Usability of Diagrams for Group Knowledge Work: Toward an Analytic Description

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Abstract: Diagrams are often conceived as static representations. In this paper, by contrast, we explore how conceptual graphic representations can be used as communicative devices for knowledge-intense activities in groups. We do so by reviewing and extending existing cognitive and communicative dimensions and criteria. The aim of our research is to formalize the description of diagrams used in management discussions, analyzing their communicative and collaborative functions in order to better use them in knowledge creation and sharing in teams. We start with reviewing and merging the literature on cognitive and communicative dimensions and the literature on boundary objects, as well as information visualization, in order to compile the most relevant dimensions for knowledge creation and sharing in team. Thus, we cluster those dimensions obtaining eight macro-dimensions. We propose a formal analysis of diagrams which can be used as a tool for selecting and modifying appropriate visualizations for different knowledge-intensive activities in teams. An application example illustrates this approach.

Keywords: diagram, communicative dimensions, cognitive dimensions, visualization, knowledge visualization, knowledge work.

Categories: H.4.3, H.5.3, J.5

1 Introduction: Toward an Analytic Description of Diagrams

In recent publications, the potential of interactive, dynamic visual languages for knowledge creation and particularly sharing have been highlighted ([Maurer et al. 03], [Stubenrauch et al. 03] and [Ewenstein and Whyte 07]). Our on-going research effort that is described in this paper is part of this emerging *visual turn in knowledge management* and tries to identify the factors that make interactive visualizations effective catalysts for knowledge sharing and creation. Specifically, we aim to isolate the dimensions that increase the communication and collaboration function of diagrams in knowledge-intensive interactions. The term *dimension*, as used by Green [Green and Petre 96] and others, indicates a desired feature of an interactive diagram that supports communication and can be modified and implemented in a software application. Our research draws on three main research fields: (1) the cognitive and communicative dimensions framework literature (rooted in diagrams studies), (2) the

literature on boundary objects (rooted in management research) and (3) the information and knowledge visualization literature. The first area is based on the cognitive dimensions framework developed by Green and Blackwell [Green and Petre 96], [Blackwell et al. 01], and the communicative dimensions framework by Hundhausen [Hundhausen 04]. Our objective is to analyze, adapt, and extend those frameworks, developed originally in the context of notation and visual programming languages, to the field of team knowledge creation and sharing. The second area of research is the discourse on boundary objects [Star and Griesemer 89] as knowledge transfer and integration devices. The dimensions proposed in that stream of literature, however, have so far not been applied to interactive diagramming. A third field where we find elements for the formal description of diagrams is information and knowledge visualization, as in the works of [Shneiderman 96], [Rollett et al. 01], [Eppler 04], [Bugajska 05] and [Karabeg 06]. Based on this body of literature, we can distinguish between *basic* communicative dimensions (i.e., low level functionalities based on pre-attentive stimuli such as changing size, color, position of diagram elements) and more sophisticated, *high-level* dimensions that support sense making. In order to provide a conceptual overview and develop a theoretical basis, we focus on the latter in this paper. The scope of our research is thus to provide a framework for the analytic description of diagrams used as catalysts for knowledge processes. This formalization will help to match the usability dimensions of diagrams with communicative and collaborative requirements of various knowledge-intensive interaction types as, for example, idea creation, knowledge sharing, problem solving, assessment and deliberation. This matching process will allow us to provide a formal tool for choosing or adapting an appropriate diagram for a specific collaborative situation. In the next section, we will summarize those dimensions. In the third section we categorize them and provide a new conceptual framework. In the forth section, we apply it to an example. Finally, in the last section, we provide directions for future research.

2 Review: Diagram Dimensions

In the table below, we present a first description of dimensions derived from the literature that highlights the cognitive, communicative and collaborative functions of diagrams [Tab. 1]. We anticipate that some of these attributes are always beneficial to communication, whereas others depend on the interaction context.

Author	Dimension	Description
Star and Griesemer 89	Plastic-robust	Plastic graphic structures to be adapted to local needs; robust structures to maintain a common identity
	Weakly-strongly structured	Weakly structured in common use; may become strongly structured in individualist use
	Abstract-concrete	Abstract refers to conceptual representation; concrete refers to specific depictions
	Different meaning - common structure	Different meaning in different social worlds, but their structure is common enough to be recognizable
	General-specific	Specific for an application; general to be understandable

	Conventionalized-customized	Conventional to be recognizable; customized to be more meaningful
Green and Petre 96	Abstraction	Types and availability of abstraction mechanisms
	Hidden dependencies	Important links between entities are not visible
	Premature commitment	Constraints on the order of doing things
	Secondary notation	Extra information in means other than formal syntax
	Viscosity	Resistance to change
	Visibility	Ability to view components easily
	Closeness of mapping	Closeness of representation to domain
	Consistency	Similar semantics are expressed in similar syntactic forms
	Diffuseness	Verbosity of language
	Error-proneness	Notation invites mistakes
	Hard mental operations	High demand on cognitive resources
	Progressive evaluation	Work-to-date can be checked at any time
	Provisionality	Degree of commitment to actions or marks
	Role-expressiveness	The purpose of a component is readily inferred
Blackwell 01	Creative Ambiguity	A notation encourages the user to see something different
	Specificity	Elements have a limited number of potential meanings
	Detail in context	How elements relate to others in the same notational layer
	Indexing	Includes elements to help the user find specific parts
	Synopsie	Understanding of the whole, “stand back and look”
	Free rides	New information is generated as a result of following the notational rules
	Useful awkwardness	Awkward interfaces force the user to reflect on the task
	Unevenness	The system pushes your ideas in a certain direction
	Lability	The notation changes shape easily
	Permissiveness	The notation allows several different ways of doing
Hundhausen 04	Programming Salience	Whatever a user focuses on during the construction of a visualization tends to become the focus of discussions
	Provisionality	Extent to which the visualization resembles a final product
	Story Content	Portrays domain concepts in terms of an underlying story
	Modifiability	Degree to which the visualization can be dynamically altered in response to the dynamics of a discussion
	Controllability	Enable a presenter to dynamically respond to the audience
	Referencability	Participants can refer to elements of the visualization
Eppler 04	Focus	Draw attention on the issue
	Coordination	Step-by-step structure to organize the interaction
	Documentation	The achieved results are documented
	Consistency	Participants can make more consistent contributions when they can see what has already been shared
	Accountability	Participant’s contribution are captured and documented
	Traceability	Re-construction of the interaction and flow of ideas
Karabeg 06	Visual immediacy	The first impression; characteristic that enables the viewer to perceive and recognize “at a glance”
	Visual impetus	How attractive and inviting to action and further exploration
	Visual impedance	The hindrance; the often unintended negative implicature that causes the receiver to be less receptive

Table 1: Diagram dimension from the literature

From the table we can observe that the existing dimensions *differ* in many ways and form a heterogeneous list: they are on different levels of abstraction (such as synopsie and salience); some are binary (indexing), while others are on a spectrum (controllability); some dimensions are close to being functionalities (such as documentation), while others are more on a conceptual level (such as unevenness). Some dimensions are mainly communicative (story content), while others are cognitive (premature commitment) or collaborative (coordination). A few are always desirable (consistency), whereas some are more or less desirable (such as provisionality or hidden dependencies), depending on the task. Finally, various dimensions are strongly oriented towards electronic interaction (such as indexing) or specific contexts (such as programming salience). Given this great variety of dimensions, we attempt to reduce and structure the most relevant dimensions as explained in the next section. Then, we apply them to a real-life example in section four. This will enable us to see whether they can actually lead to improvements in the communicative and collaborative function of a diagram.

3 Reduction and classification of diagram usability dimensions

From the literature review we have obtained a long list of dimensions that differ in their level of abstraction, purpose and context, and that cannot be used for practical purposes such as designing visual knowledge management systems. We have considered classification a viable method for organizing and categorizing those dimensions, in order to be able to provide a tool for the analytic usability description of diagrams. As a first step, we have focused on high-level dimensions, eliminating the most functional dimensions, that are actually attributes and not dimensions (such as indexing, synopsie, detail in context, and most of the elements found in information visualization literature). Then, we have constructed a schema with three axes: cognitive, communicative and collaborative dimensions, on which we placed all the high-level dimensions from the analyzed literature. Based on the conceptual proximity of the dimensions emerging from the schema, we have classified them into as few groups as possible. As a rule of thumb, we have decided to consider the cognitive limit of information processing [Miller, 56] of 7 ± 2 items, in order to provide a number of clusters that is suitable for practical use. The final grouping we have obtained through this process has lead us to eight groups that we named after their overall characteristics: cooperation, interaction control, abstraction, focus, modifiability, provisionality, visibility and visual attractiveness [Fig. 1]. Each of these eight *macro-dimensions* contains a number of the original dimensions found in the literature that contribute to their definition. We consider the here presented framework provisional, as we anticipate that some dimension could still be discovered, which then need to be defined, tested, and consolidated. The process through which we plan to reach this goal is explained in the last section of the paper. We now consider an example of application of the proposed framework.

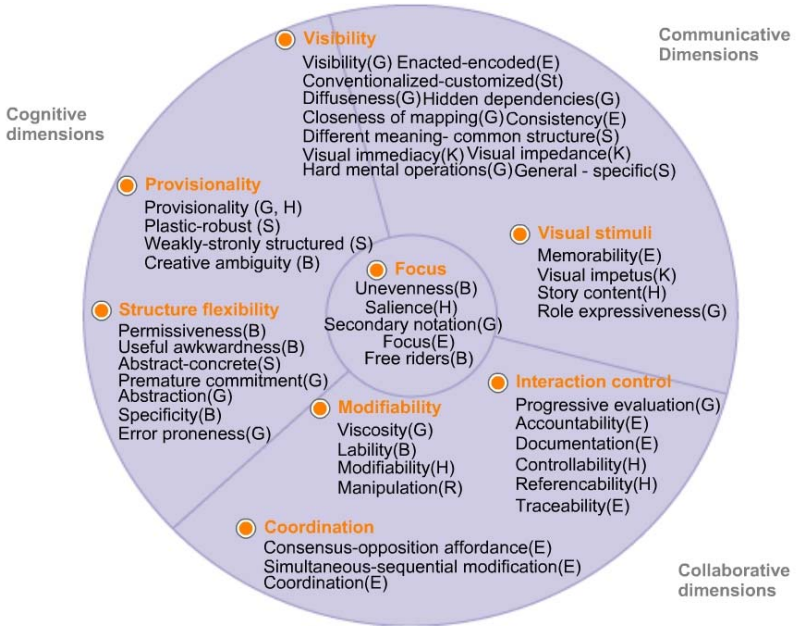

Figure 1: Classification of usability dimensions of diagrams

4 Exemplary application of the analytical usability analysis

To clarify the relevance of the previously described dimensions of diagrams, we provide an example of a formal diagram usability analysis. We consider the Gartner Hype Cycle diagram [Fig. 2] and we describe it analytically through our proposed framework in [Fig. 4]. The rating is on a five-point scale, ranging for very low (centre) to very high (external) values of the dimensions. Then, we modify the dimension values and provide a modified version with the explanation of the modifications that we have created [Fig. 3].

A Hype Cycle is a graphic representation of the maturity, adoption and business application of specific technologies. Since 1995, Gartner has used Hype Cycles to characterize the over-enthusiasm or "hype" and subsequent disappointment that typically happens with the introduction of new technologies [Gartner 07]. The diagram is used in organizations for assessment activities, as for example when making a strategic decision on a new investment in a specific technology. It supports convergent thinking, as opposed to other kinds of diagrams, such as mind maps, where divergent thinking is the goal. In its traditional format, the Hype Cycle is not a highly collaborative diagram, as the low scores on modifiability, coordination and interaction control show (and our select interviews with CIOs who use them confirmed). In our example [Fig. 3] we provide an alternative and more collaborative version of the same diagram, based on the proposed usability dimensions framework, and implemented with a software package [lets-focus 07].

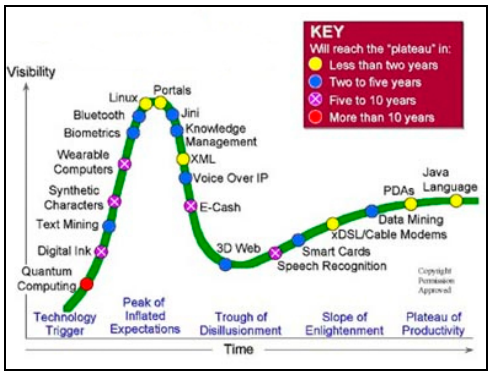

Figure 2: Gartner Hype Cycle

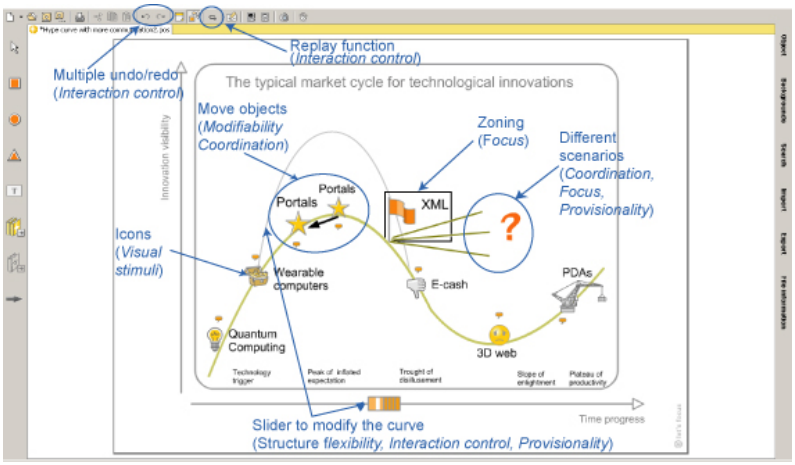

Figure 3: Gartner Hype Cycle diagram modified with desired dimensions

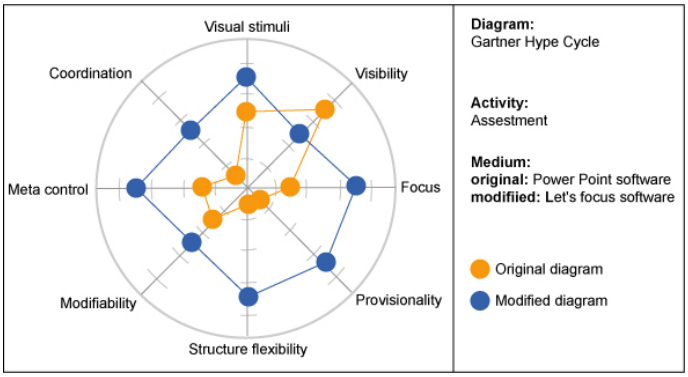

Figure 4: Original and modified Gartner Hype Cycle dimensions' rating

In detail, we have increased *visual stimuli* by providing specific icons that attract attention and are more memorable than the generic symbols used in the original version. *Visibility* - that is the ease with which the diagram is perceived at a glance- is decreased because much more items and options are present in the figure, and thus make it more complete, but also more complex to understand. Zoning, through the black square, indicates that the current debate is on XML technologies (*focus*). *Provisionality* is higher because the diagram is perceived less as a finished polished product. Higher *modifiability* is achieved through the use of a slider to modify the slope of the curve and by the possibility to move the objects in the diagram. To provide higher *structure flexibility*, the slope of the curve can be changed and different scenarios are provided. *Interaction control* is increased by allowing multiple undo/redo and the replay function, while *coordination* is supported by the multiple scenarios. From this pilot application, we have seen that simple changes in the diagram application can have significant effects on their communicative and collaborative functions and that these can be captured in the dimensions that we have proposed.

5 Outlook and conclusion

Further research is needed to refine the classification and definitions of the dimensions, to consolidate the proposed usability framework, and to match the dimensions with knowledge work types in specific organizational, collaborative settings. Appropriate and complementary research methods addressing those research purposes seem to be context-rich, but inaccurate case study analysis [Yin (03)] and context-free, but accurate in-class or natural experiments [Keppel and Wickens (04)]. Our research process started with a literature review, considering existing communicative dimensions and proposing additional ones. Then we have categorized them providing eight macro-dimensions. We now propose to conduct corporate case studies so that the dimensions can be analyzed in the context in which they become valuable. In addition, an experiment could be conducted to test and compare different communicative dimensions of diagrams and their impact on group performance. For instance a situation of knowledge asymmetry could be created in which one activity type is chosen and only one communicative dimension is manipulated or modified among groups. Post-test surveys would be given to participants to investigate their satisfaction (see [Mengis and Eppler 06] for a similar experiment). Alternatively, a focus group session could be conducted during which experienced designers discuss the role of different communicative dimensions. We also intend to investigate the tradeoffs between dimensions, to better understand the consequences of a possible design change, as described by [Green and Petre 96]. Theoretically, the contribution aims to enlarge the scope of the cognitive and communicative frameworks and adapt them to a collaborative organizational context as well as bridging the two fields of diagram research and knowledge boundary object literature. The results of this research are expected to contribute to the understanding of the function of diagrams in a managerial context as a tool for joint knowledge creation and sharing. For this purpose we need to further consolidate the dimensions, try them out on real-life applications, and improve their wording for general comprehensibility.

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