Journal of Universal Knowledge Management, vol. 1, no. 3 (2006), 151-162
submitted: 5/10/06, accepted: 15/11/06, appeared: 28/12/06 © J.UKM

Seeing versus Arguing
The Moderating Role of Collaborative Visualization in Team Knowledge Integration

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Abstract: This paper sheds light on the communicative process through which experts and decision makers integrate their domain specific knowledge in decision making situations and argues for the benefit of knowledge visualization. We present a second order model for knowledge integration that reflects the main communicative challenges of such interactions. These are: unequal participation, a lack of common ground, a lack of big picture, and an unconstructive handling of conflict. Presenting results from an experimental study, we show that supporting conversations with an interactive visualization tool moderates the relationships of these communicative challenges and knowledge integration. We find that in the supported condition, conversers rely more on the establishment of common ground and big picture and deal more constructively with conflict.

Key Words: knowledge integration, knowledge visualization, co-located conversations, collaborative visual tools, knowledge communication, decision making
Category: H.1.0, H.4.3, H.5.3

1 Introduction –Knowledge Integration between Experts and Decision Makers

Amidst the increasing complexity of markets, technologies, or consumer demands, ever more distributed expertise needs to be integrated for effective decision making. Consequently, the *integration of knowledge* becomes an important function for organizations [Grant 1996: 377]. Knowledge integration is the synthesis of individuals' specialized knowledge into situation-specific, systemic knowledge [Alavi and Tiwana 2002]. The aim of knowledge integration is not to minimize the knowledge gap between individuals, groups, or organizations, but to foster specialization while combining specialized knowledge in joint actions and decisions [Eisenhardt and Santos 2000]. Especially in complex, uncertain, and high-risk decision processes, managers need to draw on the specific knowledge of domain experts. Yet, the use of expertise is bound to cognitive, interactional, social, and political challenges that intervene in the decision making process [Eisenhardt and Zbaracki 1992]. In this paper, we focus on the interactional, i.e. communicative challenges of knowledge integration. By doing so, we aim to advance a *communication perspective on knowledge management* issues [see also: Mengis and

Eppler 2005]. This perspective is based on the idea that we create, share, and integrate knowledge in social interactions [Nonaka and Takeuchi 1995] and that communication is therefore constitutive to knowledge processes. In the context of the expert-decision maker interaction, *co-located conversations* are the main communicative form through which knowledge is integrated. Conversations allow for high interactivity (participants can pose clarifying questions and ask for the larger context of a specific piece of information). The language and complexity of discourse can be finely aligned to the characteristics of the interlocutors [Krauss and Fussell 1991] and the para- and non-verbal cues facilitate the development of a common ground [Olson and Olson 2000], a prerequisite for mutual understanding.

On the other hand, conversations are ephemeral [Bregman and Haythornthwaite 2001] so that the major reasons and motivations behind the decisions taken are often poorly documented. They are bound to the linear flow of time, which limits comparisons of multiple variables and complex issues. Finally, conversations are often characterized by conversational patterns such as defensive arguing [Argyris 1996], unequal turn-talking [Ellinor and Gerard 1998], or dichotomous arguing [Tannen 1999].

In order to better utilize the potential of conversations for knowledge integration and to overcome the drawbacks and challenges that are bound to this communicational form, conversations can be supported by interactive visualization tools [Eppler 2005]. In this paper, we will hence discuss the role of collaborative visualization for knowledge integration by presenting an experimentally tested model.

2 A Communicative Model for Knowledge Integration

So far, we have argued that knowledge integration can be viewed as a communication process, especially with regard to managerial decision making. Consequently, the way that the members of a group deal with communicative challenges, as the ones described above, affects whether or not knowledge is successfully integrated in a group. On the basis of the literature, Figure 1 presents a reflective model for knowledge integration from a communication perspective. It highlights four major communicative challenges that affect the process of knowledge integration. Below, we describe these four constructs, first in overview, then in more detail.

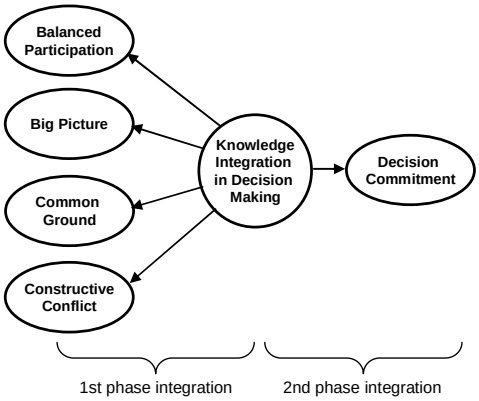

Figure 1: A Reflective Model for Knowledge Integration in Decision Making

We assume that if domain experts and decision makers manage to deal with four central communicative challenges – which are balanced participation, gaining and maintaining the big picture or overall decision context, establishing a common ground, and constructively dealing with conflict – then they can be successful in integrating their specialized, individual knowledge into synthetic common group knowledge structures, which as a consequence leads to a stronger decision commitment.

Equal Participation – Groups often fail to maximize the contribution of all members [Stasser 1992]; the reason being that interlocutors feel inhibited to expose their own ideas to management because of a fear of criticism [Dixon 1997] and due to the autocratic style of leaders which does not incite for the contribution of others [Eisenhardt, et al. 2000]. Equal participation is therefore a reflection of whether various perspectives on an issue are equally considered and knowledge integration is taking place (H1).

Big Picture – Gaining and maintaining the big picture is a particularly difficult challenge of an expert-decision maker interaction and an important indicator of knowledge integration. The big-picture challenge is related to the capacity to see and draw *interconnections* [Harkins 1999, Senge 1990] and to find an adequate *level of detail/abstraction* [Rhodes 1991]. Experts and decision makers have to understand how a specific technical aspect refers to the more general discourse of the issue and how one perspective (i.e. the engineer's view) relates to the other (i.e. the manager's view) in order to gain a more systemic view of otherwise isolated elements [Sull, et al. 2005] (H2).

Common Ground – Alavi and Tiwana argued that mutual knowledge or common ground, understood as the knowledge that is shared among people and that is known to be shared, represents one of the key challenges of knowledge integration [Alavi and Tiwana 2002]. Common ground includes the communicator's background knowledge, their goals, values, but also their social and physical context and more personal attributes as speech style or emotional state [Krauss and Fussell 1991]. In the expert-decision maker situation, sources of common ground are mostly sparse since

they do not belong to the same professional community and have little knowledge on the peculiarities of the other group (H3).

Constructive Conflict – A certain amount of content conflict is important in conversations so that people scrutinize task issues and engage in a deliberate processing of the available information [Eisenhardt, et al. 2000]. Yet, when content conflict is understood on a relational level [Argyris and Schön 1978], or when it is too dramatic, conflict can be detrimental for knowledge integration [De Dreu and Weingart 2003]. Thus, three conflict conditions have to be present in order to allow for knowledge integration: 1. a moderate level of content conflict; 2. a low level of relationship conflict; 3. a low correlation between content conflict and relationship conflict (H4).

These four constructs reflect to which degree knowledge integration, in terms of the incorporation of specialized individual knowledge into group knowledge structures [Alavi and Tiwana 2002], can take place in a group. Yet, knowledge integration is a two step process [Mengis and Eppler 2005] and involves, in a second phase, the integration of group knowledge into joint decisions and ultimately concerted actions [Grant 1996]. The construct of decision commitment reflects this second level of integration (H5). This construct as well as the four others have been measured in an experimental setting that is outlined below.

3 The Moderating Effect of Knowledge Visualization

Conversers who aim to integrate domain-specific knowledge on a group level do not have to limit themselves to verbal and body language. Especially if the topic is highly complex and uncertain, visualization becomes a fundamental tool supporting conversations. Conversers sketch on flipcharts and whiteboards, distribute handouts, use images, figures, and physical objects to illustrate their points of view. Software-based collaborative visualizations tools represent another way how conversers can support their argumentation. Such tools aim, for example, at visualizing and better structuring the conversers' use of concepts and casual arguments [Conklin 2006], at visualizing the human voice [Levin and Lieberman 2004], or at making peripheral social cues tangible [DiMicco, et al. 2004]. In the experiment reported here we have used the *let's focus positioner* [Eppler 2005] visualization tool. The tool works with compound visual metaphors and thus provides a well-known vehicle that can be drawn on when talking about a complex topic. Conversers can use such images as a frame for reasoning about an issue and they can position information within this image and draw interrelationships. Figure 3 shows such a rich visual metaphor that encloses several sub-metaphors (such as the iceberg, the lighthouse, the sail, etc.).

Figure 2: Group Conversing with the Use of a Collaborative Visual Tool

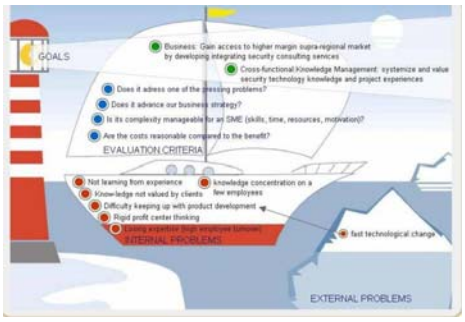

Figure 3: Constructing Rich Visual Metaphors in Conversations

In view of the proposed model for knowledge integration, the following considerations can be made for the use of collaborative visualization tools.

Visualization can be employed not only to visualize the content of a conversation, but also to communicate social cues as for example the amount of contributions of each converser [DiMicco, et al. 2004, Sack 2000]. Especially in computer mediated conversations, where conversers lack social information (i.e. body language, intonation), the visualization of social information can facilitate sense-making [Smith and Fiore 2001]. DiMicco, Pandolfo, and Bender [2004] found that in a collocated setting, providing visual cues on the amount of contributions of each converser made much-talkers limit their amount of contributions and *equilibrated participation*.

Visuals that are developed within the course of a conversation help participants to keep in mind the current state of the conversation and can be used a *mnemonic device* of what has been discussed earlier on and what are open issues in the conversation [Kraut, et al. 2003]. Dynamic visuals serve as artefacts and real time persistent reference points around which conversers can coordinate their contributions, both in terms of time and content. They are constantly reminded of the *big picture* to which they contribute with their single statements.

Several studies have argued for the importance of shared visual spaces in creating common ground among interaction partners [Kraut, et al. 2003, Olson and Olson 2000]. Interactive visuals facilitate the establishment of *common ground* since they provide communicators with an additional, often metaphoric language [Kraut, et al. 2003] and shared reference points. Since these visuals are dynamic and can be changed throughout the conversation process, the refinement and correction processes (that are important for grounding activities)[Clark 1996] can be achieved not only through verbal communication, but are also supported through the developing visual.

Finally, Cecez-Kecmanovic and Dalmaris [2000] found that when people can see the representation of a collective understanding or opinion, they can recognize the possible discrepancies with their own understanding. Such differences in opinion and inconsistencies in understanding are more easily detectable if visually depicted. Participants can critically review the various elements and the relationships among them and instead of an uncritical acknowledgement of facts, the visual leads to a certain amount of content conflict. Yet, the handling of this conflict tends to be

collaborative since the visual implies that all contributions are potentially part of the same image. Finally, the visualization of the idea gives it a physical existence and becomes, to some extent, dissociated from the person. In consequence, criticizing the idea is probably not misunderstood as personal attack.

In view of these arguments and findings, we stipulate that the use of a collaborative visualization tool has a moderating effect on the proposed model for knowledge integration on a structural level (but not on a level of the means). In particular, we argue that the four dimensions we have presented for knowledge integration (Figure 1) remain important if conversers are supported by a visualization tool; but they integrate their knowledge mainly by gaining and maintaining a big picture and through the establishment of a common ground and less so through equal participation and conflict. Second, conversers that are supported by a collaborative visualization tool manage to constructively deal with conflict (see: Figure 4, Hm= Moderation Hypothesis). The next section examines these claims empirically.

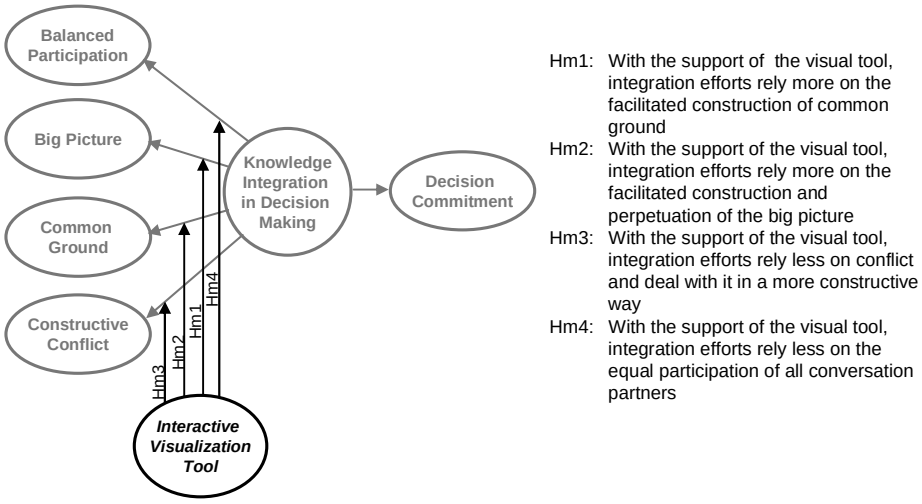

Figure 4: Moderation Effect of the Use of Interactive Visual Tools (Hm1, Hm2, Hm3, Hm4)

4 A First Empirical Test of the Model and the Visualisation's Moderating Effect

4.1 Experimental Design

In a *classroom experiment*, we conducted a first preliminary test of the proposed model. In order to test the moderating effect of the use of the content-specific [Weinberger and Mandl 2003], interactive visualization software, we operated with a two group design (tool and non-tool groups). In total, 64 people participated in the experiment, that is 32 respondents for both the tool and non tool condition, and a total of 16 groups. The unit of analysis was set at the individual level.

4.2 Task and Setting

The *task* was based on a hidden profile [Stasser 1992] scenario. Prior to the experiment, students received a case study on a small-medium enterprise (SME) and its knowledge management projects. In a one-hour discussion (see: Figure 2), students had to decide which three of the five project proposal they would choose for implementation. Half of the students (in their role as experts) received a case version that provided mainly information on the projects, whereas the other half (the decision maker role) obtained mainly strategic, corporate information. Groups were formed of two 'experts' and two 'decision makers'.

We have used the *let's focus Positioner*, which is part of the software package *let's focus (see Figure 2 and 3)*. The application is intended to support groups to share information, analyze complex issues and to structure various types of information. The tool provides a large library of interactive diagrams and metaphors and includes functionalities of clustering, annotation, replay, levelling, and overlaying, all of them using simple drag and drop interaction which allow users to visualize their thinking and communication processes in a seamless manner [Eppler 2005].

4.3 Method of Analysis

The model we have presented for knowledge integration is an indirect reflective, second order model with multiple mediating constructs [Edwards and Bagozzi 2000]. Information on the operationalization of the variables can be found in the Appendix and, in more detail, in Mengis [2006]. One remark on the constructive conflict variable seems necessary: Since we wanted to avoid building a third order model (with knowledge integration that is reflected, among others, by constructive conflict that, on its part, is reflected by content and relationship conflict), we decided not to include constructive conflict as a latent construct, but directly introduce content conflict and relationship conflict. For reasons of feasibility, the correlation between the content and relationship conflict (which represents the third precondition for a constructive handling of conflict) has been calculated with traditional correlation analysis and not within AMOS. The hypotheses we have put forward are of a structural nature and cannot be examined through a mean comparison. In view of this situation, but considering our small sample size (64 respondents), we have done a traditional confirmatory factor analysis for the first order latent constructs, and we have then introduced these constructs as observed variables in the AMOS program for structural equation analysis[MacCallum, et al. 1996]. Then, we have conducted a group comparison of the whole model. Even if approaching the analysis in this way, the problem of minimal sample size [Gefen 2000, Jackson 2003] is nevertheless not fully resolved so that this analysis can only be understood as a first inconclusive analysis that helps us to refine the model and our hypotheses for then conducting a study that allows for an analysis with more statistical power.

4.4 Results and Discussion

Results of the confirmatory factor analysis as well as of the descriptive statistics of the first order latent variables can be seen in the Appendix [for detailed results, see Appendix and: Mengis 2006]. For reasons of space limitations, we directly present the results of the structural analysis.

First, we can confirm the here proposed model for knowledge integration. We have a chi-square of 16.176 and a degree of freedom of 16 (which results even a slight overfit of the model). Considering the small sample size we have, most important are the information theoretical measures, for which we have satisfactory results. AIC (68.18) is lower for the default model than for the saturated model. With regard to the descriptive measures, the GFI (0.92) is higher than 0.9, but not the AGFI (0.80). Pclose is 0.60 and passes the usually required threshold of 0.5, as does the rmsea of 0.01, which needs to be below 0.05. In view of these satisfactory values for the various model of fit measures, we can be rather confident regarding the validity of our model for knowledge integration, yet fully acknowledging the huge limitations in power due to the very limited sample size.

Second, we have found that the visualization software has a *significant moderating effect on our model for knowledge integration* (with a p of 0.010). We have various structural differences, i.e. significant differences in terms of loadings and explained variances. As we have claimed in section 3, we can confirm that, in the *tool condition, the common ground (CG) and the big picture (BP) constructs have more weight* for the integration of knowledge than in the non-tool condition (Figures 5 and 6) *(Hm1 and Hm2 supported)*.

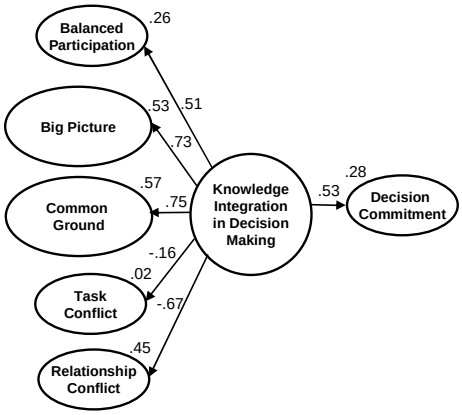

Figure 5: Knowledge Integration in the Tool Condition

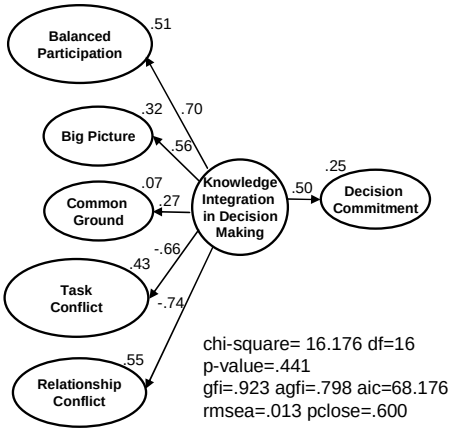

Figure 6: Knowledge Integration in the Non-Tool-Condition

On the other hand, the *conflict constructs are more important in the non-tool condition* and conflict is – following our definition (1. moderate content conflict (CC), 2. low relationship conflict (RC), 3. low correlation between CC and RC) - handled in a *less constructive manner*. In fact, in the unsupported condition, content conflict loads negatively on knowledge integration and explains 47% of its variance. On the other hand, for the groups working with the tool, it is of no importance at all. Relationship conflict is detrimental in both situations, but explains slightly less of the variance of knowledge integration in the tool situation. Finally, for groups working without the visualization tool support, content *conflict strongly correlates with*

relationship conflict, which is not at all true for the non-tool condition (0.50** for non-tool vs. 0.05 for tool). All these three findings, give us support that the tool helps conversers to deal constructively with conflict (Hm3 supported). Finally, while in the non-tool situation, conversers rely more on equal participation for the integration of their knowledge; in the tool-condition, 'equal participation' is less important (see Figures 4 and 5) (Hm4 supported).

Interpreting these findings, we can say that conversers who interact without an interactive visual support, struggle more to integrate their knowledge: *They lack common ground and the big picture in the conversation and therefore give more importance to equal participation and conflict*. In addition, we have seen that, in the unsupported condition, *they do not manage to deal constructively with conflict.* Supporting conversations with an interactive, real-time visualization tools helps conversers to integrate their knowledge in that they collaboratively create and maintain the big picture and establish a common ground among them – without taking content criticism personally.

5 Conclusion

In this paper, we have taken a conversation perspective on the topic of team knowledge integration. Hence, we have proposed a reflective model of knowledge integration that highlights key communication success factors. We have shown that conversers (in particular experts and decision makers) who 1. participate equally at the process of conversation, and who 2. manage to gain an maintain the big picture, and 3. who establish a sufficient common ground among them, and finally 4. who deal constructively with conflict, can be successful in integrating knowledge in their team decision making. On this basis, we have argued that collaborative visualization tools can positively affect the relationship between these four factors and knowledge integration. Through experimental evidence we have shown that conversers using the tool rely more on the creation of common ground and the big picture when integrating knowledge. Without the visual aid, conversers tend to give more importance to equal participation and have difficulties in dealing with conflict in a constructive way. Future research should examine whether this moderating effect can be replicated in different settings and for different decision making tasks. Additionally, situated or longitudinal studies could be employed to analyse the long term structuring effects of the enactment of such visualization tools in teams.

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Appendix

Factor Loadings, Percentages of Variance Explained, Cronbach Alphas, Mean Values, and Standard Deviations of First Order Latent Variables

Factor	Item	Factors Loading	% of variance explained	Cronbach α	Mean (S.D.)
Equal Participation (EP)	1.The other members of my group paid attention to the comments I made	.586	0.59	0.65	1.04 (0.85)
	2.There were not one or two people who dominated the discussion	.874			
	3.There was an adequate participation from all members of the group.	.814			
Big Picture (BP)	1.The conversation process was very clear	.806	0.48	0.78	1.23 (0.57)
	2.We never lost time on discussing irrelevant issues	.724			
	3.We never lost time on too detailed discussions	.602			
	4.I always knew how a specific contribution related to the more general topic of the discussion.	.603			
	5.At every point in time I knew why the group was discussing a specific issue.	.774			
	6.I knew at every point in time where we where in the discussion	.632			
Common Ground (CG)	1.During the discussion the group created a shared and deep understanding of the topic.	.879	0.77	0.70	0.95 (0.56)
	2.During the conversation, the group developed and shared a common language to deal with the task	.879			
Content Conflict (CC)	1.How many disagreements regarding different ideas were there during the one hour discussion?	.838	0.65	0.73	2.60 (0.56)
	2.How many differences about the content of decisions did the group have to work through?	.749			
	3.How many differences of opinion were there within the group?	.837			
Relationship Conflict (RC)	1.How much anger was there among the members of the group?	.854	0.78	0.847	3.60 (0.65)
	2.How much tension was there in the group during the exercise?	.898			
	3.How much personal friction was there in the group during decisions?	.901			
Decision Commitment (DC)	1.I feel confident that our group made the right decisions	.808	0.65	0.44	0.92 (0.63)