Promoting the Drawing of Inferences in Collaboration: Insights from Two Experimental Studies

Anne Meier & Hans Spada, Department of Psychology, University of Freiburg, Germany
Email: anne.meier@psychologie.uni-freiburg.de, hans.spada@psychologie.uni-freiburg.de

Abstract: Collaborative problem-solving tasks often require learners to co-construct new knowledge by drawing inferences from distributed information. We investigated the impact of information distribution and instructional support on university students' collaboration in such tasks. Two experiments using specifically designed tasks show a robust negative effect of distributed information on inferences. Detailed analyses of collaborators' discussions in Study 1 highlight the importance of specific inference patterns. Study 2 aimed to support these patterns of collaborative reasoning in a training phase, and tested the effects of support in a test phase. Two support measures were realized: written information on task difficulties and collaboration strategies, and an inference tutoring tool providing feedback and prompts based on an online assessment of students' collaboration. Results show that reflected experience with the training task improved subsequent unsupported collaboration. The best performance was achieved when the tutoring tool had been available during the training task.

In groups, the knowledge relevant for solving a given task is often distributed across group members. In fact, complementary knowledge is seen as one reason why groups are more effective than individuals: It is generally assumed that "two heads are better than one" in solving complex problems, and thus that groups holding complementary knowledge will outperform individual problem solvers (Kerr & Tindale, 2004). In pedagogical contexts, it is expected that students will learn from collaborating on joint tasks that require them to exchange and integrate complementary knowledge or viewpoints (Aronson, Balney, Stephan, Sikes, & Snapp, 1987; Kneser & Ploetzner, 2001). An important group process in these situations is the collaborative co-construction of new ideas or concepts through which students integrate and expand their knowledge (Jeong & Chi, 2007; Suthers, 2006; Webb & Palincsar, 1996), reaching insights and eventually problem solutions that go beyond what each individual problem solver would have been able to achieve (Rummel & Spada, 2005). However, collaborative knowledge creation is not without problems. A first challenge is the necessity to pool the *unshared knowledge* held by individual group members (Stasser & Titus, 1985). A large literature consistently shows that groups often come up with suboptimal decisions because they fail to take into account unshared information and instead focus primarily on the *shared knowledge* all group members knew from the beginning ("information pooling effect"; for a recent review, see Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007). However, it has not yet been studied whether similar biases can be found in groups whose task requires them to collaboratively co-construct *new knowledge*, which would be more interesting from a learning sciences perspective. This is the kind of task we study in our experiments. Our interest, specifically, is in the *inferences* collaborators draw from both shared and unshared information during collaborative problem-solving. We use the term "inference" in a broad sense, encompassing instances were at least two pieces of information are combined and, on the background of general knowledge, transformed into a new piece of information (i.e. plausible inferences, Collins & Michalski, 1989). The main questions we ask are: How does the initial distribution of information in a group influence the inferences drawn in collaborative problem-solving? And: How can the collaborative drawing of inferences be supported?

Studying Inferences from Distributed Information

Three Types of Inferences

In the simplest case of only two persons between whom the relevant knowledge is distributed, three types of inferences can be distinguished (Table 1):

- A *collaborative inference* results from unshared information that is distributed between collaborators, i.e. an individual person holds only an unconnected piece of information, while matching information is known only to his or her partner. Thus, this inference type can only be drawn in collaboration.
- An *individual inference* results from unshared information that is located with the same person ("undistributed"). An inference of this type can therefore be drawn individually by that person. During collaboration, partners need to inform each other about their individual inferences.
- A *shared inference* results from shared information. An inference of this type can, in principle, be drawn individually by both partners, and therefore does not require collaboration between them.

Table 1: Visualization of collaborative, individual, and shared inferences (adapted from Härder & Spada, 2004).

Information distribution	Person A	Person B	Inference type
unshared distributed			collaborative
unshared *un*distributed			individual
shared			shared

In analogy to the information pooling effect (e.g. Brodbeck et al., 2007), it can be expected that more inferences will be drawn from shared information (shared inferences) than from unshared information (individual and collaborative inferences). In addition, we expect that collaborative inferences should be harder to draw than individual inferences: First, the relevance of yet unconnected, unshared distributed information will be less salient, and thus it will be less likely to be pooled during discussion than unshared *un*distributed information (Fraidin, 2004), in which case the inference cannot be drawn. Second, individual inferences may be drawn individually at any point of the problem-solving process, even prior to discussion. Collaborative inferences, on the other hand, must be drawn "online" on the basis of information newly learned from one's partner and information recalled from memory. In an ongoing discussion, this retrieval process is prone to be disrupted (cf. Finlay, Hitch, & Meudell, 2000), and possible inferences may therefore be overlooked.

Murder Mystery Inference Task

We designed a Murder Mystery Inference Task specifically for studying inferences in dyads' collaborative problem-solving. Participants individually study a set of "interrogation protocols" containing information on the murder and four suspects, hand back the information after a certain reading time, and are then asked to discuss the case with a partner who received a systematically different set of protocols. Their joint task is to find motives, alibis, and incriminating pieces of evidence, and based on these name the guilty suspect. In total, the interrogation protocols contain 24 solution-relevant information items that are embedded in a larger story. From these information items, 12 solution-relevant inferences (three for each suspect) can be drawn. The relevant pieces of information are distributed between group members so that each dyad can draw four collaborative, four individual, and four shared inferences. If information items are considered without drawing the appropriate inferences, the dyad is led to choose the wrong suspect. However, if all inferences are drawn, a second suspect is revealed as the only possible murderer. Three different text versions are realized in order not to confound inference type with inference content: Each of the 12 possible inferences is shared in one text version, individual in another, and collaborative in again another; data are aggregated over these text versions.

Study 1: Difficulties Involved in Drawing Collaborative Inferences

In a first study (for details see Meier & Spada, 2007), 27 dyads of university students solved the Murder Mystery Inference Task over a desktop-videoconferencing system with a shared text editor. There was a substantial main effect of inference type: as expected, shared inferences were the easiest and collaborative inferences the hardest to draw, use, and remember. This effect was found on all levels of the problem-solving process (discussion content, written solution, and post-test). For example, students discussed 49% of the collaborative inferences, 65% of the individual inferences, and 79% of the shared inferences ($F(2;48)= 7.56$; $p= .001$; *partial* $\eta^2= .24$). This findings show that collaborative inferences, even though they hold the highest potential for creating new shared knowledge at the group level, are also very difficult to achieve. In this first study, instructional support (either as guidance from a collaboration script during problem-solving, or as support for collaborator's own planning of their problem-solving process) was not effective in overcoming this deficit.

We analyzed collaborators' discussions in more depth to find out how inferences, in particular collaborative ones, were actually drawn during discussion (*inference patterns*) and to deduce from these findings which strategies might help collaborators to make better use of their complementary knowledge resources. Inference patterns were analyzed by tracing the history of each inference in students' dialogs: For each of the twelve possible inferences, we coded when and by whom the two interdependent pieces of information as well as the corresponding inference were first mentioned during discussion. The two dominating patterns for complete inferences are illustrated in Table 2. The *same-person pattern*, in which both pieces of information and the corresponding inference are entered by the same person, was the most frequent pattern for individual and shared inferences. In the example in Table 2, it is A who informs her partner about the two interdependent pieces of information, as well as about the inference she has drawn from them. The *completion pattern*, on the other hand, dominated for collaborative inferences, where information distribution made the same-person pattern impossible. As in the example in Table 2, with this pattern, one person enters the first piece of information, and her partner enters the matching piece together with the corresponding inference – often in close temporal proximity. Further, for incomplete inferences, the most frequent pattern across all three inference types was the *missing information* pattern, in which collaborators discussed one piece of information, but both the matching piece and the inference were missing.

Table 2: Examples of inference patterns in collaborators' dialogs. The two pieces of information are printed in italics; the inference is also underlined.

Example 1: "Same person" pattern
A: Yeah, hey, I just remembered, Horst said that *Doppler (the victim) was left-handed*. And *the weapon was in his right hand, and it was supposed to look like suicide!* **B:** That means it wasn't suicide. **A:** Yes. **B:** And that the person didn't know Doppler very well. **A:** Yes. But Horst knew that Doppler was left-handed. **B:** Ah! **A:** *So he would have put the weapon in his left hand, to cover up.*
Example 2: "Completion" pattern
A: Do you know about these drugs? That *Doppler was given sleeping pills, and that it was done half an hour before (the murder at 0:30 am)*? **B:** I didn't know it was half an hour, I just know that he got them. *That definitely points towards Helga!* I remember that *Helga was chatting with Doppler from half past eleven till twelve*.

Taken together, these analyses of empirical inference patterns show that, *if* a matching piece of information was brought into discussion at all, it was typically entered together with the corresponding inference. The crucial part of an inference, even a collaborative one, therefore still seems to be an individual's Eureka-experience that two pieces of information "belong together". As said before, this process is particularly vulnerable for collaborative inferences that need to be drawn online during discussion, based on information just heard and information recalled from memory. A collaboration strategy that might help to overcome this difficulty is to react to all newly learned information during discussion immediately and attentively, trying to integrate that information with prior knowledge (similar to elaboration strategies in individual learning; Weinstein & Mayer, 1986). The results of Study 1 showed us that structuring the problem-solving process on a relatively global level, e.g. by a collaboration script, was not successful in facilitating this process. For the second study, we therefore decided to train students in the application of specific collaboration strategies.

Collaboration Strategies Deduced

We deduced three main collaboration strategies: First, collaborators should be aware that part of their information is interdependent, and will allow for new insights when integrated by inferences. As a consequence, they should *search for interconnections between pieces of information constantly,* on their own as well as in collaboration with their partner. Second, collaborators should be aware that some information may be known to only one of them, and that this information may seem rather irrelevant on its own but might still be important when considered in combination with their partner's knowledge. Thus, they should strive to *pool as much information as possible,* and ask their partner for information that matches any information they could not make sense of themselves. Finally, collaborators should *react immediately and attentively to all new information* they learn from their partner during discussion, inform their partner that this information is new to them, and try to integrate it with matching information. Reacting to a new piece of information promptly and searching one's own memory for a matching piece of information is particularly important for uncovering collaborative inferences. In addition, giving one's partner the feedback that she has just mentioned an unshared piece of information will give her the opportunity to elaborate and explain, either by providing a complete individual inference, or by providing additional information that may facilitate one's own search for matching information and eventually lead to a collaborative inference.

Unfortunately, these strategies are somewhat at odds with an intuitive strategy many students followed in Study 1, which is to first pool as much information as one can remember and *then* try to search for interconnections, in an attempt to proceed in a systematic and orderly fashion. They are also at odds with recommendations for collaborative tasks that do not require the creation of new knowledge at the group level, which advice collaborators to separate information pooling from information integration and decision making (e.g. Brodbeck et al., 2007), a sequencing that had also been part of the collaboration script in Study 1. In addition, the second strategy requires collaborators to discuss information with uncertain relevance for solving their joint problem, which is at odds with the conversational maxim of relevance (Grice, 1975, cf. Fraidin, 2004). Further, students may hesitate to react to new information immediately, because they do not want to be impolite and disrupt the flow of communication (cf. Person, Kreuz, Zwaan, & Graesser, 1995). Thus, it seems necessary to support the application of these collaboration strategies in order to facilitate the drawing of inferences from distributed information.

Study 2: Support for Inferences from Distributed Information

The primary goal in Study 2 was to train collaborators in the use of the three collaboration strategies deduced from the results of Study 1. We aimed to teach this procedural knowledge based on an improved conceptual understanding of the typical task structure and difficulties involved in solving collaborative problem-solving tasks (cf. Rittle-Johnson, Siegler, & Alibali, 2001), specifically the need to combine interdependent information by drawing inferences, and the need to pool unshared information. To help collaborators learn when and how to apply the collaboration strategies (i.e. acquire conditional knowledge; Schraw & Moshman, 1995), we adopted a training approach in Study 2. To make sure that the effects of training were really the result of improved knowledge, all support was provided only during a training phase, and its effects were tested in a subsequent, unsupported test phase. We employed two means of instructional support during training: first, expository text in the form of a small *information booklet* and, second, a computerized *inference tutoring tool*.

Support Measures

Training Task

The training task had the same structural characteristics as the Murder Mystery Inference Task: twelve pairs of interdependent pieces of information were distributed in such a way that collaborators needed to draw shared, individual, and collaborative inferences. Instead of finding a murderer among innocent suspects, however, collaborators had to diagnose a patient with one out of three fictitious tropical diseases. To help collaborators transfer the knowledge and skills acquired in the training phase to their subsequent collaboration on the test task, a *collaborative reflection phase* was added at the end of the training task: After finishing their collaboration on the training task, dyads were informed about the correct solution and important inferences leading towards it. Dyads were encouraged to reflect on the solution collaboratively, evaluate their own collaboration on the training task, and discuss how they might be able "to collaborate even better" on the following test task.

Information Booklet

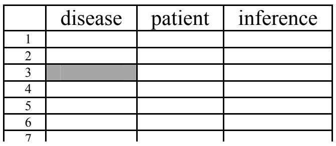
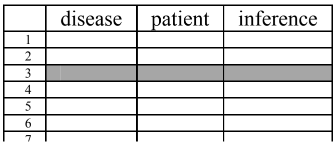
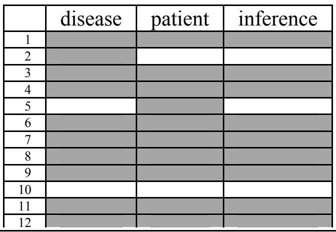
An *expository text*, compiled in a small information booklet, described typical features of collaborative problem-solving tasks as well as the three collaboration strategies. Participants read the text prior to working on the training task. The information booklet described the need to draw inferences due to the interconnectedness of information, the need to pool information thoroughly due to the distribution of information across group members, and the problem of overlooking new information during discussion. Each of these problems was described in a short paragraph, followed by a paragraph applying it to the upcoming training task. Then, a collaboration strategy was formulated. The three collaboration strategies were stated again on the last page of the booklet, advising collaborators to 1) constantly search for connections between pieces of information; 2) pool all information thoroughly, even if its relevance was unclear when it was considered alone; and 3) pay special attention to all new information during discussion and search for matching information immediately.

Inference Tutoring Tool

The inference tutoring tool was a computerized tool that provided dyads with *feedback and prompts* during their collaboration on the training task. The tool was, in this study, yet controlled by a human observer who followed collaborators' discussion and identified when relevant pieces of text information were mentioned and relevant inferences were drawn. The observer filled in a coding sheet that represented all relevant inferences in a matrix where each line corresponded to one inference (cf. Table 3). Based on this graphical representation of inference patterns, four types of messages were sent to students via the tutoring tool (Table 3).

First, whenever any of the 24 pieces of relevant information was mentioned for the first time, *New Information Feedback* was given. Collaborators heard a specific sound and saw the following message: "New information! Matching information is located with {Name A}/ {Name B} / both of you." Thus, New Information Feedback alerted collaborators to a specific piece of information, and prompted them to search for matching information. In doing so, it also modelled the immediate and attentive reaction to new information during discussion, and highlighted the structure of the collaboration task (i.e. the interdependence and distribution of information). At the same time, it served as a positive reinforcement for pooling new information. Second, when an inference pattern was completed, i.e. whenever one of the twelve relevant inferences was drawn, the inference tutoring tool provided *Complete Inference Feedback.* Collaborators heard a specific sound and saw the following message: "Well done! You have just discovered an important connection." This feedback served to inform collaborators about the correctness of their inference, and also as a positive reinforcement.

Table 3: Graphical representation of inference patterns and corresponding tutor messages.

Dialog Event	**Pattern Representation**	**Tutor Message**
Any of the 24 pieces of relevant information mentioned for the first time.		New Information Feedback
Any of the 12 inferences drawn for the first time (completed inference pattern).		Complete Inference Feedback
Incomplete or empty patterns at the end of discussion		Incomplete pattern: Missing Information Reminder Empty pattern: Missing Information Hint

During the last five minutes of their discussion, collaborators additionally received reminders and hints to help them discover information and inferences that were still missing. For each incomplete inference pattern, collaborators received one *Missing Information Reminder*. The reminder consisted of a short summary of the piece of information that had been mentioned but not yet integrated in an inference, for example: "Missing Information. You have already discussed the following information (located with Abby): The patient has been vaccinated against Blue Fever. Matching information is located with Betty." For empty patterns, or when collaborators could not supply missing information despite prompting, *Missing Information Hints* were given. They consisted of a short summary of a piece of information that collaborators had not discussed so far, and a hint towards the location of the matching piece of information, for example: "Missing information. The following information has not yet been discussed: The fire fever is transmitted by eating freshwater fish. Matching information is located with Abby." The *Missing Information* messages served to highlight once more the structure of the collaboration task and remind collaborators of the necessity to pool as much information as possible and combine it by drawing inferences. Further, they were designed to make sure that collaborators would be able to draw all or nearly all possible inferences and thus get a demonstration of a good solution.

Manipulation checks confirmed that the tutoring tool did, in fact, increase dyads' performance to a near-optimal level on the training task: Dyads who were supported by the tutoring tool drew, on average, 100% of the shared, 97% of the individual, and 98% of the collaborative inferences, while dyads collaborating without the tool drew significantly less inferences, in particular of the collaborative type (significant interaction, $F(4; 48) = 10.76$; $p < .001$; *partial* $\eta^2 = .47$).

Method

Design and Procedure

Conditions differed in the amount of training they received prior to their collaboration on the Murder Mystery Inference Task that served as the test task (Table 4). Dyads in the *No_Training condition* collaborated only on the test task, without receiving any kind of instruction regarding their collaboration. Dyads in the *Uninstructed_Training condition* collaborated on the training task, but without specific instruction regarding their collaboration. Dyads in the *Training+Text condition* read the information booklet before collaborating on the training task. Dyads in the *Training+Text+Tutoring condition* read the information booklet as well, and were supported by the inference tutoring tool during their discussion of the training task. During the test phase, no further instructions regarding collaboration and no feedback were given in any condition. During the whole experiment, except for the face-to-face introduction phase and a short recreational break between the two tasks, collaborators sat in adjacent rooms. During the discussion phases, they talked to each other over an audio connection and had access to a shared text document which both of them could see and edit from their own PC.

Table 4: Procedure of the experiment in the four conditions.

<table>
<tr><th>No Training</th><th>Uninstructed Training</th><th>Training + Text</th><th>Training + Text + Tutoring</th></tr>
<tr><td colspan="4">General & technical introduction</td></tr>
<tr><td colspan="2">--</td><td colspan="2">Read information booklet explaining task structure and collaboration strategies</td></tr>
<tr><td rowspan="4">--</td><td colspan="3">Training Task (diagnosis): individual reading phase (20 min)</td></tr>
<tr><td colspan="2">Collaborative discussion (25 min)</td><td>Collaborative discussion (25 min) supported by inference tutoring tool</td></tr>
<tr><td colspan="3">Written justification (5 min)</td></tr>
<tr><td colspan="3">Collaborative reflection phase (10 min)</td></tr>
<tr><td colspan="4">Test Task (murder mystery)
- individual reading phase (30 min)
- collaborative discussion (30 min) and written justification (10 min)</td></tr>
</table>

Participants

Participants were 72 female university students (mean age = 22.4 years; no psychology students and no medical students) in 36 dyads. Only students who did not know each other before collaboration were assigned to the same dyad. Nine dyads participated per condition. Dyads in the three training conditions were randomly assigned to one of these conditions. Dyads in the No_Training condition, who had to be scheduled for shorter experimental sessions, were recruited from the same pool of participants and run in parallel to trained dyads, but not randomly assigned. Post-hoc analyses confirmed that conditions did not differ in participants' age, subjects of study, academic grades, computer use, knowledge about tropical diseases (assessed for trained dyads only), or experience with murder mystery stories and films.

Dependent Measures

During a dyad's discussion of the murder mystery task, a trained experimenter coded which of the twelve solution-relevant inferences were actually drawn. We then counted the number of inferences of a given type that had been drawn, and divided this number by the number of possible inferences of this type. In this way, we established the relative frequencies with which inferences of a given type were drawn (*inference drawing frequency*). For example, if a dyad mentioned three of the four possible individual inferences during their discussion, this was represented as an inference drawing frequency of .75 for that inference type. *Solution correctness*, i.e. whether a dyad agreed on the correct suspect, served as outcome measure. More detailed analyses of the collaborative problem-solving process, e.g. concerning the ways in which information was exchanged and integrated into inferences, will be conducted once all discussions have been transcribed.

Results (Test Task)

Figure 1 shows the relative frequencies with which dyads drew solution-relevant inferences, depending on inference type and the kind of instructional support that had been provided in the training phase. There was a main effect of instructional support ($F(3;32)$= 4.43; *p*= .01, *partial* η^2= .29), with the lowest average inference drawing frequency (.74) in the No_Training condition and the highest average inference drawing frequency (.93) in the Training+ Text+ Tutoring condition (linear trend; $p < .01$). There were no differences in the average inference drawing frequency between the two conditions who solved the training task without support from the tutoring tool (average inference drawing frequency = .82 in both conditions). The result also replicate the findings from our first study regarding the negative effects of information distribution: Inference drawing frequency was .72 for collaborative inferences, .83 for individual inferences, and .93 for shared inferences ($F(2;64)$= 10.37; $p<$ .001; *partial* η^2= .25). Planned comparisons confirmed a highly significant difference ($F(1;32)$= 21.37; $p<$ .001; *partial* η^2= .40) between shared inferences and inferences from unshared information (individual inferences and collaborative inferences), and a marginally significant difference between individual and collaborative inferences ($F(1;32)$= 4.07; *p*= .05; *partial* η^2= .11). The difference between inference drawing frequencies for the three inference types was the most pronounced in the No_Training condition; and instructional support had the largest impact on the inference drawing frequency for collaborative inferences. However, this interaction was not significant.

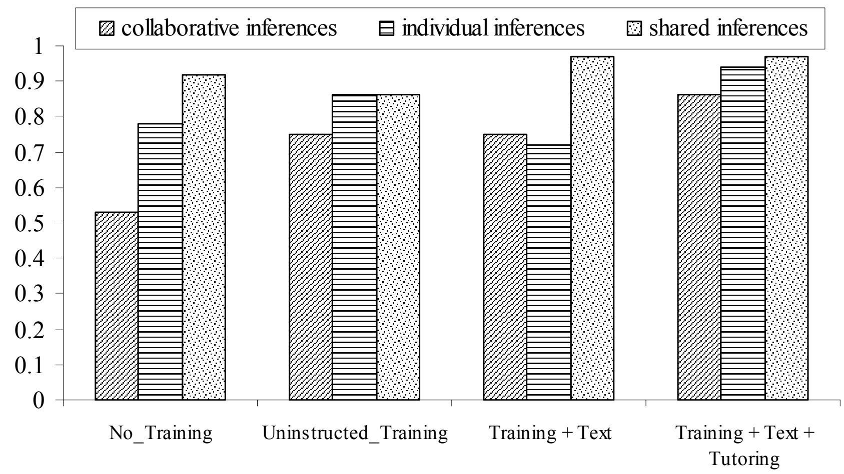


Figure 1: Inference drawing frequencies in the test phase, depending on inference type and instructional support provided during training

Overall, 2/3 of all dyads solved the Murder Mystery Inference Task correctly. The Training+Text+ Tutoring condition showed the highest solution rate (8 of 9 dyads solved the case correctly). Dyads in the Uninstructed_Training (7 correct) and the No_Training (6 correct) conditions were also quite successful. The Training+Text condition showed the lowest solution rate (3 correct; differences n.s.).

Discussion

Collaborative inferences from interdependent information that is distributed between group members are an important means of creating genuinely new knowledge at the group level, i.e. knowledge that could not have been constructed by any individual alone. Thus, they offer a high potential for improving collaborative problem-solving, as well as for fostering group members' learning from their collaborative experience. However, we have demonstrated in two experimental studies that this type of inference is also the most difficult one to achieve. It therefore seems that, even in a situation in which group members' resources are interdependent and would result in substantial process gains when integrated, successful collaboration and better problem solutions are not guaranteed. While support is necessary, it is not easy to achieve, as Study 1 has shown. In Study 2, we have demonstrated that training collaborators in the use of specific collaboration strategies may be a promising way of improving collaborative knowledge construction through inferences. Reflected training on a collaborative problem-solving task with interdependent and distributed information led to more inferences being drawn in a test task. This training was most successful when supported by online tutoring of inferences designed to facilitate the application of three collaboration strategies: searching for interconnections between pieces of information, pooling as much information as possible, and reacting immediately and attentively to newly learned information during discussion. These positive results were obtained during subsequent, unsupported collaboration, indicating that collaborators had learned important skills as well as the ability to apply them in a goal-directed way. It is also important to note that merely informing collaborators about task difficulties and helpful collaboration strategies without tutoring them was not more effective than uninstructed training. In fact, the lower solution rates in the Training+Text condition show that receiving information about task difficulties and helpful collaboration strategies may even have confused collaborators and hindered collaborative problem-solving.

We have obtained these results in a laboratory setting with a set of carefully designed tasks. Therefore, their applicability in more authentic settings, like classrooms or work teams, and with more authentic task materials will have to be tested by further research. Nevertheless, our tasks are structurally equivalent to many collaborative tasks in the real world, where groups are often formed because their members hold complementary knowledge resources (e.g. expertise, experience, ideas) needed to solve the problem (e.g. Kerr & Tindale, 2004), and where complex problems confront the group with interdependent information (e.g. Fraidin, 2004; Pennington & Hastie, 1993) and the necessity to construct new knowledge beyond the given facts (e.g. Dunbar, 2000). Thus, members of authentic groups, as well, need to co-construct new knowledge by drawing inferences, individually as well as collaboratively. For example, when studying groups of scientists doing high-end research in molecular biology Dunbar (2000) found that successful scientific teams engaged in a form of "distributed reasoning" that included the collaborative drawing of inferences, where "one scientist may provide one premise to the induction, another a second premise, and a third the conclusion" (p. 55). Our findings show that in less experienced groups this genuine co-construction of knowledge through collaborative inferences may be rare. As a result, group members may miss opportunities to generate new knowledge and may agree on suboptimal solutions. However, our findings also point towards helpful strategies for overcoming this deficit. Specifically, collaborators working with distributed, interdependent information should aim to integrate the extensive pooling of information with the prompt elaboration of newly learned information during discussion. Reflected experience with structurally similar tasks, in particular when guided by some kind of tutoring, may help collaborators to acquire these skills.

References

Aronson, E., Balney, N., Stephan, C., Sikes, J., & Snapp, M. (1978). *The jigsaw classroom*. Beverley Hills, CA: Sage.

Brodbeck, F. C., Kerschreiter, R., Mojzisch, A., & Schulz-Hardt, S. (2007). Improving group decision making under conditions of distributed knowledge. *Academy of Management Review, 32*, 459-479.

Collins, A., & Michalski, R. (1989). The logic of plausible reasoning: a core theory. *Cognitive Science, 13*, 1-49.

Dunbar, K. (2000). How scientists think in the real world: implications for science education. *Journal of Applied Developmental Psychology, 21*(1), 49-58.

Finlay, F., Hitch, G. J., & Meudell, P. R. (2000) Mutual inhibition in collective recall: evidence for a retrieval based account. *Journal of Experimental Psychology: Learning, memory & Cognition, 26,* 1556-1567.

Fraidin, S. N. (2004). When is one head better than two? Interdependent information in group decision making. *Organizational Behavior and Human Decision Processes, 93,* 102-113.

Grice, H.P. (1975). Logic and conversation. In P. Cole & J.L. Morgan (Eds.), Syntax and semantics 3: Speech acts. New York: Seminar Press.

Härder, J., & Spada, H. (2004). Exchange of unshared information and their utilization in collaborative inferences in work via a desktop video-conferencing system. Paper presented at the conference of the German Society of Psychology (DGPs) 2004.

Jeong, H., & Chi, M. (2007). Knowledge convergence and collaborative learning. *Instructional Science, 35* (4), 287-315.

Kerr, N. L. & Tindale, R. S. (2004). Group performance and decision making. *Annual Review of Psychology, 55*, 623-655.

Kneser, C., & Ploetzner, R. (2001). Collaboration on the basis of complementary domain knowledge: observed dialogue structures and their relation to learning success. *Learning and Instruction, 11,* 53-83.

Kollar, I., Fischer, F., & Hesse, F. (2006). Collaboration scripts – a conceptual analysis. *Educational Psychology Review, 18*, 159-185.

Meier, A., & Spada, H. (2007). Information pooling and processing in group problem-solving: analysis and promotion of collaborative inferences from distributed information. In D. S. McNamara & J. G. Trafton (Eds.), *Proceedings of the 29th Annual Cognitive Science Society* (pp. 473-479). Austin, TX: CSS

Pennington, N., & Hastie, R. (1993). Reasoning in explanation-based decision making. *Cognition, 49,* 123-163.

Person, N., Kreuz, R., Zwaan, R., & Graesser, A. (1995). Pragmatics and pedagogy: conversational rules and politeness strategies may inhibit effective tutoring. *Cognition and Instruction, 13*(2), 161-188.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting problem-solving in computer-mediated settings. *The Journal of the Learning Sciences,* 14, 201-241.

Rittle-Johnson, B., Siegler, R.S., & Alibali, M.W. (2001). Developing conceptual understanding and procedural skill in mathematics: an iterative process. *Journal of Educational Psychology, 93,* 346-362.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7,* 351-371.

Stasser, G. & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology, 48,* 1467-1478.

Suthers, D. (2006). A qualitative analysis of collaborative knowledge construction through shared representations. *Research and Practice in Technology Enhanced Learning, 1,* 1-28.

Webb, N.M., & Palincsar, A.S. (1996). Group processes in the classroom. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology (pp. 841-873).* New York: Macmillan.

Weinstein, C. E. & Mayer, R. E. (1986) The teaching of learning strategies. In M. C. Wittrock Ed.), *Handbook on Research in Teaching* (3rd Edition. pp. 315-327). New York: Macmillan.

Acknowledgments

The first author is being funded by the Virtual Graduate School “Knowledge Acquisition and Knowledge Exchange with New Media” (www.vgk.de) of the German Science Foundation. The authors would like to thank Kurt VanLehn for inspiring discussions about the design of the inference tutoring tool.