knowledge building block they may be represented in different contexts using the appropriate set of transformation rules. With each created result pattern an additional access point to the represented knowledge is created, a *redundancy* which delivers an additional "explanation". Mayer and Moreno (1998) term this the multi-representation principle and refer to a number of experiments which showed an improved knowledge transfer (Mayer and Anderson, 1991, 1992; Mayer and Gallini, 1990; Mayer and Sims, 1994). According to the contiguity principle multiple representations further increase the facility of comprehension when they are shown simultaneously as is the case in cross-referencing and parallelisms (Mayer and Moreno, 1998; Tufte, 2001b).

Information compression: Visualizations represent a powerful method for generating a high *information density* often representing millions of data points and carrying multiple messages (Tufte, 2001a). An image can serve as a form of "abstract" to a whole set of insights, particularly when coupled with metaphorical analogies (cp. above). The design rule simply states to optimally utilize this "diagrammatic efficiency" which is based on human perceptual inference (Mayer and Gallini, 1990). Due to this compression capability visual representations can also offer simultaneous views of a detail and the context in which it is embedded. Visually, this *context preservation* may be facilitated by applying hyperbolic geometries or similar techniques producing fish-eye effects (cp. section 3.2).

Machine intelligence: Apologies to the AI community but in a way, "intelligence" is a misnomer when it comes to describing a characteristic of a machine. All manipulations of data which are performed are based on rules which were designed and programmed by humans and the machine merely serves as a proxy for this intelligence and an execution platform[2]. Once the organization principle is known, software can create an *automatic layout* from the building blocks the user provides, a task which is not intuitively performed well by humans (Novick and Hurley, 2001). At the same time, there has to be an optimal balance between allowing the user to customize the layout to his specific needs and simultaneously restricting these choices referred to as the optimal *option space*. Too few choices complicate an adaptation to the specific problem at hand, too many choices may critically dilute the clarity of image created by applying formal structures.

[2] The fact that a machine may actually produce results a human being would not have been capable of (such as in "learning systems" or large-scale simulations) is merely a consequence of the human brain's limitations of possible computational operations required in combinatorial explosion problems.

Aesthetic compellingness: For completeness, this aspect needs to be mentioned in the context of producing good visualizations. Aesthetics in software fulfill no different role than in any other product. An appealing *interface* may increase a user's willingness to work with a software tool as well as the ability to turn a *model* into a visual "sculpture". In addition, it has been shown that the emotional experience which could be associated with the sensation of moving through an aesthetic visual environment may contribute significantly to improving memorability of content (Alesandrini, 1992; Richter-Levin and Akirav, 2003).

2.3 Preparing for Adoption: The Interactivity Dimensions

The role of interactivity. The dialogue between man and machine should employ the capabilities of each in a manner which allows an efficient division of tasks. Zhang and Norman (1994) use the term "distributed cognitive task" to describe the cooperative problem-solving process building on internal (human) and external (machine-based) representations. The human effort in sense-making becomes visible in iterative queries and internal model adaptation. The software supports this by supplying a number of individually configurable access points to the represented content (of which the image itself is one). The learning process is made possible through different forms of interaction allowing users to manipulate the representation of relationships in a manner which optimally adapt it to their cognitive capabilities (Healy, 1998).

In this interactive process, the software no longer serves as a pure transmission medium for the knowledge message but slips into the role of a "cognitive tool" (Derry and LaJoie, 1993; Kozma, 1994; Jonassen, 1996), which shares the burden of the cognitive task with the learner (Salomon, 1993). Due to this interaction the learning process can take place on two levels: on the one hand, by understanding the content communicated by the sender, on the other, from the experience resulting from manipulating the presented content (Salomon et al., 1991; Norman, 1983).

This reflects a constructivistic understanding of knowledge acquisition (Salomon and Globerson, 1987; Jonassen et al. 1994; Papert, 1990) where the mental model of the learner is adapted iteratively by processing the externally represented contents (Wittrock, 1974, 1989; Rumelhart and Norman, 1978, cp. also the experiential learning model by Kolb and Fry, 1975, cited in Petkoff, 1998: 207-209). This notion of knowledge acquisition also corresponds to findings in brain research according to which during learning processes different neural connections are tested in search of one that makes sense of the perceived (Leamnson, 2001).

Design principles. The most important software design criteria associated with the interaction dimension are summarized in Fig. 5.

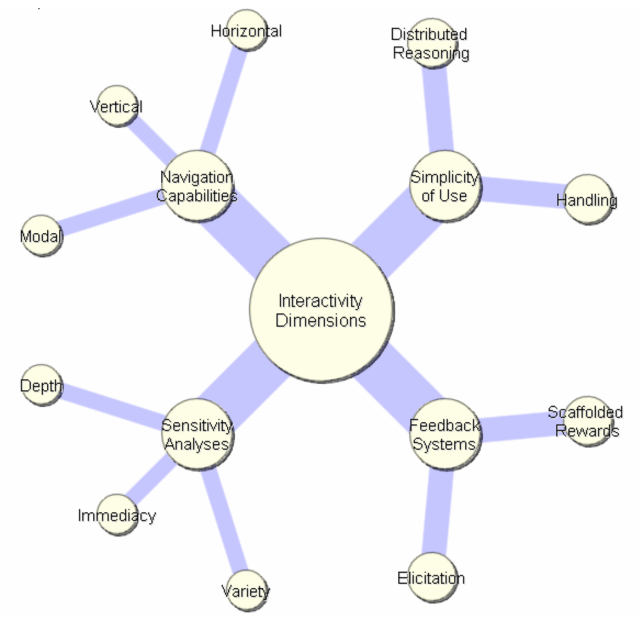

Fig. 5. Design criteria associated with the interaction dimension

Navigation capabilities: Orientation in space is supported by moving around in it. By changing the point of view it is possible to learn about a lot of different aspects embedded in a complex knowledge structure. Three different kinds of navigation possibilities may be differentiated: *Horizontal* navigation helps to understand procedures and causalities in order to trace logico-functional relationships from origin to conclusion (backward-/forward-tracking). With *vertical* navigation it is possible to switch between different levels of aggregation in order to focus attention either on a detail or a synopsis (zoom in, zoom out). *Modal* navigation helps to change perspectives thereby allowing the same representation to be interpreted using different evaluation schemes (e.g. change between causality, dynamics and controllability in a system diagram).

Sensitivity analyses: These kinds of analysis capabilities serve the understanding of model behavior by observing changes in results emerging from parameter adjustments. The iterative process of variation and observation may be a playful means of "probing" the represented content and challenging the relevance of some of the implicit assumptions. For an optimal "shrug & play" sensation it is necessary to insure a high degree of *immediacy* implying that changes are easy to make and resulting effects become visible almost instantly. The greater the *variety* of possible hypotheses which can be tested and the greater their *depth* – challenge of fundamental assumptions rather than only fine-tuning of parameters –, the greater the confidence that the represented model adequately reflects the complexity of a real-world situation.

Feedback systems: Particularly in the context where a knowledge workbench is not used as a platform for group communication but rather as a desktop application it is important that feedback systems are provided. In case of *elicitation*, i.e. the process of transferring information from a human brain to a machine, the software must slip into the role of a potential knowledge recipient (Thaller, 2002). This is best done through the use of wizards which, similar to pre-structured interviews, prompt the user with adequate cues to provide the answers to specific questions. Since this so-called specification process tends to be the most annoying part of working with software – apart from the experience of working with software that fails to function! – it is useful to provide regular machine feedback in the form of *scaffolded rewards*. This simply implies that the process of providing the inputs necessary for further processing be divided into short intervals at the end of which the current progress status and especially interim results are visualized (Preim, 1999).

Simplicity of use: Simplicity is for the hand what aesthetics are for the eye. "We have started to recognise that a tool is something that fits the hand, we should not need to bio-reengineer our hands to fit the tool" (Snowden, 1999:1). Good *handling* therefore typically refers to the adherence to certain profane rules of interface design, such as intuitive access to dialogs and results, short click sequences, organization of tool bar and menu commands etc. to which a lot of studies have been devoted (cp. Shneiderman, 1998; Preim, 1999; Raskin, 2001; Thaller, 2002). In the context of group use, a further useful characteristic is the support of distributed reasoning. This refers to the fact that a good solution tends to be the result of changing the setting from working individually, in small groups or with the entire team. Simplicity of use under these circumstances requires collaborative features such as the splitting and merging of documents and controlling the degree of access to certain parts of content.

3 Empirical Evidence – Knowledge Workbenches in Practice

The previous section described a set of guidelines for the design of an interactive knowledge workbench based on empirical evidence and a number of experiments in cognitive science. This section presents five examples of specific software applications which illustrate forms in which essential parts of the formulated design profile have already been realized in practice. This underlines a correspondence between theory and practice by providing some validation for the theory through practical realizations and an explanation for current practice through the given theoretical foundation.

3.1 Guiding access to knowledge content – categorial structures

An important process supporting the organization of knowledge is the categorization of content. The taxonomies to be applied for the segmentation of the knowledge space ideally coincide with the classification scheme to be expected from those users seeking information.

Similar to search categories known from libraries, web portals today provide the access gates to searched content. In this function they may apply several categorization methods simultaneously and independently. The example shown in Fig. 6 shows a typical web portal format which allows users to progress to searched content by selecting among different sets of key categories. While a portal provides numerous navigation capabilities between documents it is typically not designed to offer explanations for how the content was generated. With static documents, knowledge transfer tends to be successful the more operational and context-specific the provided content is. However, as was pointed out in section 2, the portal may also serve as an access point to applications which offer interaction capabilities according to the organization principles they are based on.

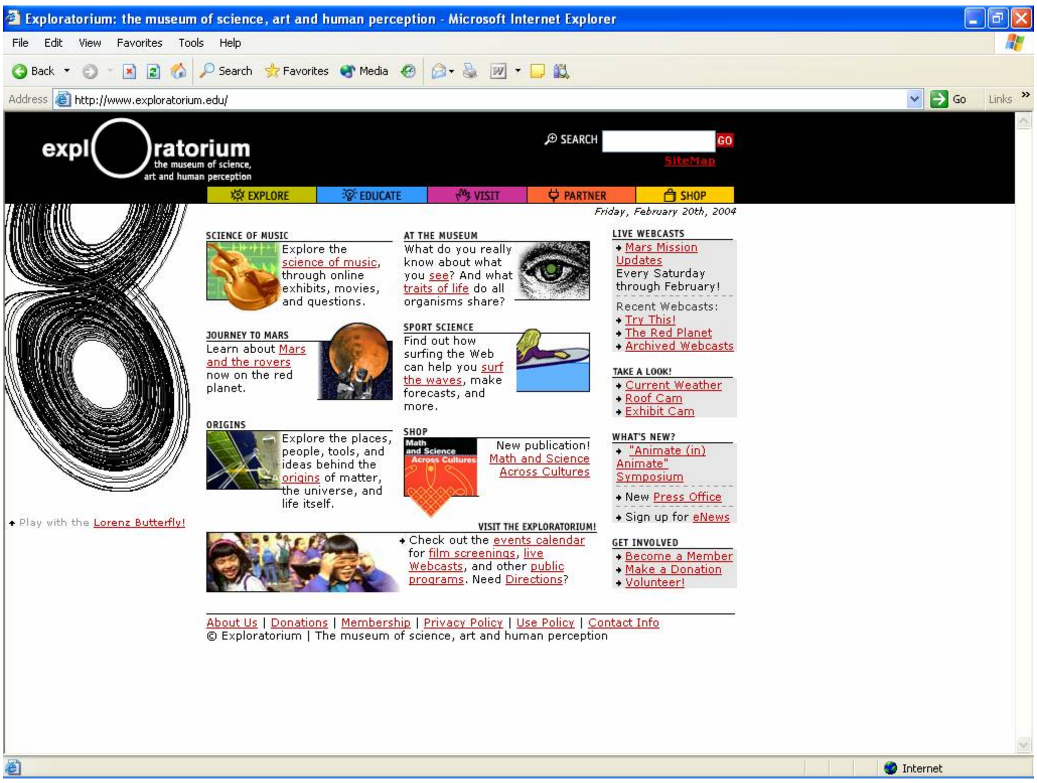

Fig. 6. Example of an internet portal (www.exploratorium.edu)

3.2 Exploration of knowledge spaces – associative structures

Frequently, the target of an information search cannot be explicitly articulated or there is an interest to find topics related to a specific term. Orientation in any space requires to develop a notion of distance and neighborhood. In associative structures, spatial equivalents can be computed in the form of so-called knowledge maps where elements with similar characteristics are shown adjacent to each other.

In order to be able to represent large amounts of data, the use of hyperbolic spaces has become increasingly popular. These are superior to euclidian geometries in that they are able to generate a "fish-eye" effect by simultaneously representing all elements in one view (context) and at the same time show significant detail in the focal area. This is done by exponentially compressing the represented spaces with increasing distance from the focal point (Walter et al. 2003).

Fig. 7 shows 21578 Reuters news clips organized in a hyperbolic plane according to their thematic similarity. The vicinity of different news items is computed using the degree of their semantic correspondence, which is derived from the multi-dimensional linguistic characteristics of the different documents (e.g. frequency distribution of words contained in the text) and projecting these into a two-dimensional plane according to the principles of self-organizing maps or using dimensionality reduction techniques.

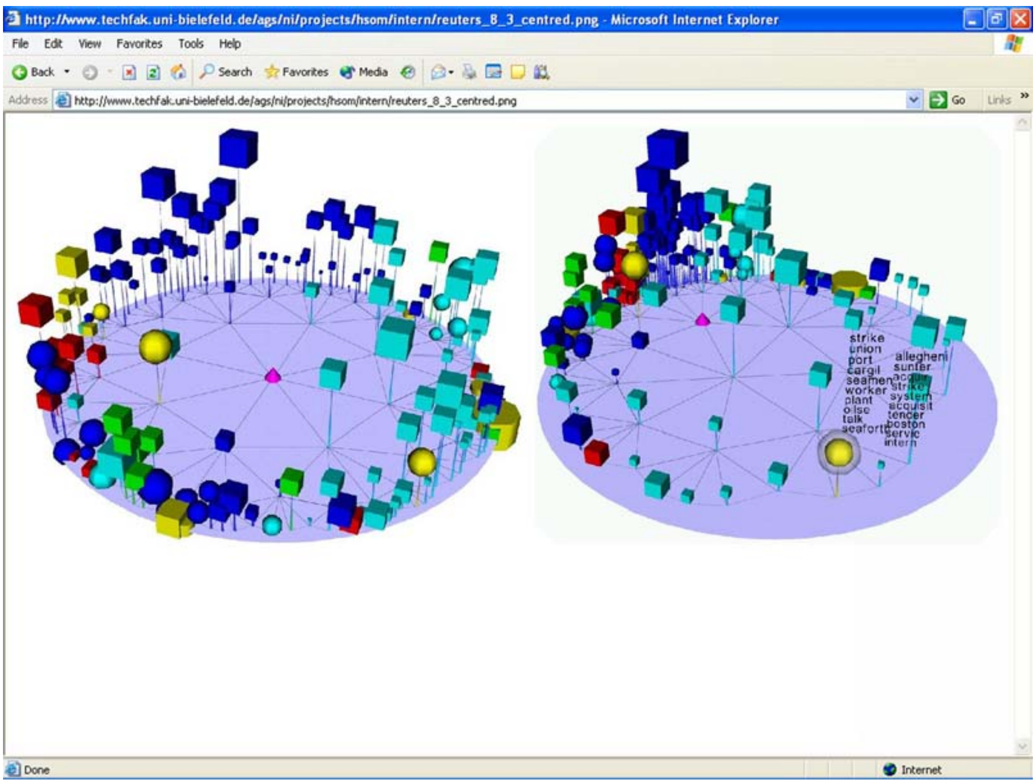

Fig. 7. Example of a knowledge map (www.techfak.uni-bielefeld.de/ags/ni/projects/hsom/intern/index.html)

For any object representing a topic cluster and located at a node of the hyperbolic grid, additional characteristics can be visualized by choosing shape, color, size or expansion into the third dimension. By moving the “attention cone” the user can navigate horizontally through the different topic areas and influence the area of detail which best corresponds to the neighborhood of his search request. By selecting a cluster, detail information on the contained topics all the way to individual documents can be viewed thereby increasingly refining the degree of resolution (vertical navigation with zoom in).

3.3 Knowledge about values as basis for evaluation – normative structures

Evaluations are the basis of decisions and require knowledge about values. The reference of objectives to the underlying values frequently isn’t performed explicitly but helps to provide a transparent justification for actions.

Different objectives stand in a mutual relationship. There may be a goal hierarchy if the fulfillment of an objective is a condition for achieving a superior one and a priority system where the relative importance of goals is rated differently. On the basis of this information it is possible to derive a weighted value structure in the shape of a hierarchical tree where the thickness of the branches represent the respective contribution of different factors in the entire value structure. Such a normative structure is depicted as a concentric tree in Fig. 8.

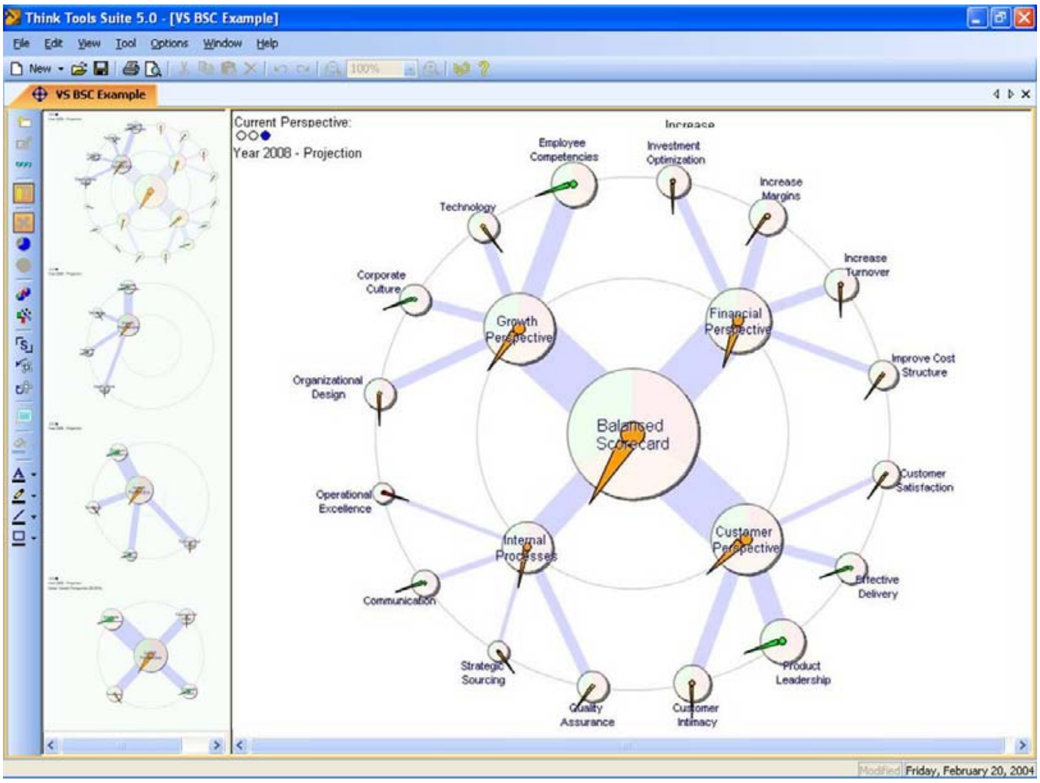

Fig. 8. Example of a value structure (www.thinktools.com/solutions/tools/vs.asp)

The overall objective (a vision, mission statement or similar) is shown as the central element and the contributing sub-objectives as different-sized nodes depending on their relative contribution. Each objective's fulfillment is represented by a needle whose angular position ranges between 0% and 100% depending on the applied evaluation norm.

The convention is applied that each super-goal delivers the rationale for the contained sub-goals while the achievement of the sub-goals determines the degree of fulfillment of the served super-goals. This allows a horizontal navigation in the represented value space. On the left hand side, the incremental transformation of the structure with vertical navigation is shown, when a detail view – here: "growth perspective" – is selected (logical zoom in).

3.4 Knowledge about consequences as basis for action – inferential structures

The examination of causal dependencies in terms of „if-then" relationships typically represents the core of analytical considerations in a problem-solving process. To handle these questions a large number of mathematical methods are available which describe the form of causal influence with different degrees of quantitative precision (cp. Dürr et al., 2004).

In Fig. 9, a Bayesian Network represented in form of an influence diagram is shown which is also called a "belief network" as it corresponds to the assessment of a network of likely effects whose probabilities may be updated through real observations. The nodes of such a network represent variables, the directed arcs (arrows) impacts between variables which describe the probability with which (discrete) states in source variables lead to (discrete) states in a target variable. These transition probabilities are typically captured in matrices which are shown in two of the embedded dialogue windows (zoom in on impact details). The local causal-probabilistic information determines the entire network since the information is accumulated to an overall effect according to the rule of Bayesian inference.

Influence diagrams can be augmented by decision nodes and translated into so-called decision trees which visualize evolutionary paths from events or decisions to outcomes. This allows for horizontal navigation between causes and effects and thereby serves to predict future states and explain given states. Furthermore, Bayesian inference makes it possible to examine the effects of (hypothetical or real) observations or decisions on outcomes (sensitivity analysis). These are represented as risk profiles showing which outcome results with which probability.

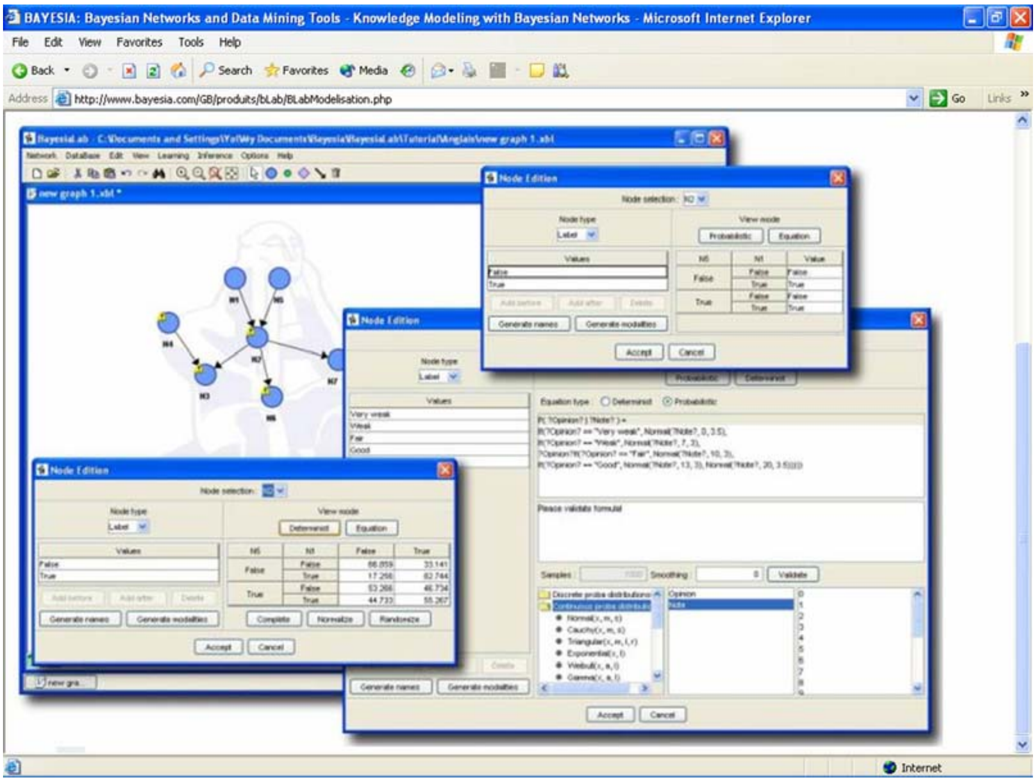

Fig. 9. Example of an influence diagram (www.bayesia.com/GB/produits/bLab/BLabModelisation.php)

3.5 Knowledge about processes as basis for planning – procedural structures

Planning and implementation link specific tasks and events into a (chrono-)logical sequence. Contrary to "if-then" relations, in procedural structures the linkages between elements essentially represent "before-after" relations although logical checks may be integrated as part of the process. Due to the linearity of time no identical states exist since the time of occurrence is an essential characteristic of an event or decision. Therefore, temporal sequences of events may always be uniquely derived from influence networks with causally linked variables but not vice versa since generally different impact scenarios may produce the same outcomes.

Process models can be applied in real-time and therefore be used for monitoring the current state (status checks). In Fig. 10, an exemplary workflow diagram for processing an order is shown. Each symbol represents the associated task and the linkage with arrows illustrates the processing sequence over time from which a processing path and status indications may be derived. By selecting a symbol it is possible to navigate vertically, invoking the subprocesses linked to the represented task which are located on a level of higher resolution. In the context of planning, the model – similar to inferential ones – can be used to play through different scenarios in order to incrementally optimize the process structure.

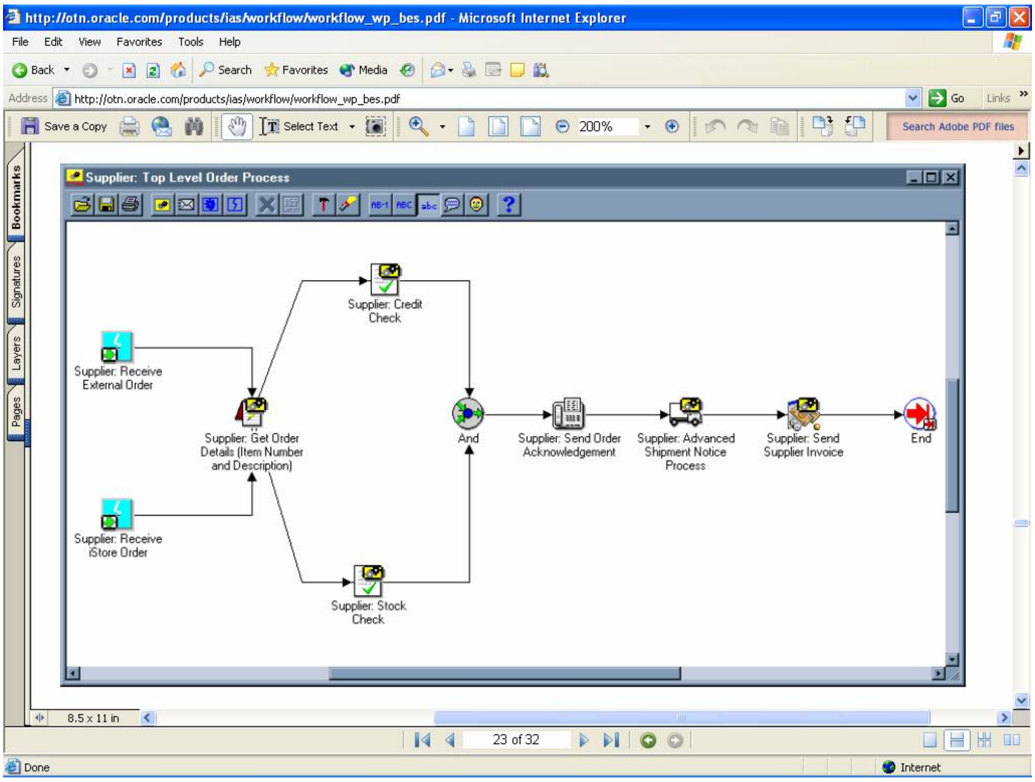

Fig. 10. Example of a business process (http://otn.oracle.com/products/ias/workflow/workflow_wp_bes.pdf)

4 Conclusions

The primary objective of knowledge communication is creating access to something that is known. In the past, access has primarily been understood in a *physical* sense, meaning that a knowledge holder or documents created by him are made available to a knowledge seeker. For this purpose, several digital platforms have been devised to facilitate the retrieval of documents (e.g. search engines) or people (e.g. electronic Yellow Pages) based on a specific query. Knowledge transfer under these circumstances tends to be successful the more operational and content-specific an issue is.

On the other hand, access in a *cognitive* sense involves more than having information at your fingertips. It implies an effort in sense-making by reconstructing the relevant building blocks in an interactive process between knowledge seeker and subject matter. This becomes particularly relevant in the context of communicating strategic or orientational knowledge in environments characterized by high uncertainty and complexity and a focus lying more on structural than contextual aspects of a problem.

In a dialogue between human beings the process of building and articulating understanding is heavily interlinked as the recipient can influence order and format of the communicated content by asking the sender questions. However, in most existing digital communication the processes of documenting and analyzing information are separated from their retrieval and presentation.

This paper has argued that if software tools evolve towards removing this machine-dictated separation, communication of content will be augmented by the facility to lay open the underlying reasoning thereby improving the generation of insights for the recipient. In order to support these interactive dialogues, the role of the machine is understood as that of a knowledge workbench for the exchange of ideas and insights.

It was shown that following a set of design rules may facilitate the transfer of knowledge and that these principles are increasingly becoming standard features in commercial software applications.

In comparison to text documents the application of software has only a short history in knowledge communication. But even centuries of being accustomed to reading documents have not removed people from their role as conveyors of knowledge. This is so because the accumulation of content and familiar representations by itself does not yet tell a story but only acts as an agent for the recipient to construct one. From this it may be concluded that the value of software for the communication of knowledge has the greatest effect if it helps to complement our thinking and conversation.

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