Effects of resource distribution and feedback on computer-mediated collaboration in dyads

Joerg ZUMBACH*, Peter REIMANN**, and Jochen SCHÖNEMANN*

** Department of Psychology, University of Heidelberg, Germany*
*** Computer Supported Learning and Cognition (CoCo), University of Sydney, Australia*

Abstract. Two methods for fostering collaborative behavior in dyads are compared: a feedback-mechanism to scaffold collaborative behavior, and use of distributed learning resources. Based on recent research on what constitutes effective collaboration behavior, we developed a coding scheme to categorize learner-learner interaction as collaboration. In a collaboration environment for learner dyads specifically implemented to test our hypotheses, a human observer identified, in parallel with students' interactions, instances of real collaboration, and gave online feedback. In the same two-factorial design, we varied the resources available to the partners. The influence of these interventions on outcomes related to knowledge acquisition, problem-solving, group climate and collaborative behavior was tested. Overall, collaboration was infrequent. Results suggest there are benefits in providing a feedback approach in fostering collaboration and enhancing problem-solving quality.

1. Approaches to collaboration support

For groups to realize their potential as a learning resource, more needs to be done than just providing them with a tool to exchange information. Groups have a number of functions: in addition to accomplishing a learning goal, getting a task done or solving a problem, groups have to manage their interaction, establish and maintain common ground, keep the group stable and take care of individual members' concerns [1]. The move to net-based forms of interaction among group members makes it even more important to attend to these group functions.

A number of methods for scaffolding collaboration have been developed. A general distinction needs to be made between support that is design-based (all decisions are made before the collaboration begins and there is a blueprint for how collaboration will be conducted) and support that is provided dynamically (the major decisions are made based on observations from learners' ongoing interaction, and decisions are made at "run time").

One method to scaffold collaboration by design involves the selection of specific tasks and resource distributions. Examples are Group Jigsaw [2], Reciprocal Teaching [3] or Problem-Based Learning [4]. The rationale behind this approach is that students are forced to collaborate in order to accomplish a goal because of task demands and the manner in which information necessary for accomplishing the task is distributed. An elementary method is to distribute expertise among group members in early stages of group formation [5] [6]. As this is not always possible (for example, when ad-hoc groups are formed) other methods have to be taken into account. A second and more applicable method is to vary resources (for example, the learning material). This method implies that only groups in which members exchange their resources or put them together can successfully complete a (learning) task. Komis et al. [7] or Muehlenbrock [8] provide examples of this methodology by distributing learning resources for collaborative problem solving among learners. In the study of Komis et al. [7] this intervention did not automatically lead to better learning outcomes (in this case, quality of solutions) compared to dyadic groups with individuals owning all relevant material. However, groups with distributed resources were more active, exchanged more contributions and became more involved in discussion.

A number of researchers in the field of Computer-Supported Learning (CSCL) have begun to address this issue of *collaboration management*. Managing on-line collaboration by means of intelligent support can take a number of forms: mirroring, metacognitive and advice tools [9]. They all require the ability to trace the interaction going on among the team members in some level of detail (*data collection*). Information about learners' collaborative performance can be traced on a number of dimensions. A first dimension is *problem solving*: how does the contribution of a group member change the problem state and contribute to the solution [10]. A second dimension is *participation*: how often, in what sequence, around which topics do members contribute to the group's work [4]? A third dimension concerns members' *emotional and motivational state*, or well-being. We [10] [11] have been able to show that enriching CMC by means of dynamic motivational/emotional parameters of group members helps to positively influence the group climate as well as individuals' motivation [12] and, thus, contributes to groups' well-being functions [1] [13]. A fourth dimension along which feedback can be provided is *collaboration behavior* proper: how does the action of one group member affect other group members' interaction behavior? Of particular interest in this regard is knowledge sharing [14].

Design-based and dynamic approaches can easily be combined and, given that they address different issues and phases of group work, this should probably occur. To prepare the ground for this, we have conducted a study that analyses how combining the distribution of learning resources (a design approach) with providing feedback on collaboration behavior (a dynamic approach) affects various parameters of collaboration. Varying both factors in one experimental design allows us not only to assess the effects of combining the two approaches, but also to study interactions between the two methods.

2. Experimental study

2.1. Identifying instances of collaboration in dyadic interactions

Analysing collaboration behavior requires to define units of analysis that capture interaction among group members. (Aggregated) observations on individual participation behavior and assessment of individual psychological states are not sufficient. Table 1 shows the categories derived from a literature review for dyadic learning in terms of action-reaction-patterns (references to the underlying literature are in the note at the bottom of the table).

Letters A to I in Table 1 describe nine different possible ways to start collaboration (resulting in 26 possible action-reaction chains). All utterances, for example, in category A classify openings with a proposal for a problem solution (or all openings in category F represent coordinative contributions). Each code stands for another chain of interactions and is a unique collaborative event.

Table 1: Operationalization of collaborative events in dyads.

	Action of Person 1	Reaction of Person 2	Reaction of Person 1 (to Person 2)
A1	proposal (related to problem) [1, 2, 3] also: contraproposal [1, 2, 3]	agree/ accept [1, 3, 7]	
		or	
A2		support [1]	
		or	
A3.1		propose a next step [1]	agree/ accept [1, 3, 7]
			or
A3.2			support [1]
			or
A3.3			propose a next step [1]
			or
A3.4			document the proposal [1]
		or	
A4		document the proposal [1]	
		or	
A5.1		query, challenge [2]	modify proposal (for solution) [2]
			or
A5.2			assert or justify or explain (in this case a further positive reaction of person 2 is necessary) [2]
			or
A5.ex			agree, bear out (in this case: no collaboration) [1]
		or	
A6		request time (e.g. for documenting or thinking about) [1]	agree/ accept [1, 3, 7]
		or	
A7		elaborate (active) [2, 6]	
		or	
A8		elaborate (passive) [2, 6]	perform [2]
		or	
A9		ask (in case of lack of understanding) [1, 2, 7]	restate or repeat [2]
B1	ask for help advice [2, 3, 4]	inform [2, 3]	
C1	shift focus to a new aspect [2]	agree/ accept [1, 3, 7]	
		or	
C2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
D1	encourage partner or peer group [2, 5, 8] support group cohesion [2, 5, 8]		
E1	refer to emotional-motivational process [2, 4, 5, 8]	acknowledge [1, 2, 3, 7]	
		Or	
E2		Answer (referring to contribution) [2, 3]	
F1	coordinate task (steps for solution) [8, 9]	agree/ accept [1, 3, 7]	
		Or	
F2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
G1	reflect on group processing or analyze group performance [5, 9]	agree/ accept or answer [1, 3, 7]	
		Or	
G2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
H1	construct meta-knowledge/ reflect on distribution of knowledge [8]	agree/ accept or answer [1, 3, 7]	
I1	drag text block in shared workspace (chat) [2, 5, 7]	continue to work with text	

Notes:
[1] [3] [2] [15][3] [4] [4] [2] [5] [16] [6] [9] [7] [17] [8] [18] [9] [19].

In addition to the coding scheme, we developed a computer supported learning scenario for dyadic problem solving. The technical platform was an HTML-based interface with several components (see Figure 2). Each learner had (via a Web browser) access to a frame page with several integrated components. The first component is a window containing tasks and the learning material (HTML; left upper corner of Figure 2). The second component is a text editor where solutions to the presented problems had to be developed (left lower corner in Figure 2). The third component was a chat window for possible collaboration purposes (upper right column in Figure 2). The fourth and last component was an MS Excel© based counter providing feedback about the number of collaborative events (lower right corner).

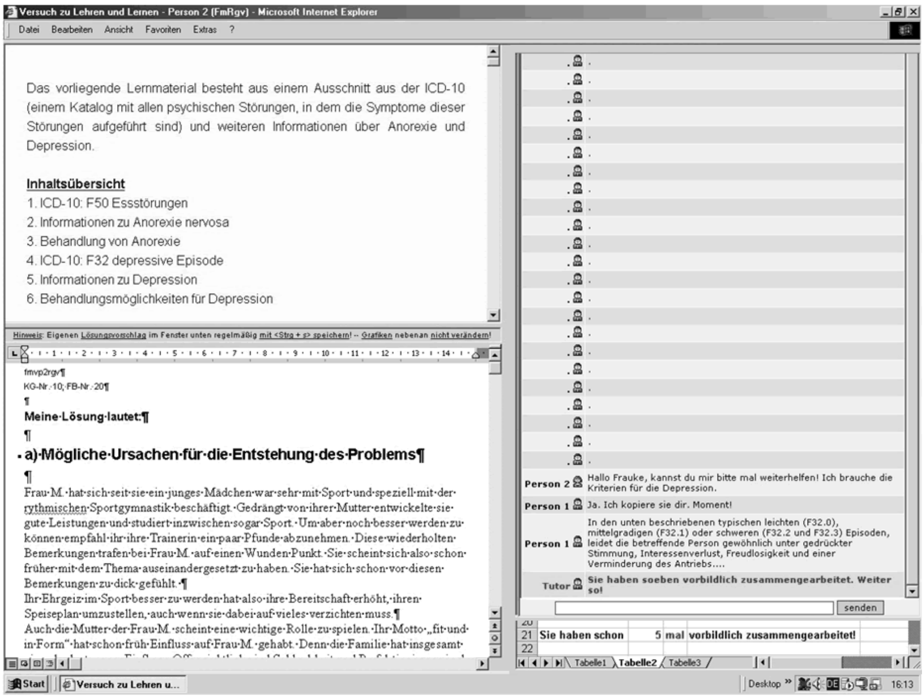


Figure 1: User Interface for individual and cooperative learning.

2.2. Experimental setting

Learners were randomly assigned to pairs and conditions and participated synchronously in different rooms. After an introductory pre-test, participants were introduced to the learning environment. Each student had the same task, which was to solve a problem in the field of clinical psychology in a written essay (with the text editor). The problem itself was a case description about a woman with a co-morbid disorder (depression and anorexia nervosa).

The main purpose of this study was to assess the influence of two basic interventions on the quantity of collaboration and cognitive outcomes as well as group climate: first, the influence of distributed learning resources and second, the availability of feedback on collaborative events (i.e. an underlying 2 X 2 factorial design). The first factor was the variation of the learning resources (homogenous versus distributed). In one condition (homogenous resources), each learner had access to the complete learning material relevant for solving the case. In a second condition, one participant had access only to relevant passages about depressive disorders and the other participant of the dyad to the learning material related to anorexia nervosa. As both parts were single chapters in the underlying textbook, they were simply divided. The second factor was the availability or absence of feedback on collaborative events. In one condition, the dyadic learning groups received feedback as operationalized and described above. In a second condition, the experimenter analyzed collaborative feedback events but no feedback was provided (the visualization was also removed from the user interface).

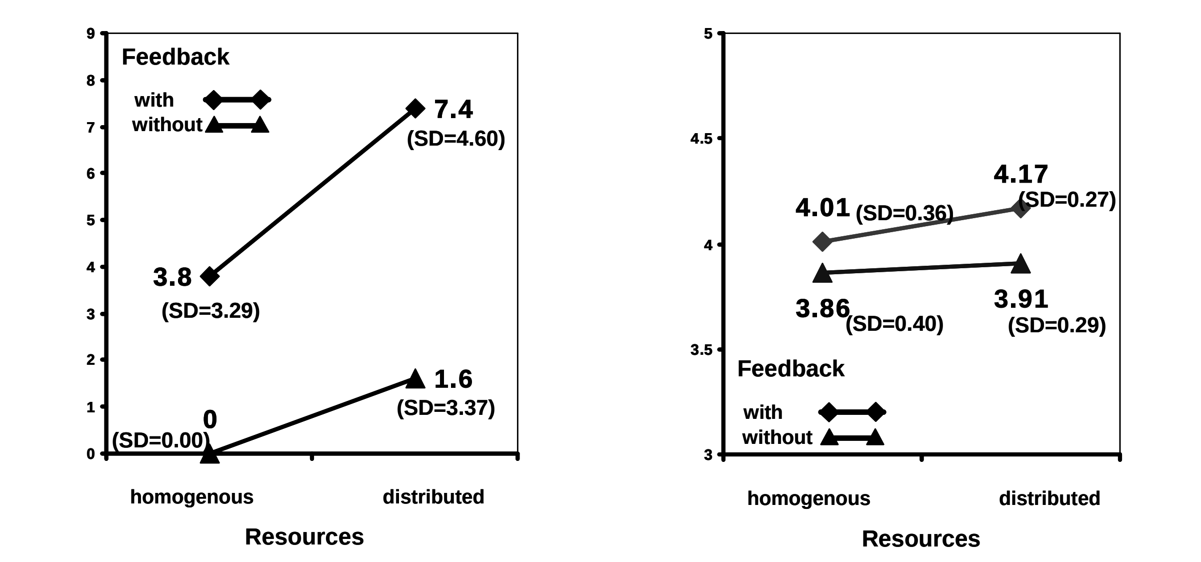
In order to realize the feedback condition, we had to rely on human judgement because sufficiently powerful methods for computer-based analysis of students' written exchanges were not available to us. Thus a trained human rater analyzed the discourse in the chat window as it was typed in, and in this manner monitored the contributions of the partners in the dyads. Whenever the rater identified an interaction sequence as matching one of the categories mentioned in Table 1, he gave (only general) feedback to the dyad: "You have successfully cooperated! Keep on!" There was no other interference by the experimenter.

2.3. Main Results

Our major goal was to find out if distributed learning resources as well as collaboration feedback improve collaborative learning and, thus, contribute to learning success, the quality of problem-solving and have a positive influence on group climate. Overall, 40 participants (7 men and 33 women with a mean age of 24.5 years; most of them students at the University of Heidelberg) took part in this study. In a pre-test we assessed participants' prior knowledge with a test related to the learning objectives of the case solution. The same test was used as post-test. In the post-test we also assessed the group climate experienced by participants using an adopted subscale of the Medical School Learning Environment Survey [20] [21]. We also took into account the number of collaborative events as well as each participant's quality of problem solution as dependant variables. Overall, participation in this study took about 2 ½ hours with pre- and pos-test lasting about one hour altogether.

Results related to absolute events of collaboration revealed rather poor cooperation among individual group members (see Figure 2, left side). In the condition with homogenous resources and no collaboration feedback there was no collaborative event at all. The several interventions led to an increased number of collaborative interactions (Chi-square (df=1) = 3.86, $p<.05$; calculated on group level). The highest amount was in the condition with distributed resources and collaboration feedback. The numbers are, in general, very low (each dyad had about 1 ½ hours time for problem-solving/cooperation). Several aspects might explain this. First, students had to read the case description and scan the learning material (which contained about 8500 words overall; learners were encouraged to read selectively). This took a major part of the available time. Second, the chat limited exchange between students not only to short sentences, but also allowed them to exchange longer paragraphs of the learning material or their own problem solutions. Most interaction chains (considered here as collaborative events) included exchange of major text parts.

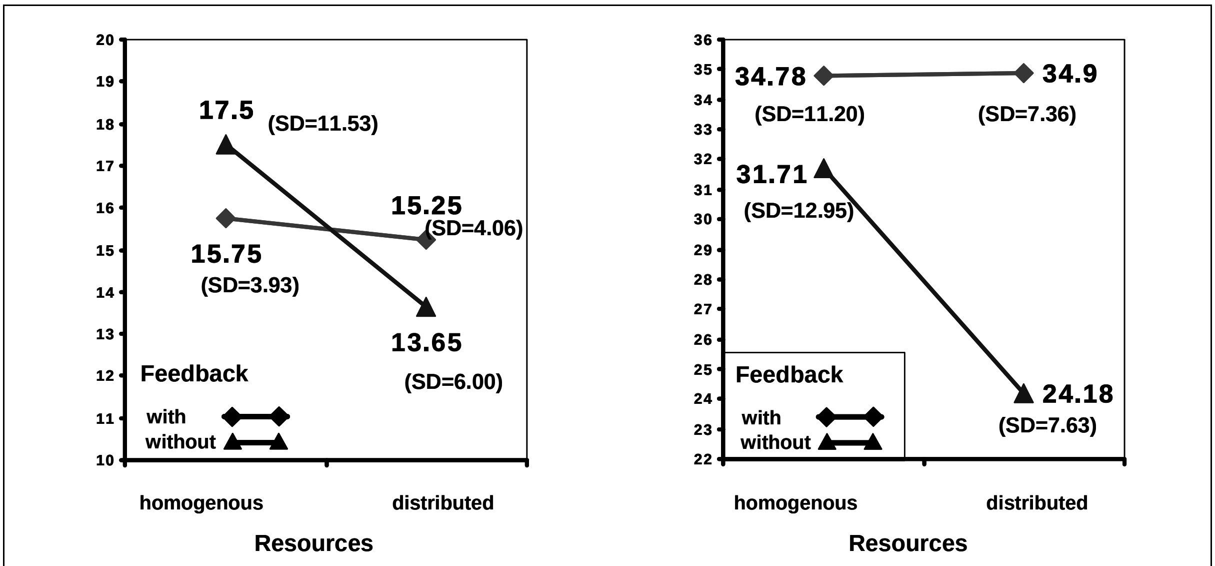
Another dependant variable was the group climate as experienced by the learners. There was no effect of the factor "distributed resources" but a marginal effect of "collaboration feedback" ($F(1, 38) = 3{,}744$, $p< .061$): dyads that received this kind of feedback experienced the group climate better than dyads without this feedback (see Figure 2 right).



Number of collaborative events *Group climate*

Figure 2: Results on collaborative events and group climate.

We were also interested in learning outcomes. Results of the standardized knowledge tests (pre- and post test) were compared in order to compute an overall score of knowledge acquisition from before to after the treatment. Results reveal no significant effects (see Figure 3, left). Participants in the condition with distributed resources and no collaboration feedback received the lowest scores. A lack of collaboration as well as additional learning material (owned by the other partner of the dyad) could explain this.



Knowledge increase *Problem-solving quality*

Figure 3: Results in knowledge tests and problem solving.

For analyzing the quality of problem solutions provided by the participants, we developed an expert solution (including causes, diagnoses and therapy of depression and anorexia nervosa as well as interrelationships between both disorders). Two expert raters compared participants' case solutions with the expert model using a scoring scheme (r_{corr}=0.97). Participants in dyadic groups with collaboration feedback scored significantly higher than those in groups without feedback (F(1, 38) = 4,687, p< .037; see Figure 3, right). There was no significant effect of distributed versus homogenous resources (F(1, 38) = 1,353, n.s) as well as no significant interaction effect. The following table shows results on correlations of dependant measures.

Table 2: Correlation matrix of dependant variables.

	Number of collaborative events	Group climate	Problem-solving quality	Knowledge (post test)
Number of collaborative events	-	0.56**	0.24	-.02
Group climate	0.56**	-	0.18	-0.17
Problem-solving quality	0.24	0.18	-	0.39*
Knowledge (post test)	-.02	-0.17	0.39*	-
Notes: Spearman R correlation. * = p<.05; **p<.01				

3. Summary and Discussion

In a 2 x 2 factorial experiment we tested the influence of distributed learning resources as well as feedback related to collaboration on outcomes of knowledge acquisition, quality of problem-solving, group climate and number of collaborative events in a network-based cooperative learning scenario. Learners in dyads had to solve a single case following a Problem-Based Learning approach. Results suggest that a distribution of learning resources and feedback about collaboration enhance collaborative behaviour (compared to homogenous learning material and/or no collaboration feedback). Although we could not find an enhancement in knowledge acquisition using a common test format, we were able to show that the feedback approach led to significantly better problem solutions. Results related to group climate also suggest that feedback on collaborative events could foster collaboration itself and, thus, positively influence group climate.

Taken together, results suggest that by distributing learning material, collaboration can be positively influenced but this will have no substantial effect on cognitive outcomes or group climate. In addition, monitoring students' interaction behaviour and providing feedback on collaboration triggers further collaborative behaviour and influences problem-solving processes as well as group climate.

4. REFERENCES

[1] McGrath, J. E. (1991). Time, Interaction, and Performance (TIP). A theory of groups. Small Group Research, **22**, 2, 147-174.

[2] Aronson, E. (1984). Förderung von Schulleistung, Selbstwert und prosozialem Verhalten: Die Jigsaw-Methode [Enhancement of performance in school, self value and pro social behavior: The Jigsaw method]. In G. L Huber, S. Rotering-Steinberg und D. Wahl (Hrsg.). *Kooperatives Lernen* [cooperative learning] (pp. 48-59). Weinheim: Beltz-Verlag.

[2] Barron, B., Martin, C., Roberts, W., Osipovich, A. and Ross, M. (2002). Assisting and assessing the development of technological fluencies: Insights from a project-based approach to teaching computer science. In G. Stahl (Ed.), *Computer support for collaborative learning: Foundations for a CSCL community* (pp. 668-669). Hillsdale, N.Y.: Erlbaum.

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

[4] Barrows, H. S. (1985). *How to Design a Problem-based Curriculum for the Preclinical Years*. New York: Springer.

[3] Barron, B., and Sears, D. (2002). Advancing understanding of learning in interaction: How ways of participating can influence joint performance and individual learning. In G. Stahl (Ed.), *Computer support for collaborative learning: Foundations for a CSCL community* (pp. 593-594). Hillsdale, N.Y.: Erlbaum.

[4] Barros, B., and Verdejo, M. F. (2000). Analysing student interaction processes in order to improve collaboration. The DEGREE approach. *International Journal of Artificial Intelligence in Education*, **11**, 221-241.

[5] Hermann, F., Rummel, N., and Spada, H. (2001). Solving the case together: The challenge of net-based interdisciplinary collaboration. In P. Dillenbourg, A. Eurelings, and K. Hakkarainen (Eds.), *European perspectives on computer-supported collaborative learning. Proceedings of the European conference on computer-supported collaborative learning* (pp. 293-300). Maastricht, NL: McLuhan Institute.

[6] Rummel, N., Spada, H., Hermann, F., Caspar, F., and Schornstein, K. (2002). Promoting the coordination of computer-mediated interdisciplinary collaboration. In G. Stahl (Ed.), *Computer support for collaborative learning: Foundations for a CSCL community* (pp. 558-560). Hillsdale, N.Y.: Erlbaum.

[7] Komis, V., Avouris, N., and Fidas, C. (2003). A study on heterogeneity during real time collaborative problem solving. In B. Wasson, S. Ludvigsen, and H.-U. Hoppe (Eds.), *Designing for Change in Networked Learning Environments* (pp. 411-420). Dordrecht: Kluwer.

[8] Mühlenbrock, M. (2001). *Action-based Collaboration Analysis for Group Learning*. Amsterdam: IOS Press

[9] Kneser, C., Fehse, E., and Hermann F. (2000). Kooperatives Lernen auf der Grundlage komplementären Vorwissens: ein Experiment und eine Simulationsstudie [Collaborative Learning on the Basis of Complementary Knowledge: An Experiment and a Simulation Study]. *Kognitionswissenschaft*, **9**, 17-31.

[10] Zumbach, J., and Reimann, P. (2003). Influence of feedback on distributed problem based learning. In B. Wasson, S. Ludvigsen, and H.-U. Hoppe (Eds.), *Designing for Change in Networked Learning Environments* (pp. 219-228). Dordrecht: Kluwer.

[11] Zumbach, J., Mühlenbrock, M., Jansen, M., Reimann, P., and Hoppe, H.-U. (2002). Multidimensional tracking in virtual learning teams. In G. Stahl (Ed.), *Computer support for collaborative learning: Foundations for a CSCL community* (pp**.** 650-651). Hillsdale, N.Y.: Erlbaum.

[12] Zumbach, J., Hillers, A., and Reimann, P. (2003). Supporting Distributed Problem-Based Learning: The Use of Feedback in Online Learning. In T. Roberts (Ed.), *Online Collaborative Learning: Theory and Practice* (pp. 86-103). Hershey, PA: Idea.

[13] McGrath, J. E., and Hollingshead, A. B. (1994). *Groups interacting with technology*. Thousand Oaks, CA: Sage.

[14] Soller, A. (2004). Computational modeling and analysis of knowledge sharing in collaborative distance learning. *User modeling and user-adapted interaction: The journal of personalization research*, **14,** 4, 351-381.

[15] Soller, A., and Lesgold, A. (2000). Knowledge acquisition for adaptive collaborative learning environments. In American Association for Artificial Intelligence, *Proceedings of the AAAI Fall Symposium: Learning How to Do Things* (pp. 57-64). Cambridge: MIT Press.

[16] Johnson, D. W., and Johnson, R. T. (1996). Cooperation and the use of technology. In D. H. Jonassen (Ed.), *Handbook of research for educational communication and technology* (pp. 1017-1044). New York: Macmillan.

[17] Clark, H. H. (1996). *Using language*. Cambridge: University Press.

[18] Reinmann-Rothmeier, G., and Mandl, H. (1999). *Teamlüge oder Individualisierungsfalle? Eine Analyse kollaborativen Lernens und dessen Bedeutung für die Förderung von Lernprozessen in virtuellen Gruppen* [Team lie or individualization trap? An analysis of collaborative learning and its meaning for the promotion of learning processes in virtual groups] (Forschungsbericht Nr. 115). München: Ludwig-Maximilians-Universität, Lehrstuhl für Empirische Pädagogik und Pädagogische Psychologie.

[19] Welch, M., and Tulbert, B. (2000). Practitioners' perspectives of collaboration: A social validation and factor analysis. *Journal of Educational and Psychological Consultation*, **11**, 3-4, 357-378.

[20] Lancaster, C. J., Bradley, E., Smith, I. K., Chessman, A., Stroup-Benham, C. A., and Camp, M. G. (1997). The effect of PBL on students' perceptions of learning environment. *Academic Medicine*, **72**, 10, Suppl. 1, 10-12.

[21] Marshall, R. E. (1978). Measuring the medical school learning environment. *Journal of Medical Education,* **53**, 98-104.