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Fostering shared knowledge with graphical representation in different collaboration scenarios

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Abstract

This study investigated how two types of graphical representation tools influence the way in which learners use shared and unshared knowledge resources in two different collaboration scenarios, and how learners represent and transfer shared knowledge under these different conditions. Moreover, the relation between the use of knowledge resources, representation, and the transfer of shared knowledge was analyzed. The type of graphical representation (content-specific vs. content-unspecific) and the collaboration scenario (video conferencing vs. face-to-face) were varied. 64 university students participated. Results show that the learning partners converged in their profiles of resource use. With the content-specific graphical representation, learners used more appropriate knowledge resources. Learners in the computer-mediated scenarios showed a greater bandwidth in their profiles of resource use. A relation between discourse and outcomes could be shown for the transfer but not for the knowledge representation aspect.

Keywords: cooperative learning, collaborative learning, graphical representation, shared knowledge, shared active representation, video conferencing, visualization

Zusammenfassung

In dieser Studie werden die Wirkungen von verschiedenen Arten graphischer Repräsentation auf die Nutzung geteilter und ungeteilter Wissensressourcen in zwei verschiedenen Kooperationsszenarien untersucht. Des Weiteren wird analysiert, wie Lernende geteiltes und ungeteiltes Wissen unter diesen verschiedenen Bedingungen repräsentieren und transferieren. Schließlich wird die Beziehung zwischen der Nutzung von Wissensressourcen auf der einen Seite sowie der Repräsentation und dem Transfer geteilten Wissens auf der anderen Seite geprüft. Mit der Art der graphischen Repräsentation (inhaltsspezifisch vs. inhaltsunspezifisch) und dem Kooperationsszenario (Videokonferenz vs. face-to-face) werden zwei Faktoren experimentell variiert. 64 Studierende nahmen an der Studie teil. Ergebnisse zeigen, dass die Lernpartner in ihren Profilen der Ressourcennutzung konvergierten. Lernende, die durch die inhaltsspezifische graphische Repräsentation unterstützt wurden, verwendeten angemessenere Wissensressourcen. Lernende in den computervermittelten Szenarien weisen eine größere Bandbreite in ihren Profilen der Ressourcennutzung auf. Eine direkte Wirkung vom Diskurs der Lernenden auf die Entwicklung geteilten Wissens konnte für den Transfer, aber nicht für die Wissensrepräsentation gezeigt werden.

Schlüsselwörter: Kooperatives Lernen, gemeinsame aktive Repräsentation, geteiltes Wissen, graphische Repräsentation, Videokonferenz, Visualisierung

FOSTERING SHARED KNOWLEDGE WITH ACTIVE GRAPHICAL REPRESENTATION IN DIFFERENT COLLABORATION SCENARIOS

Background and goals of the study

The psychology of knowledge acquisition has been investigating first and foremost processes of knowledge acquisition and knowledge representation with respect to the single individual. Even when analyzing cooperative learning processes, the focus of attention was how individuals represent their knowledge, how they solve problems, etc. What the learning partners of these individuals do exactly, how they represent their knowledge and solve problems, has played a subordinate role up to this point (Jeong & Chi, 1999). We see three lines of development, which are shifting the focus away from the single individual: Firstly, the idea to conceptualize groups as information processors developed in the field of social psychology (e.g. Hinsz, Tindale, & Vollrath, 1997; Resnick, 1991). Secondly, the discussion on situated cognition (e.g. Salomon, 1993) in the field of cognitive and educational psychology which has shed light on the important role of the social and physical context for cognitive processes. Thirdly, technological developments, especially new technologies for computer-mediated communication that enable new forms of cooperative learning. On this basis we suggest to expand the analysis of traditional and new cooperation scenarios by two important aspects: (1) the use of shared and unshared knowledge resources and (2) the representation and transfer of shared knowledge.

(1) If two or more learning partners cooperate, they use *shared and unshared knowledge resources*. An important question is how two or more group members use the knowledge available to them (e.g., from their prior knowledge, from learning material) to collaboratively construct new knowledge in discourse. From studies in collaborative decision making and problem solving we know that groups often show a tendency to neglect unshared resources, i.e. knowledge and information that only one person or a small proportion of the group members has access to (e.g. Buder, Hesse, & Schwan, 1998; Stasser & Stewart, 1992). Instead, the group members discuss the knowledge resources and information which they are all aware of. So far, few empirical studies investigated the role of this biased information sampling phenomenon *in the context of learning.*

An important issue in the literature on cooperative learning is how learners influence the learning outcomes of their learning partners (e.g. Tudge, 1989). Recent approaches from social psychology emphasize the interdependence of cognitive responses within dyads or groups (e.g. Nye & Brower, 1996). Interdependence means that "each individual’s cognitive responses are influenced by the interaction in which he or she is a participant" (Ickes & Gonzalez, 1996, p. 297). As the most basic aspect of this interdependence, *convergence* (or divergence) of the cognitive responses could be determined. Convergence means that the reciprocal influence of the collaborators leads to increasing similarity of the cognitive responses within the group (Ickes & Gonzales, 1996). With regard to grounding approaches (Clark, 1992) it is plausible to assume that learning partners also have mutual impact on the *processes* of resource use. Presupposing that a range of different resources is available (prior knowledge, new conceptual knowledge, contextual information etc.), we assume that dyads or groups develop a specific profile of resource use in a given context, i.e. they *converge* with respect to their resource use. Beside this content-oriented resource aspect, a meta-communication component might be relevant for learning. The explicit coordination of the learning partners on how to proceed with the task, and which resources are to be included how and when, is often seen as a crucial promoter for learning (Rogoff, 1991).

(2) *Representation and transfer of shared knowledge.* If group members learn together, they can construct shared cognitive representations. Here, it can be of interest to what extent the learning partners construct similar conceptual mental models. A number of studies shows that team members converge in a similar conceptual model during collaboration (Klimoski & Mohammed, 1994). Such a dynamically developing shared knowledge base can increase team efficiency in work settings (e.g. Cannon-Bowers & Salas, 1998; Orr, 1990). At least some degree of shared knowledge seems to be necessary for teams to work effectively. Although different types of teams might require different degrees of shared knowledge to function appropriately, the extremes (all knowledge in common vs. no shared knowledge at all) can be detrimental (see Klimoski & Mohammed, 1994). Recently, more team-oriented approaches to learning, like the "learning communities"-approach (Bielaczyc & Collins, 1999; Scardamalia & Bereiter, 1996) explicitly emphasize shared knowledge. Members of intentional learning communities search, collect, and share resources which could be of relevance for the topic of interest. Some degree of shared knowledge can improve collaborative learning in small groups as well as classroom discussions (e.g. Nicolopoulou & Cole, 1993). However, the pioneering study of Jeong and Chi (1999) showed that only a relatively small portion of the knowledge, which a dyad constructed during collaboration, is actually represented by both of the learners.

It is not guaranteed that shared representation will lead to similar knowledge application (Renkl, Mandl, & Gruber, 1996). Therefore, we also consider *the transfer of shared knowledge* to be an important aspect. One main question is to what extent former learning partners are similarly able to apply the knowledge in new contexts.

A further important question is how the use of shared and unshared knowledge is related to shared knowledge representation and transfer.

Computer-mediated, cooperative learning. So far, cooperation scenarios with internet-based communication technologies have hardly been investigated systematically with respect to the aspects of shared knowledge. Sassenberg, Boos, Laabs, and Wahring (1998) showed the phenomenon of biased information sampling (the tendency to neglect unshared knowledge resources in group decision making, see above) for synchronous text-based cooperation. However, in that study the effect was of comparable size in the computer-mediated scenario and in a face-to-face setting. Concerning the use of knowledge resources and the construction of shared and unshared knowledge, it is unclear to what extent the *conditions of video conferencing* have an impact (see Fischer & Mandl, in press). Up to this point, no systematic studies have been conducted on this topic. The mutual influence of the partners concerning the knowledge resources used in a joint problem space might be mediated through non-verbal and para-verbal aspects. Although non-verbal and para-verbal signals can partly be transported through audio and video connections, important differences do exist between face-to-face communication and video conferencing (Fussel & Benimoff, 1995; O'Connaill & Whittaker, 1997). For example, the lack of eye contact and gaze awareness as well as the reduced possibility to make deictic gestures in a video conference might increase the difficulty of common reference in a joint problem space. Overlapping turns and unwanted interruptions can often occur under these conditions. Collaborators frequently react on these problems with longer turns and more verbally explicit attempts to coordinate their activities (Sellen, 1992).

However, most empirical studies on problem solving and decision making found no differences between video conferencing and face-to-face conditions with regard to the outcome. In spite of partly different process characteristics, cooperation partners frequently come to qualitatively similar solutions in the setting of a video conference and in face-to-face settings (see Finn, Sellen, & Wilbur, 1997; Fischer & Mandl, in press).

Facilitating the construction of shared knowledge through shared graphical representation. Researchers in the field of cooperative learning often emphasize the importance of instructional support (e.g. O'Donnell, 1996). A number of different approaches has been developed and tested in empirical studies (see Cohen, 1994; Slavin, 1996). With respect to computer-supported collaboration, visualization and shared graphical representation tools play an increasingly important role (e.g. Roschelle & Pea, 1999). We distinguish two forms of shared graphical representation. Content-unspecific representation: The widespread shared whiteboards (mostly simple graphic editors) are supposed to support interaction between remote collaborators by providing them with the possibility to collaboratively visualize graphical elements as well as written notes (Dillenbourg & Traum, 1997). The subject area (e.g. medical diagnosis, botanical classification) as well as the task type (e.g. discussion, decision making, learning) do not play a role in the design of this tools. In the content-specific graphical representation, the degrees of freedom of the external representation are constrained by task-relevant structures. For example, so-called visual languages are designed to support discourse by providing the collaborators with a set of symbols for task specific categories (Lakin, 1990; Suthers, 2000). The CardBoard system, for instance, is a core component of a network learning environment that provides learners with a visual language for a scientific discussion. Learners can visualize their contributions by using categories like clarifying question, inference, rejection, pro and contra argument, or association (Gassner & Hoppe, 2000). To what extent content-specific shared representation as compared to content-unspecific graphical representation support the construction of shared knowledge, has barely been subject to empirical investigation up to this point. We expect that the provision of categories in the content-specific graphical representation would promote the convergence of the dyads with respect to their resource use and, as a consequence, facilitate the construction of shared knowledge. It has not been investigated empirically so far, if the two types of representation have different effects in face-to-face and computer-mediated scenarios.

Goals of the study and research questions. On this basis, this study will examine how two types of graphical representation tools and two different cooperative learning scenarios influence (1) how learners use shared and unshared knowledge resources and (2) how learners represent and transfer shared knowledge. A final research question (3) is directed to the relation of the use of knowledge resources in the cooperation process to representation and transfer of shared knowledge.

Method

Sample and design. Sixty-four students of Pedagogy from the Ludwig-Maximilians-University of Munich volunteered in this study. The participants were separated into dyads and each dyad was randomly assigned to one of the four experimental conditions in a 2x2-factorial design. We varied the type of graphical representation tool (content-unspecific vs. content-specific) and the collaboration scenario (face-to-face vs. computer-mediated). Time-on-task was held constant in all four conditions (three hours).

Learning environment. Students in both conditions had to work on complex cases in the domain of education. In these cases, fictitious teachers describe a plan for an instructional unit and ask the participants for an evaluation of the plan from a theoretical perspective. During collaboration, students were provided with a text of three pages describing important theoretical concepts of the subject domain in question (e.g. intrinsic motivation). The students' task was to prepare an evaluation of each case together. While working on a case, the students were provided with a collaborative synchronous visualization tool to graphically represent their developing solution. After each case, they were asked to give a short oral evaluation of the case from a theoretical perspective.

Collaboration scenario. All dyads collaborated in synchronous computer-supported learning environments. In the computer-mediated scenario we used a desktop video conferencing system and application sharing technologies to support the collaborative and synchronous use of the representation tools. In the face-to-face scenario, learners collaborated in physical co-presence with reference to one computer screen. Each learner had his/her own keyboard and mouse.

Type of graphical representation. Dyads in the content-specific representation tool condition were provided with the CoStructure-Tool, a computer-based graphical mapping tool that includes boxes for case information and boxes for theoretical concepts, in which text can be typed in directly. Positive and negative relations can be used to connect the boxes. Moreover, the screen of the CoStructure-Tool is divided into an empirical and a theoretical level. Both learners of each dyad were provided with a keyboard and a mouse and could access the different objects on the screen virtually simultaneously. Learners in the content-unspecific graphical representation condition worked on a computer tool which comprises the functionality of a simple graphic editor. The learners could type and edit text, draw lines, circles and rectangles, change the colors of these items, and drag the items across the screen.

Procedure. After a pre-test consisting of a content-specific declarative knowledge test and a case task, students were made familiar with the learning environment, especially with the use of the representation tools. Then, learners worked together on three cases. The collaboration was followed by an individual post-test which paralleled the individual pre-test.

Variables and data types. As data source for the variables of collaborative knowledge construction and outcome we used tape recordings of discourses and (oral) final evaluations. These tape recordings were transcribed and analyzed (i.e. segmented and classified). (1) *Use of shared and unshared knowledge resources.* As two indicators for the use of shared resources we determined the number of *theoretical concepts* (shared conceptual resources) and *case information* (shared contextual resources) which were given in the text and case description. Three indicators for unshared knowledge resources (i.e. resources not overtly given in the learning environment) were determined: the number of *relations between theoretical concepts and case information*, the number of *prior knowledge concepts*, and the number of *relations between prior knowledge concepts and case information*. A *profile of resource use* was determined as the set of frequencies for the different resource categories. As a dyadic divergence measure, all of these resource variables were z-standardized and used to calculate a dissimilarity score on the base of euclidian distances. Similar approaches are described in Cooke, Salas, Cannon-Bowers, and Stout (2000). Moreover, we measured *explicit task coordination* as the number of verbally explicit attempts to regulate or sequence the use of knowledge resources in discourse. (2) *Representation and transfer of shared and unshared knowledge*. Using a method similar to that used by Jeong and Chi (1999) we measured *shared knowledge* as the number of concepts both former dyad members remembered in the (individual) knowledge test (for the representation aspect) and the individual transfer case (for the transfer aspect). *Unshared knowledge*, in contrast, was determined by the number of concepts and relations which only one of the two dyad members used in the test (for the representation aspect) or applied in the case solution (for the transfer aspect). The reliability coefficients for the variables ranged from alpha = .78 (shared knowledge transfer) to alpha = .87 (for shared knowledge representation).

Nominal dyads were used as a baseline for a number of dyadic variables (see Jeong and Chi, 1999). Two learners of the same experimental condition who had not worked together were randomly assigned to nominal dyads post-hoc.

Controlled variables. Concerning learning prerequisites we found that the experimental groups did not differ systematically with respect to prior knowledge, experiences with visually-oriented learning strategies, and intrinsic vs. extrinsic motivation. In the different analyses, we used the dyad or the individual as the unit of analysis. We used univariate ANOVAs to analyze the effects of the conditions on the dependent variables; t-tests were used for the comparison of real to nominal dyads.

An α-level of .05 was used for statistical tests with the individual as the unit of analysis. An α-level of .1 was chosen for the dyad as unit of analysis.

Results

Resource use (research question 1)

The type of graphical representation tool (table 1) had no effect on the use of *shared contextual resources* (case information) ($F(1,28) = 0.1$; n.s.).

The computer-mediated dyads did not differ from their face-to-face equivalents concerning this variable ($F(1,28) = 1.11$, n.s.). The collaboration scenario and the type of graphical representation did not interact with regard to this variable ($F(1,28) = 0.00$; n.s.).

Table 1: The use of the different kinds of knowledge resources in the experimental conditions.

Type of resource	Content-specific graphical representation		Content-unspecific graphical re-presentation	
	Collaboration scenario		Collaboration scenario	
	computer-mediated M (SD)	face-to-face M (SD)	computer-mediated M (SD)	face-to-face M (SD)
Shared resources:				
Case Information	47.50 (29.03)	61.75 (43.37)	46.50 (28.53)	59.63 (42.91)
Theoretical concept	9.12 (7.41)	17.62 (6.35)	7.63 (11.01)	3.75 (3.20)
Unshared resources:				
Relation theoretical concept - case information	36.13 (19.33)	42.25 (22.70)	29.75 (29.79)	26.25 (23.90)
Prior knowledge concept	1.13 (2.47)	0.38 (1.06)	3.63 (5.26)	1.63 (4.60)
Relation prior knowledge concept - case information	14.63 (11.33)	6.63 (10.32)	11.50 (16.96)	9.25 (12.02)

The use of *shared conceptual resources*, however, was affected by the tool type: Dyads learning with the content-specific representation tool used and elaborated substantially more shared conceptual resources than dyads with the content-unspecific representation tool ($F(1,28) = 8.35$; $p < .01$; $\eta^2=0.23$), while the collaboration scenario had no effect on this variable ($F(1,28) = 0.76$; n.s.). The effect of the tool type was stronger in the face-to-face collaboration than in the computer-mediated scenario (indicated by the interaction term type of representation tool X collaboration scenario: $F(1,28) = 5.41$; $p < .05$; $\eta^2=0.16$). Concerning explicit relations between conceptual resources and case information, no differences were found between conditions (factor type of representation $F(1,28) = 2.46$; n.s.; factor collaboration scenario $F(1,28) = 0.01$; n.s.; interaction type of representation X collaboration scenario $F(1,28) = 1.27$; n.s.). The same is true for the use of unshared conceptual resources (prior knowledge) and the relations between unshared conceptual resources and shared contextual resources, i.e. case information ($0.00 \leq F(1,28) \leq 2.01$, n.s.; for all main and interaction effects).

The results from the convergence analyses concerning the use of the resources were even more interesting (table 2). Compared to the content-unspecific representation tool the content-specific representation tool led to a more narrow scope of the dyads' resource use profiles, i.e. lower nominal dyad divergence ($F(1,60) = 9,79$; $p < .01$; $\eta^2=0.14$).

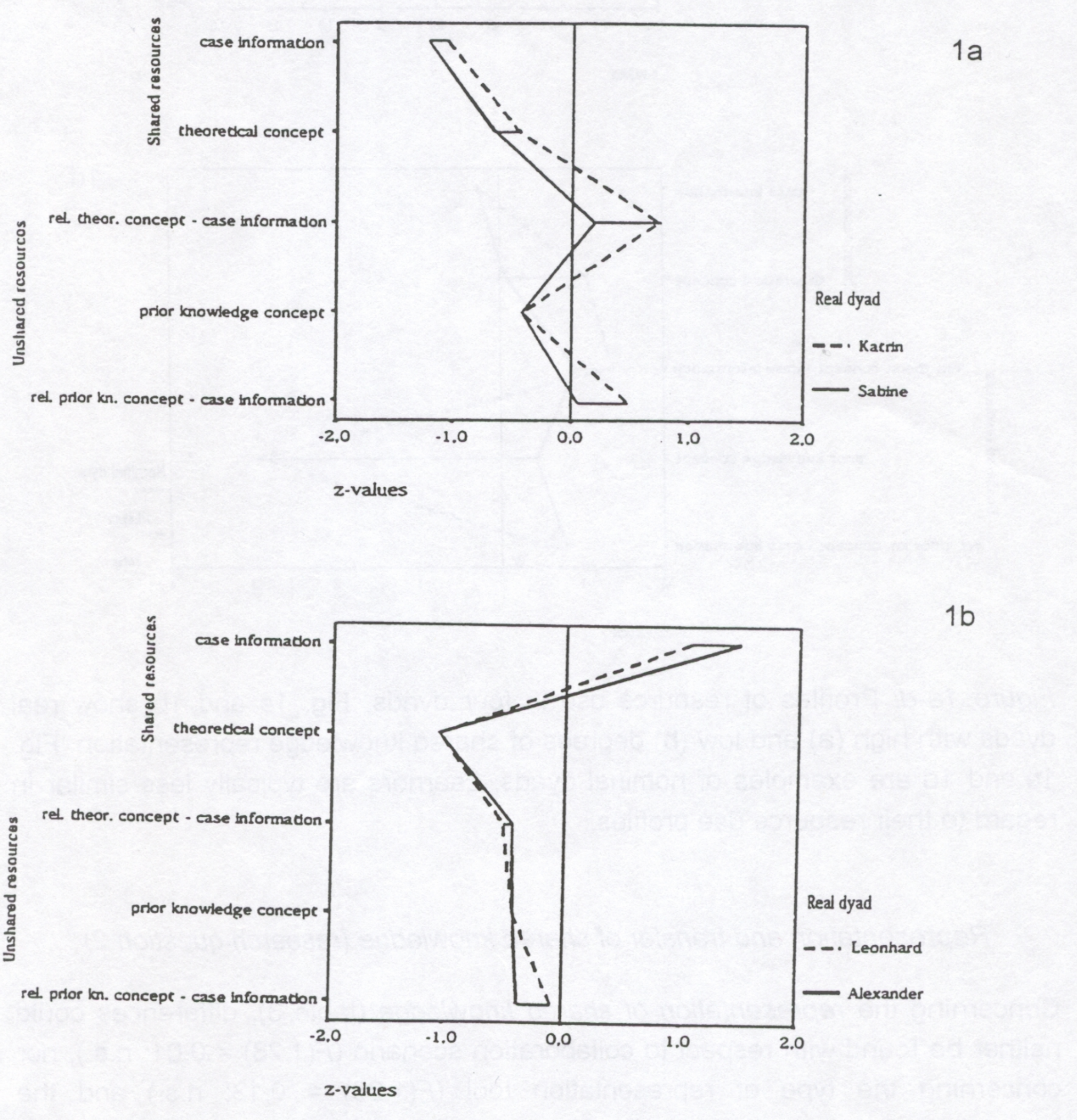
The collaboration scenario independently explained a substantial part of the variance of the nominal dyad similarity: Computer-mediated cooperation led to a wider scope of resource use profiles ($F(1,60) = 4.08$; $p < .05$; $\eta^2=0.06$). The two factors did not interact ($F(1,60) = 1.22$; n.s.).

Table 2: Divergence concerning the profiles of resource use in the four experimental conditions of real dyads and nominal dyads.

Profile of resource use	Content-specific graphical representation		Content-unspecific graphical re-presentation	
	Collaboration scenario		Collaboration scenario	
	computer-mediated M (SD)	face-to-face M (SD)	computer- mediated M (SD)	face-to-face M (SD)
Divergence in real dyads	1.33 (0.61)	1.41 (0.46)	1.21 (0.99)	1.25 (0.62)
Divergence in nominal dyads	2.72 (0.89)	2.44 (0.86)	4.00 (1.17)	3.05 (1.72)

Concerning the intra-dyadic divergence neither collaboration scenario nor type of graphical representation had an effect ($0.00 \leq F(1,28) \leq 0.66$, n.s., for all main and interaction effects). The computer mediation in the video conferencing scenario did not result in a lower or higher mutual influence of the learning partners on the resources use. Neither did the content-specific graphical representation have an effect on this variable.

A final question concerning the mutual influence in resource use was whether the dyadic interaction itself led to a more convergent resource use. A comparison of real dyads with nominal ones with respect to the divergence measure should help answer this question. Figure 1 shows two typical profiles of resource use of real and nominal dyads. Most real dyads showed such similarities in their profiles. This impression could be quantitatively validated (table 2). In 59 of the 64 cases the divergence in resource use was smaller for the real dyads than for their nominal controls. Partners from real dyads used resources in a substantially more similar way than the learners randomly paired in nominal dyads within one experimental condition ($t(63) = 10.22$; $p < .01$).



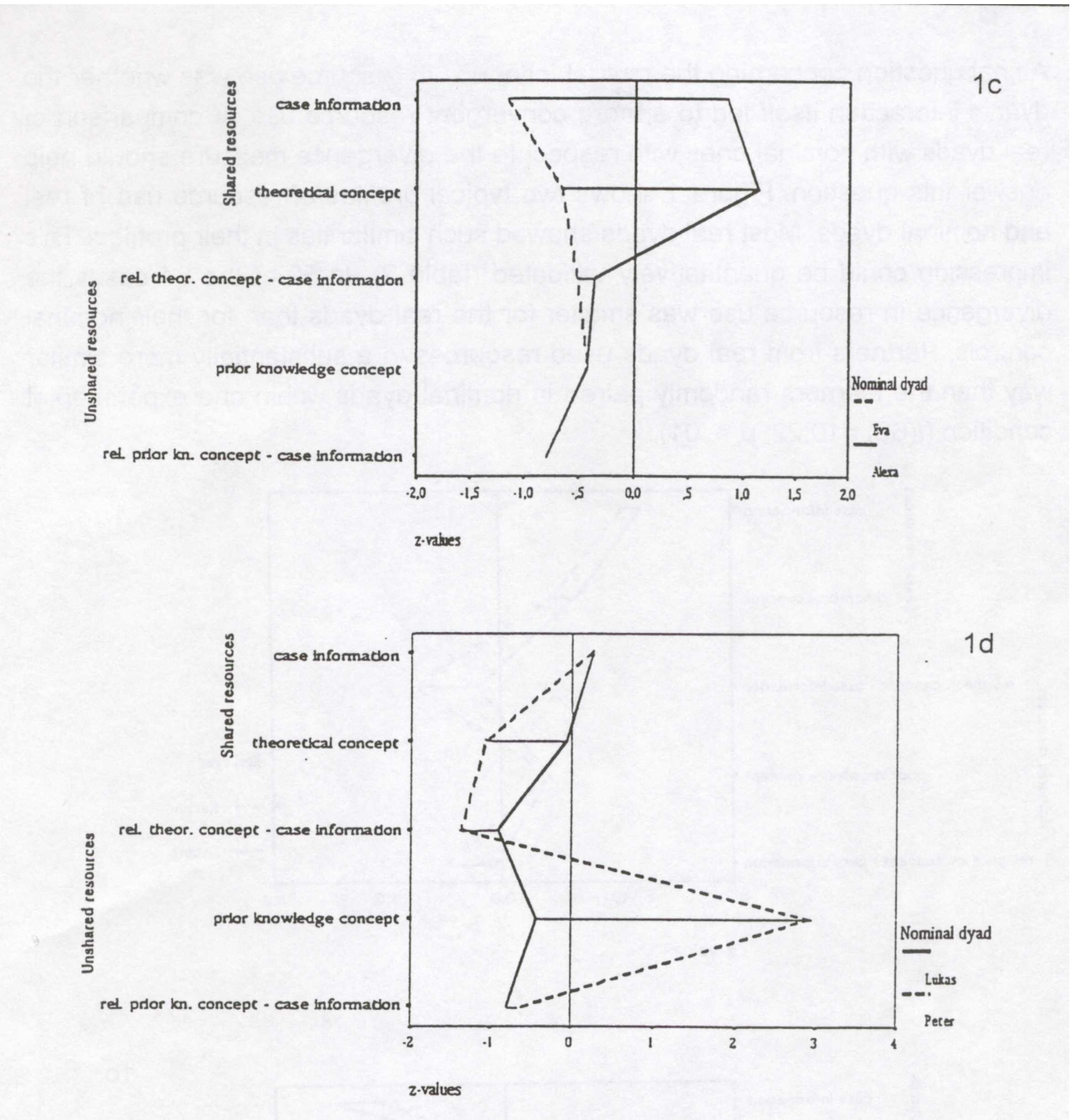


Figure 1a-d: Profiles of resource use in four dyads. Fig. 1a and 1b show real dyads with high (a) and low (b) degrees of shared knowledge representation. Fig. 1c and 1d are examples of nominal dyads. Learners are typically less similar in regard to their resource use profiles.

Representation and transfer of shared knowledge (research question 2)

Concerning the *representation of shared knowledge* (table 3), differences could neither be found with respect to collaboration scenario (F(1,28) = 0.01; n.s.), nor concerning the type of representation tool (F(1,28) = 0.13; n.s.) and the interaction of the two factors (F(1,28) = 0.51; n.s.). The same is true for the *unshared representation of knowledge* (factor type of representation F(1,28) = 1.24, n.s.; factor collaboration scenario F(1,28) = 0.43, n.s.; interaction type of representation X collaboration scenario F (1,28) = 0.12, n.s.).

Table 3: Shared knowledge representation and transfer in the four experimental conditions.

Learning outcome	Content-specific graphical representation		Content-unspecific graphical representation	
	Collaboration scenario		Collaboration scenario	
	computer-mediated	face-to-face	computer- mediated	face-to-face
	M (SD)	M (SD)	M (SD)	M (SD)
Representation				
Shared	2.63 (2.13)	3.25 (3.37)	3.75 (3.45)	2.88 (2.70)
Unshared	15.75 (6.86)	14.38 (7.21)	11.75 (8.48)	10.88 (7.95)
Transfer				
Shared	0.88 (1.36)	0.88 (1.13)	0.63 (1.06)	0.63 (0.74)
Unshared	3.25 (1.75)	2.50 (2.39)	3.13 (3.18)	4.88 (3.52)

Regarding the *transfer of shared and unshared knowledge* no substantial differences between the experimental conditions could be found (table 3). With respect to the transfer of *shared* knowledge neither main effects (factor type of representation $F(1,28) = 0.42$, n.s; factor collaboration scenario $F(1,28) = 0.00$, n.s.) nor the interaction term ($F(1,28) = 0.00$, n.s.) were significant. Similar results were obtained for the transfer of *unshared* knowledge (factor type of representation $F(1,28) = 1.29$, n.s.; factor collaboration scenario $F(1,28) = 0.26$, n.s.; interaction term $F(1,28) = 1.60$, n.s.).

So far, the findings on representation and transfer of shared knowledge suggest that the construction of shared knowledge is neither hampered nor facilitated by the conditions of the synchronous computer-mediated collaboration in a video conferencing environment in comparison with a face-to-face condition. The content-specific graphical representation which differentially affected the use of knowledge resources and proved to be effective in supporting processes of collaborative knowledge construction (see Fischer & Mandl, in press) is not more effective than the content-unspecific representation in facilitating the representation and transfer of shared knowledge.

Table 3 shows that only a small proportion of knowledge is actually shared in all the conditions we employed in our experiment.

With the following step of our analysis we tried to rule out the possibility that the shared knowledge we measured was caused by similarities in experimental conditions alone, e.g. the learning material. We therefore compared real dyads with nominal dyads with respect to the representation and transfer of shared and unshared knowledge (table 4). Results show that real dyads did not differ from nominal dyads regarding the representation of shared and unshared knowledge ($t(31) < 1$; n.s.). However, more shared knowledge is transferred in real dyads than in nominal ones ($t(31) = 1.96$; $p < .05$; $d = 0.34$). Real dyads did not differ from nominal ones concerning the transfer of unshared knowledge ($t(31) = -0.87$; n.s).

Table 4: Knowledge representation and transfer in real and nominal dyads.

Type of Dyad	Knowledge representation		Knowledge transfer	
	Shared M (SD)	Unshared M (SD)	Shared M (SD)	Unshared M (SD)
Real Dyads	3.13 (2.85)	12.84 (7.63)	0.75 (1.05)	3.44 (2.80)
Nominal Dyads	2.97 (2.53)	12.81 (7.35)	0.47 (0.62)	4.00 (3.19)

The relationship between the use of knowledge resources and the representation and transfer of shared knowledge (research question 3)

Using the representation and transfer variables as criteria, we selected six dyads: 3 dyads with little or no shared knowledge and 3 dyads with a high degree of shared knowledge. Figure 2 shows the profiles of resource use for these dyads. Dyads without shared knowledge (after collaboration) often showed a high degree of use concerning shared contextual resources (i.e. case information) (e.g. dyad 31 in Figure 2). Conceptual resources - whether appropriate or inappropriate - were rarely used. Other "low shared knowledge" dyads used conceptual resources more frequently. For example, dyad 2 seemed to fully rely on prior knowledge resources, which were partly inadequate for the problem solution. Single case studies of discourse sequences reveal that some dyads used the available time mostly for "hegemonic discussions" on the basis of their prior knowledge. Dyad 15 discussed conceptual resources from their prior knowledge and applied relevant theoretical concepts more frequently. In contrast to "high shared knowledge" dyads, the learning partners did not elaborate on their theoretical concepts and did not emphasize on task coordination. Results of case studies suggest that the *secret master plan*, i.e. the lack of explicit task coordination, may be related to very low degrees of shared knowledge. It seems to be typical with secret master plans that one learner assumes the role of the guide but his task strategy remains completely implicit.

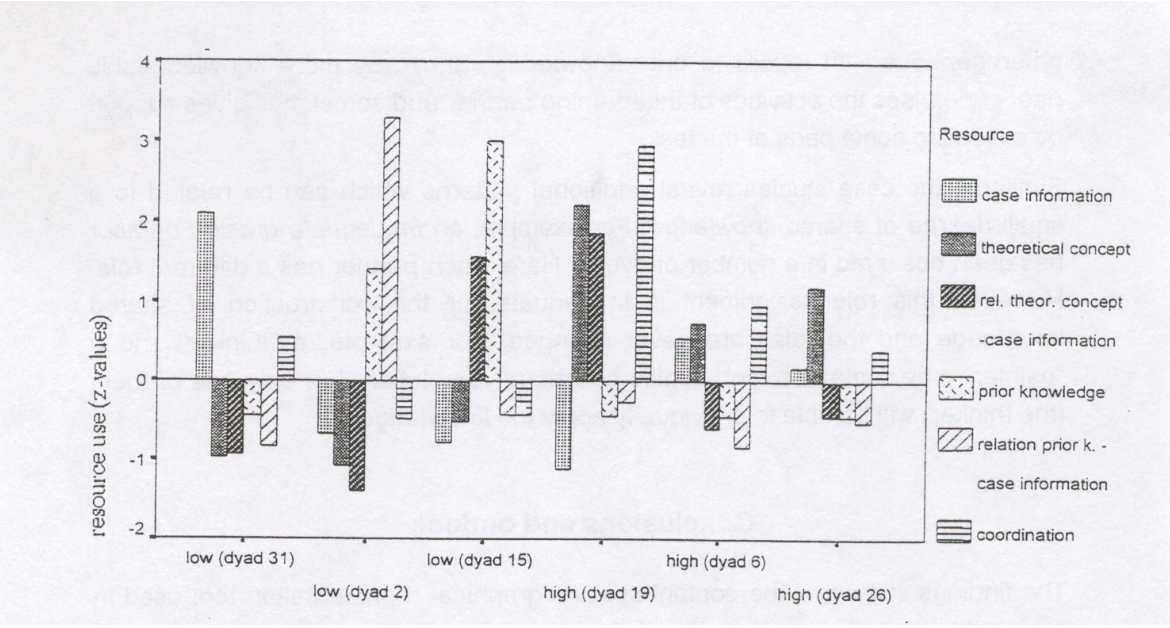


Figure 2: Profiles of resource use for dyads with little or no shared knowledge (dyads 31, 2, 15) and dyads with a higher degree of shared knowledge (dyads 19, 6, 26).

"High shared knowledge" dyads generally elaborated more frequently on appropriate theoretical concepts and often coordinated their activities more explicitly (dyads 19, 6, 26 in Figure 2). In contrast to the dyads 6 and 26, who showed high degrees of shared knowledge representation, learning partners of dyad 19 additionally had a high degree of shared transfer. During their collaboration they elaborated more frequently on conceptual resources and applied them more frequently to the case information. Moreover, they coordinated their learning activities even more explicitly than the dyads with shared knowledge representation only (dyads 6 and 26).

Beyond these quantitative impressions, the single case studies revealed even more discourse patterns (Fischer & Mandl, 2000). Some of them can be related to the representation or transfer of shared knowledge. For example, in *flexible co-construction* the learners frequently divided content-related and coordinating tasks but changed their responsibilities after some time. In discussion phases the two of them contributed quantitatively and qualitatively to a similar degree. *Adaptive scaffolding* is a discourse strategy that can be observed in dyads which are heterogeneous with regard to prior knowledge. Here, the more knowledgeable peer supervises the activities of the learning partner and sometimes gives support by executing some parts of the task.

Similarly, the case studies reveal additional patterns which can be related to a small degree of shared knowledge. For example, an *inadequate division of labor* has been observed in a number of dyads. Here, each partner has a different role. However, this role assignment is inadequate for the construction of shared knowledge and the roles are never changed. For example, a "thinker" and a "painter" may come to a high-quality collaborative solution, but only one of them (the thinker) will be able to individually apply the knowledge.

Conclusions and outlook

The findings show that the content-specific graphical representation tool used in our study can influence the use of the resources. Firstly, with content-specific representation the use of appropriate conceptual knowledge resources could be promoted. These findings could be of relevance beyond the field of psychology of education. For example, they have implications for the improvement of information sampling in decision-making groups in social and organizational psychology (e.g. Sassenberg et al., 1998; Wittenbaum & Stasser, 1996;). Concerning their profiles of resource use, most dyads in our study converged strongly. It seems as if dyads establish (mostly implicit) rules on their proceedings concerning the task. The type of graphical representation does not change these convergence processes substantially.

The results of our study show that absolute differences between the collaboration scenarios (face-to-face and video conferencing) with regard to the resource use are rare. However, interesting findings came up concerning the convergence of the resource use. First of all, a direct effect of the dyadic interaction on the convergence of the resource use could be shown: Within (real) dyads the profiles of resource use are more similar than in nominal dyads. The condition of the video conference does not show a moderating influence. Secondly, a direct effect of the collaboration scenario on the bandwidth of resulting profiles of resources use can be determined: In the video conference condition the bandwidth of actual profiles of resources use is clearly higher than in physical co-presence. However, these differences in process do not appear in the outcomes: The collaboration scenario hardly influenced shared and unshared knowledge representation as well as shared and unshared knowledge transfer. So far, our results are in line with earlier work on video conferencing which showed that possible differences concerning the process hardly ever result in outcome differences (Finn et al., 1997; Fischer & Mandl, in press).

It is often assumed that visualization can improve communication between learning partners. Indeed, effects of visualization on discourse could also be shown for our learning environments. However, the differences regarding the resource use did not result in a changed representation or transfer of shared knowledge. In our setting, the content-specific representation is not superior to the content-unspecific representation.

In comparison to the study by Jeong and Chi (1999) which employed a similar quantitative methodology, visualization hardly caused an increase of the proportion of shared knowledge. In this earlier study neither visualization nor any other form of support of the co-operation were included. So far, comparison values from studies on effect of other interventions on shared knowledge are not available (as for instance for reciprocal teaching, group puzzle etc.). Therefore, no general statements on the effectiveness of the two types of dynamic visualization can be made. On the whole, doubts about exclusively positive effects of visualization on collaboration seem to be justified on the basis of our single case studies. The example of the inadequate division of labor into a painter role and a thinker role clearly illustrates that dysfunctional effects of shared visualization on the process of knowledge construction are possible. In all our experimental conditions, most of the knowledge constructed in co-operation is individually constructed unshared knowledge. The proportion of shared knowledge makes up about 15-20% of the acquired knowledge. This value corresponds to the proportion found in earlier investigations (Jeong & Chi, 1999). A higher degree of shared knowledge could have been expected considering that the learners were supposed to negotiate a consensus regarding a problem solution. Furthermore, the findings clearly show that the extent of shared representation can hardly be explained with intra-dyadic variance. This means that the fact that learning partners have similar knowledge representation at the end of their collaboration cannot be explained with the specific interaction in the dyads. The other learning conditions (the theory text, the case etc.) are better predictors. On the other hand, shared knowledge transfer is clearly affected by dyadic interaction: Here the former learning partners are more similar than coincidentally grouped partners. This constellation of findings can be seen as an indicator that the special effects of cooperative learning are to be expected rather with processes of higher order related to transfer than with the acquisition of factual knowledge (Gabbert, Johnson, & Johnson, 1986; Mandl & Renkl, 1992; Nastasi & Clements, 1992; Salomon & Perkins, 1998).

The results of single case analyses are considered as preliminary and tentative indicators of how discourse aspects may be related to the representation and transfer of shared knowledge. At least two hypotheses for further empirical work can be formulated on the basis of the analysis of the identified profiles and strategies: First of all, the explicit task coordination transfer could be of great importance for the outcome similarity, especially concerning the transfer. If the pursued task strategy remained implicit, none of the analyzed individual cases managed to transfer a considerable amount of shared knowledge. The important role of the explicitness of the task strategy is emphasized by theoretical and empirical work (Collins, Brown, & Holum, 1991; Rogoff, 1991; Vygotskij, 1978). Outside the educational field, several cognitive approaches highlight the important role of explicit meta-communication in constructing a shared situation model or team mental model (e.g. Klimoski & Mohammed, 1994). An instructional consequence would be to find ways to facilitate the explicitness of task coordination. Secondly, learners who share less knowledge with their learning partners often dedicate less time to discuss the appropriate conceptual resources. Instead, some dyads focus on the contextual resources given by the case information. In these dyads, an inadequate distribution of labor with inappropriate but stable role assignments is frequently observed. Yet, learners of these dyads do not necessarily learn less than learners of dyads with much shared knowledge. They may even come to appropriate collaborative solutions. However, it is often only one of the two partners who is able to perform the task on his own later on.

In summary, the findings of this study suggest that the emergence of shared knowledge in dyadic learning is rather the exception than the rule. With video conferencing the degree of shared knowledge is very low. However, it is not higher for the face-to-face condition. Even worse: Visualization tools, often thought of as a support for knowledge sharing, might change processes and even individual outcomes (see Fischer, Bruhn, Gräsel, & Mandl, 1998), they do not facilitate the construction and transfer of shared knowledge. More research is needed on at least two issues: (1) On the one hand, the facilitating effects of other cognitive or motivation-related interventions (e.g. Palincsar & Brown, 1984; Slavin, 1996) on representation and transfer of shared knowledge should be determined. Concerning this point, important insights may also come from studies on the interaction of different types of knowledge in the process of collaborative problem solving (e.g., Plötzner, Fehse, Kneser, & Spada, 1999). (2) On the other hand, more effective interventions concerning the construction and representation of shared knowledge need to be developed. The analysis of process patterns or strategies suggest that important process features in connection with the emergence of shared knowledge are not affected by the tools: the inadequate role assignment and distribution of labor as well as the lacking explicitness of task coordination ("secret master plan"). A more adequate instructional support would include some kind of cooperation script including the assignment and the change of adequate roles (e.g. O'Donnell, 1996) as well as prompts or scaffolds for a more explicit task strategy. Maybe a combination of shared graphical representation with a coordinating cooperation script as *scripted graphical representation* could provide the instructional support needed to foster shared knowledge representation and transfer.

In our view, the phenomenon of shared knowledge should be considered more seriously in theoretical approaches to cooperative learning. Theoretical models should include statements about how shared knowledge arises, and how it can be promoted. They should further allow for the formulation of hypotheses concerning the use and construction of shared knowledge in specific cooperative learning arrangements. Theoretical approaches as well as empirical studies may consider at least the following three aspects of shared knowledge: (1) The use of shared and unshared knowledge resources, (2) the construction of shared and unshared representations, and (3) shared and unshared transfer. Aspects of this framework can also be used to evaluate cooperative learning environments in practice. For example, a seminar throughout a whole semester would gain much in quality, if participants share more and more knowledge because the discourse level is likely to increase (Nicolopoulou & Cole, 1993).

References

Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (pp. 269-291). Mahwah, NJ: Erlbaum.

Buder, J., Hesse, F. W., & Schwan, S. (1998). A cognitive model of knowledge exchange in telematic learning groups. In *Proceedings of the 10th World Conference on Educational Multimedia and Hypermedia.* Freiburg, June 1998 (pp. 1588-1589). Available: WWW: http://www.wissenskommunikation.de/staff/buder/index.html

Cannon-Bowers, J. A., & Salas, E. (1998). Team performance and training in Complex Environments: Recent Findings From Applied Research. Current Directions. *Psychological Science*, *7* (3), 83-87.

Clark, H. H. (1992). *Arenas of language use*. Chicago: The University of Chicago Press.

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127-149). Washington: American Psychological Association.

Cohen, E.G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*, 1-35.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator, 15* (3), 6-11, 38-39.

Cooke, N. J., Salas, E., Cannon-Bowers, J. A., & Stout, R. (2000). Measuring team knowledge. *Human Factors, 42*, 151-173.

Dillenbourg, P., & Traum, D. (1997). *The role of the whiteboard in a distributed cognitive system.* Paper presented at the Swiss Workshop on Distributed and Collaborative Systems, Lausanne, Switzerland.

Finn, K. E., Sellen, A. J., & Wilbur, S. B. (Eds.). (1997). *Video-mediated communication*. Mahwah, NJ: Erlbaum.

Fischer, F., & Mandl, H. (in press). Being there or being where? Video conferencing and cooperative learning. In H. v. Oostendorp (Ed.). *Cognition in a digital world.* Mahwah: Erlbaum.

Fischer, F., & Mandl, H. (2000). *Construction of shared knowledge in face-to-face and computer-mediated cooperation.* Paper presented at the AERA Annual Meeting, New Orleans, LA, USA.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (1998). *Fostering collaborative knowledge construction with visualization tools* (Research report No. 97). Munich, Germany: Ludwig-Maximilians-University, Institute of Educational Psychology and Empirical Pedagogy.

Fussell, S. R., & Benimoff, N. I. (1995). Social and cognitive processes in interpersonal communication: Implications for advanced telecommunications technologies. *Human Factors, 37* (2), 228-250.

Gabbert, B., Johnson, D. W., & Johnson, R. T. (1986). Cooperative learning, group-to-individual transfer, process gain, and the acquisition of cognitive reasoning strategies. *Journal of Psychology, 120* (3), 265-278.

Gassner, K., & Hoppe, H. U. (2000). Visuelle Sprachen als Grundlage kooperativer Diskussionsprozesse. [Visual languages for collaborative discussion processes]. In H. Mandl & F. Fischer (Eds.), *Wissen sichtbar machen. Wissensmanagement mit Mapping-Techniken* (pp. 93-118). Göttingen: Hogrefe.

Hinsz, D. A., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121* (1), 43-64.

Ickes, W., & Gonzalez, R. (1996). "Social" cognition and social cognition. In J. L. Nye & A. M. Brower (Eds.), *What´s social about social cognition?* Thousand Oaks: Sage.

Jeong, H., & Chi, M. T. H. (1999, April). Constructing shared knowledge during collaboration and learning. Poster presented at the AERA Annual Meeting, Montreal, Canada.

Klimoski, R., & Mohammed, S. (1994). Team mental model: construct or metaphor. *Journal of Management, 20* (2), 403-437.

Lakin, F. (1990). Visual languages for cooperation: A performing medium approach to systems for cooperative work. In J. Galegher, R. E. Kraut, & C. Egido (Eds.), *Intellectual teamwork. Social and technological foundations of cooperative work* (pp. 453-488). Hillsdale, NJ: Erlbaum.

Mandl, H., & Renkl, A. (1992). A plea for "more local" theories of cooperative learning. *Learning and Instruction, 2*, 281-285.

Nastasi, B. K., & Clements, D. H. (1992). Social-cognitive behaviors and higher-order thinking in educational computer environments. *Learning and Instruction, 2*, 215-238.

Nicolopoulou, A., & Cole, M. (1993). Generation and transmission of shared knowledge in the culture of collaborative learning: the Fifth Dimension, its play-world and its institutional contexts. In E. A. Forman, N. Minick, & C. A. Stone (Eds.), *Contexts for learning* (pp. 283-314). Oxford: Oxford University Press.

Nye, J. L., & Brower, A. M. (Eds.). (1996). *What´s social about social cognition?* Thousand Oaks: Sage.

O'Connaill, B., & Whittaker, S. (1997). Characterizing, predicting, and measuring video-mediated communication: A conversational approach. In K. E. Finn, A. J. Sellen, & S. B. Wilbur (Eds.), *Video-mediated communication* (pp. 107-132). Mahwah, NJ: Erlbaum.

O'Donnell, A. (1996). Effects of explicit incentives on scripted and unscripted cooperation. *Journal of Educational Psychology, 88* (1), 74-86.

Orr, J. E. (1990). Sharing knowledge, celebrating identity: War stories and community memory among service technicians. In D. S. Middleton, & D. Edwards (Eds.), *Collective remembering: Memory in society* (pp. 169-181). London: Sage.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. *Cognition and Instruction, 1*, 117-175.

Plötzner, R., Fehse, E., Kneser, C., & Spada, H. (1999). Learning to relate qualitative and quantitative problem representations in a model-based setting for collaborative problem solving. *The Journal of the Learning Sciences, 8*, 177-214.

Renkl, A., Mandl, H., & Gruber, H. (1996). Inert knowledge: Analyses and remedies. *Educational Psychologist, 31*, 115-122.

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1-20). Washington: American Psychological Association.

Rogoff, B. (1991). Social interaction as apprenticeship in thinking: guided participation in spatial planning. In L. B. Resnick, J. Levine, & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 349-364). Washington: American Psychological Association.

Roschelle, J., & Pea, R. (1999). Trajectories from today's WWW to a powerful educational infrastructure. *Educational Researcher, 28* (5), 22-25 + 43.

Salomon, G. (Ed.). (1993). *Distributed cognitions: psychological and educational considerations*. Cambridge: University Press.

Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education, 23*, 1-24.

Sassenberg, K., Boos, M., Laabs, I., & Wahring, S. (1998, September). *Bedeutung des Wissens um eigene und fremde Expertise für das Information Sampling in computervermittelter Kommunikation* [The role of knowledge on the own expertise and on the expertise of the other for information sampling in computer-mediated communication]. Paper presented at the Kongress der Deutschen Gesellschaft für Psychologie, Dresden, Germany.

Scardamalia, M., & Bereiter, C. (1996). Computer support for knowledge-building communities. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm* (pp. 249-268). Mahwah, NJ: Erlbaum.

Sellen, A. J. (1992). Speech patterns in video-mediated communications. In *Proceedings of the Conference on Computer Human Interaction (CHI)* (pp. 49-59). New York: ACM.

Slavin, R. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology, 21*, 43-69.

Stasser, G., & Stewart, D. (1992). Discovery of hidden profiles by decision-making groups: Solving a problem versus making a judgement. *Journal of Personality and Social Psychology, 63* (3), 426-434.

Suthers, D. (2000, November). *Initial evidence for representational guidance of learning discourse.* Paper presented at the International Conference on Computers in Education, Taipei, Taiwan.

Tudge, J. (1989). When collaboration leads to regression: Some negative consequences of socio-cognitive conflict. *European Journal of Social Psychology, 19,* 123-138.

Vygotskij, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge: Harvard University Press.

Wittenbaum, G. M., & Stasser, G. (1996). Management of information in small group. In J. L. Nye, & A. M. Brower (Eds.), *What´s social about social cognition?* (pp. 3-23). Thousand Oaks: Sage.