Title: Monitoring students' collaboration in computer-mediated collaborative problem-solving: Applied feedback approaches.

Running Head: Monitoring collaborative online learning.

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Abstract

The research describes a methodology for applying design- and management-based scaffolding techniques aimed to enhance cooperative behaviour. Based on assumptions of how successful online learning groups act together we developed feedback-based mechanisms that aimed at contributing to group functions of well-being, member support, and productive learning outcomes. The collaborative online learning environments were enriched by functions such as tracking, analyzing, and feeding back parameters of participation, collaboration, motivation, and emotional state to group members. Two studies were conducted to analyze effects of these mechanisms. In the first study, we showed advantages of feedback on processes of group well-being, parameters of participation and interaction. In the second study, we combined feedback approach for monitoring and fostering collaborative behaviour with a design-based approach using distributed learning resources. Results suggest that by distributing learning material collaboration can be positively influenced. However, this intervention had no substantial effect on cognitive outcomes or group climate. In addition, monitoring students' interactions and providing feedback on collaboration triggered collaborative behaviour, facilitated problem-solving processes, and enhanced group climate.

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Introduction

Current research on Computer-supported Collaborative Learning CSCL has shown that there is a need of fostering and enhancing students' collaboration in network-based learning scenarios (Koschmann, Suthers & Chan, 2005). Several methods for supporting computer-mediated collaborative learning have been developed in the past, such as coaching or scaffolding. Coaching aims at behavioural change and typically involves a human instructor directly interacting with individual students or a small group (Hannafin, Land & Oliver, 1999). In comparison, scaffolding learning and collaboration is achieved in a more indirect manner by incorporating constraints and affordances into the design of the collaboration and the collaboration environment.

There are several reasons why individuals in a group do not automatically cooperate and act as a group. This is in particular the case for groups that are newly formed, or formed for a comparatively short time, or where group members work under conditions where individual learning goals are predominant (Reimann, 2003). Cooperation problems particularly occur in groups with no or little experience in (net-based) group work (Salmon, 2000). Under such circumstances, groups profit greatly from guidance regarding cooperation and collaboration. Such guidance can consist of monitoring group members' progress and providing coaching and scaffolding where necessary. By these means, disorientation, conflicts and cognitive load can be reduced. Such support is particularly useful in computer-mediated collaboration. In computer-mediated communication (CMC), even basic communication is difficult due to problems such as reduced cognitive and social grounding (Dillenbourg & Traum, 1996; 2006), coordination overhead, and more need for attention management.

The continouos evaluation of learners in computer-supported collaborative learning environments is a prerequisite to provide appropriate scaffolding.

Scaffolding Computer Supported Collaborative Learning

Several strategies to enhance collaborative learning have been indentified. One way is to coach learners in collaborative behaviour and to teach the use of technology in CSCL environments and the coping with technological obstacles (e.g., Rummel, Spada, Hermann, Caspar & Schornstein, 2002). The major purpose of this paper is to examine mechanisms of collaboration scaffolds.

Collaboration can be scaffolded in various ways, including behavioural and technological scaffolding or a combination of both. Figure 1 shows a taxonomy of scaffolding methods provided by Zumbach, Schönemann and Reimann (2005; see also Jermann, Soller & Lesgold, 2004). We make a basic distinction between (instructional) design approaches and collaboration management approaches. In instructional design-based scaffolding, all decisions are made before the collaboration begins. This leads ideally to a kind of blueprint for how collaboration will be conducted. In contrast, in management-based scaffolding the major interventions are made based on observations of learners' ongoing interaction. Typically, this involves monitoring students' performance and (automatic) analysis of performance. Decisions and interventions are made at 'run time', so to speak.

*** Insert Figure 1 about here ***

Design-based Scaffolding Approaches

Design-based scaffolding approaches involve instructional decisions that are typically made well before a collaborative learning session takes place. A popular method is to select specific tasks and resources and to distribute them among group members. Well-known approaches are Group Jigsaw (Aronson, 1984) or Reciprocal Teaching (Palinscar & Brown, 1984). The rationale behind these approaches is straightforward: To design situations (tasks and resources) in which students have to collaborate in order to accomplish the task goal because of task and resource demands. Without cooperating and collaborating groups would not be successful in accomplishing predefined learning goals. Another method involves distributing expertise among group members in the early stages of group formation (e.g. Hermann, Rummel & Spada, 2001; Rummel et al., 2002). If this is not possible (for example, when ad-hoc groups are formed) other methods such as distributing resources can be applied. This strategy implies that only groups in which members exchange their resources or put them together can successfully complete a (learning) task (cf. Komis, Avouris & Fidas, 2003; Muehlenbrock, 2001). Distributing learning material among group members does not automatically lead to better learning outcomes, but can result in learners being more active, to exchange more information and to get involved deeper in discussions (Komis et al., 2003).

Another common approach to foster collaboration is *scripting*. Scripting of collaboration (such as assigning specific roles to the members of a team) has proven effective in order to enhance turn-taking (Pfister & Mühlpfordt, 2002; Reiserer, Ertl & Mandl, 2002), elaborate design rationales (Buckingham Shum, 1997), and increase reflection (Diehl, Ranney & Schank, 2001). Reiser (2002) differentiates two basic mechanisms of these scaffolding techniques: providing structure (when to do what) and problem orientation (how to solve a problem within several stages of problem-solving). Structured communication is one method to guide learners, for instance by providing them with a problem solving template or a coordinated exchange between several learners. Furthermore, scaffolding allows to draw the attention of learners to relevant aspects or elements of a collaborative problem-solving process. Thus, scaffolding and scripting can help to avoid irrelevant or distracting tasks, strategies, and processes.

However, scripting as a scaffolding mechanism not always beneficial. Guiding learners strictly through problem solving and interaction steps reduces the opportunities to practice meta-cognitive skills and to see a problem from multiple perspectives. Reiser (2002, p. 263) states: “However, given the importance of connecting students’ problem solving work to disciplinary content, skills, and strategies, it may also be important to provoke issues in students, veering them off the course of non-reflective work, and forcing them to confront key disciplinary ideas in their solutions to problems.” In addition, structuring of discourse always interferes with natural discourse. And scripting often requires external guidance on sequencing or categorization of contributions without an underlying, empirically proven rationale for the structuring method itself (Reimann, 2003).

A third approach to foster collaboration is to provide groups with specific representational guidance about communication and collaboration. Representational guidance (Suthers, 2001) specifies a vocabulary for expressing and exchanging information. A classical example is the IBIS notation (Conklin, 1993), developed to support computer-supported collaborative decision making and organisational memory (for an application to CSCL see, for instance, Zumbach & Reimann, 1999; 2002). Other examples are the representational notations developed by Suthers to support collaborative inquiry dialogues (Suthers, 2001).

Design-based scaffolding approaches are particularly appropriate for groups that are working together for the first time or whose members have little domain knowledge. In such circumstances, strong external guidance can help members to focus on the task and to avoid extrinsic cognitive load. Monitoring the progress of groups with an underlying design-based scaffolding usually includes formative evaluation and has a higher level of granularity than monitoring and scaffolding by means of management-based scaffolding. Management-based scaffolding seems to be more appropriate when groups are supposed to work together over longer periods of time (such as problem-based learning teams) or when groups need to learn about collaboration to successfully complete the problem solving tasks. Here the granularity of feedback has to be on a more specific level in order to support groups or group members.

Management-based Approaches to Scaffold Collaboration

Scaffolding based on collaboration management works with “run time” data derived from tracing the (on-line) interaction between group members, ranging from dynamic feedback of participation behavior all the way to fully-fledged advice-giving systems (Soller et al. 2003). We suggest a methodology of tracking user data, aggregating these data and feeding them back to groups in order to enrich their available resources by means of their recent collaborative efforts. A major rationale for this method is that a group's recent work is too valuable to be forgotten or left unused and that traces of learners' own behavior provide the best source for learning through reflection. In addition, group members need information about their interaction and communication behavior, if we are to expect that learning about adequate collaboration and communication is to take place.

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 (e.g., Zumbach & Reimann, 2003)? A second dimension is *participation*: how often, in what sequence, and around what topics do members contribute to the group's work (Barros & Verdejo, 2000)? A third dimension concerns members' *emotional and motivational state*, or well-being (cf. McGrath, 1991; McGrath & Hollingshead, 1994). A fourth dimension along which feedback can be provided is *collaboration behavior*: how does the action of one group member affect other group members' interaction behavior?

Major challenges for this feedback approach are the (automatic) identification of collaborative acts while avoiding cognitive load problems. Previous research (in particular by Mühlenbrock, 2001; Mühlenbrock & Hoppe, 1999; see also Barros & Verdejo, 1999; Komis et al., 2003, for a similar analysis approach) has shown that while collaborative acts can be identified automatically by screening users' interface actions for certain patterns, some problems remain. Learners may not profit from the feedback because of information overload. Feedback must be presented (on limited screen space) in an easily understandable manner to a team of people who work on often complex tasks. Visualization techniques (e.g., Donath, Karahalios, & Vigas, 1999) become particularly important.

A further challenge for the feedback-approach that has not been discussed much in the CSCL literature is the identification of *missing* communication and collaboration acts. While it is comparatively straightforward to look for patterns in collaboration that should be discouraged or reinforced, it is much more difficult to identify missed opportunities. In particular, software systems can analyze performance data for evidence of loops, conflicts etc., but it is harder for them to identify the absence of performance aspects. This in general requires to move from a pattern-matching approach to a schema-matching approach.

Open Research Questions

While we find ample research on use of design-based scaffolding approaches of face-to-face and computer supported collaborative learning, there is less evidence for the advantages of management-based feedback approaches. While one can argue that feedback approaches to group learning are well-aligned with basic research on the psychology of small groups and teams (e.g. Arrow, McGrath & Berdahl, 2000), they face challenges not only empirically but also conceptually. For instance, which of the many aspects of cognition, emotion, motivation, discourse and interaction should be made subject to monitoring, data aggregation and feedback possibilities? In the absence of an established theoretical framework, empirical studies can contribute to inform design practices, but this strategy is clearly not sufficient. Being aware of this limitation, the two studies reported here do contribute to the empirical basis for the future design of group support systems. In general, we want to analyse how feedback approaches can be applied and how they influence the domain of their application. Furthermore, we are interested in investigating how a combination of design-based and management-based scaffolding can interact in order to enhance CSCL.

In the first, exploratory study, we present a synchronous computer-mediated learning scenario where we utilized feedback based on measures of group members' participation, emotion, and motivation. In the second study, we analyzed the influence of management-based feedback on collaborative behaviour itself and on the interaction of this type of feedback with a design-based scaffolding approach (distributed learning material).

Experiment 1: Influence of management-based feedback on cognitive, emotional, and motivational parameters.

In this study, we examined parameters influencing group processes during a co-constructive learning task. The main question for this study was how groups can be influenced by feedback on socio-emotional parameters and what kind of interaction patterns are realized during a co-constructive learning-by-design task in the area of information design. McGrath (1991) suggested in his TIP theory three success factors for (learning) groups: working on the common task (production function), maintaining the communication and interaction among group members (group well-being), and helping the individual member where necessary (member support). These factors are even more important in virtual groups that communicate via text-based communication. In particular, social cues are lost when communication is limited to media which do not convey non-verbal information about other users' behaviour and appearance (Kiesler & Sproull, 1992). Thus, it seems to be necessary to support learning groups in CSCL-environments with respect to group well-being. This requires awareness of the members' motivational and emotional state which is a prerequisite for adapting to individual or collective problems. Current technological approaches are not or only with limitations able to trace emotion or collaboration.

Several techniques were applied to dynamically elicit emotional and motivational state of the group members and to feed this information back to the group by making use of visualization techniques for highlighting trends over time and for pointing out individual deviations from the group average. Thus, individual motivational and emotional states were turned into information that can be shared by all group members. We analyzed how groups made use of such information that was intended to support group well-being in addition to supporting the group's production function and how these feedback approaches affected the outcomes of the learning process.

Based on these considerations, an experiment was conducted in order to test the following hypotheses:

Hypothesis 1: Providing feedback on participation behaviour should lead to an increased number of contributions of each learner (Hypothesis 1.1). In addition, the feedback should increase participants' awareness about the importance of their exchange and, therefore, lead to a more elaborated discussion (Hypothesis 1.2) and increased knowledge acquisition (Hypothesis 1.3).

Hypothesis 2: Feedback on participants' motivation should initiate a group monitoring process that helps to analyze motivational problems of individual group members and facilitates corresponding interventions. This should lead to higher levels of overall motivation for groups receiving this kind of feedback.

Hypothesis 3: The same relationship as stated in Hypothesis 2 holds for the application of feedback about group members' current emotional state.

Design

Subjects were randomly assigned to small groups of three members each. Nine subjects (= three groups) participated in an experimental condition. The tracking of interaction and motivational and emotional parameters were directly fed back to the members of a group. The other nine subjects in the control condition (also three groups) did not get any automatic feedback about interaction, motivational, and emotional parameters. The task for all groups was the same: to collaboratively re-design a text into a didactically structured hypertext, a kind of learning-by-design task (Sadler, Coyle & Schwarz, 2000). The task required participants to chunk the linear text into coherent parts, add or delete parts, provide adequate headings and develop a navigation structure. As typical for design tasks, there was no single "right" solution, but it was possible to solve the task in different ways. The overall objective was to get to know and apply basic principles of information design. As our learners had no previous experience in such tasks, we provided them with an informative hypertext containing the required information.

Participants used the synchronous CMC tool *EasyDiscussing* for their communication. In order to provide further information a tutorial on instructional screen design was available online. All subjects had to perform a multiple-choice pre- and a post-test regarding knowledge about instructional screen design.

Material

The collaboration tool *EasyDiscussing* is based on the *MatchMaker* server (Muehlenbrock, Tewissen & Hoppe, 1998). It comprises a shared whiteboard with a set of 'cards' that can be dragged to an arbitrary position within the workspace and can be linked to each other (see Figure 2).

*** Insert Figure 2 about here ***

These cards serve as text cards or annotation cards, and they are 'typed' according to the IBIS notation (Conklin, 1993); that is to say, a single card can either be of type "general comments", "Supporting facts", "pro" and "contra". Links between cards are here not labelled. Further components of the application were an overview panel (showing the whole whiteboard), a chat interface with typed contributions corresponding to the annotation cards, and a feedback component, which visualizes quantitative measures such as the number of each user's contributions in the chat and the shared workspace.

The experimental groups were able to use the full feedback functionality of *EasyDiscussing*. The control groups had the same interface save the feedback component and chat interface. In the control groups, only annotation cards (which had to be erased after their use) were available for discussing decisions. Annotation cards, hence, had the same function as the chat interface in the feedback condition. The chat interface had to be removed for the control groups in order to make sure that no social information was exchanged among group members.

Parallel to participants' collaboration task, emotion and motivation were surveyed on-line. In intervals of 30 to 40 minutes, participants were asked to fill in a 5-point Likert-scale in reaction to the question "How do you feel?" and "To which degree are you motivated to work on this task?". These values appeared in form of a dynamic graph on each screen of the experimental groups and were not shown to the control groups (Figure 3). In order to assess subjects' knowledge, a multiple choice test with 16 items was applied as a pre- and post-test.

*** Figure 3 about here **

Procedure and sample

The experiment started with a general introduction into the handling of the collaboration platform and the visualization tools (in experimental groups only). The pre-test was administered afterwards and an introduction into the design task was given. Then, subjects had about 2 hours to work collaboratively on the task and to collect necessary information from the online information resources. Each team member worked in a different room in the same building, connected with the others only by means of the collaboration interface. After these 2 hours the online post-test was applied. Overall 18 subjects in 6 groups participated in this study. All were students at the University of Heidelberg with different majors aged between 21 and 42 years (M = 26.2, SD = 5.46; 11 female and 7 male). All subjects received 20 € (~ 18 US$) for their participation.

Results

The results of subjects' performance in the pre-test concerning domain knowledge revealed no significant differences. There were no differences between both groups in post-test performance (see Table 1 for detailed results). Both groups mastered the post-test significantly better than the pre-test. Interaction between both knowledge tests and groups was not significant (ANOVA with repeated measurement; $F(1, 16) = 0.19$, $p = 0.67$).

*** Insert Table 1 about here ***

There was not pre-post effect and no significant interaction between repeated measurement and experimental condition in emotional state ($F (1, 16) = 0.8$, $p = 0.78$; see Table 1: mood). The groups also showed no differences in pre- and post-test regarding motivation. The interaction of repeated measurement became significant ($F (1, 16) = 5.90$; $p < 0.05$; see Figure 4).

*** Insert Figure 4 about here ***

For analysis of group communication a summative value for all objects (“cards”) created in *EasyDiscussing* was computed and compared. This included in the experimental groups (EG) all postings in the chat-window and the shared workspace, in control groups (CG) all nodes created in the shared workspace. An ANOVA revealed no significant difference between overall number of postings in both conditions ($F (1, 16) = 0.16$; $p = 0.7$; see Table 1). Additional analysis concerning links between cards showed no significant results. A more detailed analysis of communication behaviour using an Activity Recognition approach (Muehlenbrock, 2001) revealed that participants in the experimental group had longer interaction chains ($F (1, 16) = 5.59$; $p < 0.05$) and used a more elaborated argumentation structure by means of *pro*- ($F (1, 16) = 5.33$; $p < 0.05$) and *contra-statements* ($F (1, 16) = 5.62$; $p < 0.05$; see Table 1).

Discussion

This experiment was conducted in order to investigate the role of feedback on different parameters of collaboration and group processes. We did not find significant effects of the experimental conditions on subjects’ knowledge acquisition (Hypothesis 1.3). Instead, we found that both experimental conditions have been effective means to teach the basic principles of designing instructional hypertexts. Furthermore we found no influence of feeding back individuals’ emotional state to the whole group (Hypothesis 3). This may be due to the short time in which the collaboration took place. In this time, the emotions may have been too stable to be influenced by the task and the problem-solving process. We found an influence of feeding back groups motivational parameters on group members' motivation (Hypothesis 2). Although there were no differences between the experimental groups there was a significant interaction between time of measurement and experimental condition. This effect indicates that computer-supported collaboration can be influenced by means of tracking parameters outside the task itself and immediate feedback on these to a group. Regarding contribution behaviour, we found slight advantages of the feedback of each subject's number of postings (Hypothesis 1.1). Although the difference became not significant, mean deviations in-between groups revealed more equally distributed contributions in the experimental condition. Similar results have been found in communication patterns where subjects of the experimental group displayed more interactive behaviour and longer interaction chains (Hypothesis 1.2).

Overall, we were able to show some effects of tracking parameters of group interaction and feeding it back to the group members. Sample size of this study was due to its exploratory character very small. Further analysis of this experiment and additional experiments are needed to investigate the role of this kind of protocols and their feedback in detail. Above all, it is questionable whether feedback of participation behaviour itself is a type of information rich enough in order to foster collaborative learning. Instead of informing group members on the level of frequencies about their participation, it may be more beneficial to analyse learner-learner-interactions not only on a quantitative but rather on a qualitative level. One possibility is to focus on collaborative behaviour by directly monitoring it (instead of monitoring participation) and to use this information as a management-based feedback approach. Experiment 2 pursues this approach, and in addition integrates management-based and design-based scaffolding.

Experiment 2: Using collaboration feedback and design-based scaffolding

Design- and management-based approaches to scaffolding can easily be combined. Given that they address different issues and phases of group work, this approach has face validity. This study analyses how the combination of distributed learning resources (a design approach) and providing feedback on collaboration behaviour (a management approach) affects various parameters of collaboration. Varying both factors in one experimental design allowed us not only to assess the effects of combining the two approaches, but also to study interactions between the two factors.

Study 2 examined the influence of heterogeneous distribution of learning material among individual learners (design-based) and the use of management-based feedback on collaborative behaviour itself, as well as the interaction of these approaches on measures of knowledge acquisition, problem-solving, group climate, and collaboration. The rationale behind these choices was that feedback on the quality of collaboration has rarely been provided in prior studies, although such feedback is clearly informative.

This study was conducted with dyads of students working together on a clinical case problem in the domain of clinical psychology. The first factor, information distribution, had two conditions. In one condition (homogenous resources), each learner had access to the complete learning material relevant for solving the problem. In a second condition, one participant had access only to relevant passages about depressive disorders and the other only to learning material related to anorexia nervosa. The second factor was the availability or absence of feedback on collaborative events.

Explicitly, we tested the following hypotheses:

Hypothesis 1: By simply dividing resources among learners, we expect participants to develop and experience the need for collaboration. We assumed that this would lead to an increased number of collaborative events and, thus, in higher performance in problem-solving and knowledge acquisition. As successful groups were expected to be more satisfied with their “production-function”, we also expected them to experience a better group climate (corresponding to the group well-being function).

Hypothesis 2: We expected positive effects from providing feedback on ‘real’ collaboration events back to learners in a dyad. We specifically assumed an increased number of collaborative events and, thus, positive effects on problem-solving, knowledge acquisition, and group climate.

Hypotheses 3: Both interventions, the design- and the management-based approach, were expected to interact. The provision of the design-based approach should lead to a higher need of collaboration and, thus, lead to more collaborative events at the beginning. By means of collaboration feedback, collaborative behaviour was assumed to be maintained and enhanced. We expect the combination of both interventions to render the highest outcomes on dependent measures.

Design

40 subjects were randomly assigned to dyads. These dyads were assigned to one of four experimental conditions, with five dyads in each cell. The four experimental conditions result from combining the factor Distributed Learning Resources (with conditions homogenous vs. distributed) with the factor Availability of Feedback on collaborative events (available vs. absent).

Material

Based on the considerations mentioned above, we developed a web-based learning environment for dyadic problem solving with several components (see Figure 5). Via a web browser interface, each learner had access to a framed web page with several components. The first component was a window containing tasks and the learning material (left upper corner of Figure 5). The second component was a text editor capturing the text addressing the problems (left lower corner in Figure 5). The third component was a chat window (right space in Figure 5). The fourth component was a counter providing information about the number of collaborative events (lower right corner).

*** Insert Figure 5 about here ***

The problem itself was a text-only case description of a woman with a co-morbid disorder (depression and anorexia nervosa). Learning objectives included knowledge about causes, diagnosis, development and therapy of depression and anorexia nervosa, and the relationship between both disorders. Resources consisted out of passages of a clinical psychology text book. These passages were digitalized and provided together with the case description in an HTML-document (in the upper left corner of the user interface; see Figure 5).

In order to provide feedback on collaborative events, a trained experimenter analyzed the discourse in the chat window parallel to participants' input, thus monitoring the dyads. In case of a contribution sequence identified as a "collaborative event", the tutor posted the message "You have successfully cooperated! Keep on!" (in German) and the counter of collaborative events was incremented. This was the only contribution of the experimenter.

The experimenter was provided with a coding scheme for the analysis of the chat contributions. This coding scheme is based on a synthesis of previous research on computer-mediated communication. Barron and Sears (2002) emphasize the role of sequence and interdependence of learner contributions. They suggest that collaboration can be regarded as a sequence of different actions and depending reactions (based on a categorization scheme similar to the suggested definition of single actions by Barros & Veredejo, 2000). Soller and Lesgold (1999, 2000) also use such a categorization. They define three basic categories of collaborative learning skills (Active Learning, Conversation and Creative Conflict) and eight dependent sub-skills (Request, Inform, Motivate, Task, Maintenance, Acknowledge, Argue and Mediate) with each specifying detailed actions. Starting from these definitions and approaches, we developed a coding scheme for defining actions that indicate a “collaborative event” (see Table 2).

*** Insert Table 2 about here ***

Table 2 shows the categories, based on interaction chains, that we derived from a literature review for dyadic learning in terms of action-reaction-patterns (references to the underlying literature can be found at the bottom of the table).

Letters A to I in Table 2 represent nine different possible ways to start a collaboration, resulting in 26 possible exchanges. For instance, all utterances in category A classify openings with a proposal for a problem solution, and all openings in category F represent coordinative contributions. Each code stands for another chain of interactions and is a unique collaborative event.

The following examples should demonstrate the use of the coding scheme: In one of the sessions participant A stated in the chat (translation): “I need more information on the physiological background of depressive disorders. Can you help?“. Participant B answered: “Yes of course. There is something with the neurotransmitters. According to my resources there might be a relationship between Serotonin, Noradrenalin, Dopamine, Acetylcholine and depressive disorders (…).” The example is coded as a B1 event with student A asking for help/advise and student B sharing requested information. In another example, participant B dragged some text into the chat for A who did not have any need for the pasted text because it was not relevant to the problem. In that case no collaborative event has been coded; in case of pasting a “useful” text this would have been an I1 event. Of course one can find longer interaction chains in the data. Our coding scheme does not account for such macro-structures, but breaks them down into elementary components, i.e. “collaborative events”.

Procedure and sample

Learners were randomly assigned to dyads and conditions, and participated synchronously in different rooms. After a pre-test, participants were introduced to the learning environment. In the introductory part of the experiment, participants received information about their task and the possibility of cooperating with a peer over the computer interface. They were not informed about the different factors of this study. For example, in the condition concerned with distributed learning resources they did not know that the other person had different resources that might be additionally relevant for solving the given problem. Since each participant was assigned the task of producing an individual case solution, the approach was cooperative rather than collaborative.

The pre-test assessed participants' prior knowledge with items related to the learning objectives of the case solution (six open and twenty multiple choice questions with each assessing knowledge about depression and anorexia nervosa). The same test was used as post-test. In the post-test, we also assessed the group climate experienced by participants using an adapted subscale of the Medical School Learning Environment Survey (Lancaster, Bradley, Smith, Chessman, Stroup-Benham & Camp, 1997; Marshall 1978; some sample items are "The learning experience made students feel a sense of achievement.", "The experience of the learning environment made students feel depressed." or "The learning experience made students value themselves.". By fostering collaboration we expected to establish not only cognitive but also positive social interdependence. Thus, we expected processes of cognitive and social grounding to contribute to dyads' well-being (cf. McGrath, 1991).

As dependent variables, we took the number of collaborative events and the quality of problem solutions into account. Participation in this study took about 2 ½ hours, with pre- and post-testing lasting about one hour altogether. Overall, 40 participants (7 men and 33 women, mean = 24.5 years, SD = 5.3); mostly students at the University of Heidelberg took part in this study.

Results

Collaboration counts rendered a poor level of cooperation among dyad members' overall (see Table 3).

*** Insert Table 3 about here ***

In the condition with homogenous resources and no collaboration feedback, there was no collaborative event at all. The interventions led to an increased number of collaborative interactions. The highest amount of collaboration occurred in the condition with distributed resources and collaboration feedback. But even their numbers were very low (each dyad had about 1 ½ hours time for problem-solving/cooperation).

Another dependent 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 as being better than dyads without this feedback (see Table 3).

Results of the standardized knowledge tests (pre- and post test) were compared in order to compute an overall score of knowledge gain. Results reveal no significant effects (see Table 3). Participants in the condition with distributed resources and no collaboration feedback received the lowest scores.

For analyzing the quality of problem solving, 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 dyads with collaboration feedback scored significantly higher than those in groups without feedback ($F(1, 38) = 4{,}687$, $p < .037$). There was no significant effect of distributed versus homogenous resources ($F(1, 38) = 1{,}353$, n.s) and no significant interaction effect (see Table 3).

Discussion

The analysis of collaborative events revealed that the numbers are, in general, very low, even when taking into account that each dyad had only about 1 ½ hours for problem-solving/cooperation. Several aspects might explain this. Firstly, 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. Secondly, the chat medium did not limit exchange of students to short sentences, but 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. It is within these limitations that we conclude that the management-based scaffolding approach was successful in enhancing collaborative behaviour (Hypothesis 2) while the design-based approach (Hypothesis 1) had less influence.

The outcomes of the knowledge tests show that participants in the condition with distributed resources and no collaboration feedback received the lowest scores. A lack of collaboration and additional learning material (owned by the other partner of the dyad) can potentially explain this.

In general, 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 (Hypothesis 2). There is no evidence for an interaction effect as postulated in Hypothesis 3.

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 can trigger collaborative behaviour and influences problem-solving processes and group climate.

General Discussion and Summary

In this paper we described several approaches to foster collaborative learning. We developed a taxonomy of possible interventions that distinguishes between instructional design-based and management-based scaffolding approaches. Based on theoretical and empirical evidence that (online) learning groups need scaffolding to master obstacles of collaboration we concentrated our work on fostering cognitive, motivational, social, and emotional parameters. We highlighted the role of external representations as a result of monitoring a group's natural interaction. These interactions can be recorded and used to provide immediate feedback to a group by means of graphical representation. In our first study we investigated the role of such a management-based feedback on different parameters of collaboration and group processes. We examined how explicit and implicit protocolling and its re-use as feedback for participants influenced learners' group behaviour, problem-solving, knowledge acquisition as well as emotional and motivational parameters. We did neither find significant effects of the experimental conditions on subjects' knowledge acquisition nor did we identify influences of feeding back individuals' emotional state to the entire group. This may be due to the short time the first experiment was run. During this time the emotion may have been too stable to be influenced by the task and the problem-solving process. Nevertheless, we found an influence of feeding back the groups' motivational parameters. We also found slight advantages of the feedback of each subject's number of contributions and on interactive behaviour in favour of the feedback approach.

Since the influence of our interventions was not as strong as expected, we decided to conduct a second experiment focussing on monitoring and feeding back collaborative behaviour directly instead of reflecting it via basic participation measures. Furthermore, we combined this management-based approach with a design-based methodology by means of distributed learning resources. Results suggest that a distribution of learning resources and feedback on collaboration enhanced collaborative behaviour (compared to homogenous learning material 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 solving. Results related to group climate suggest that feedback on collaborative events fostered collaboration itself and, thus, positively influenced the group climate.

Taken together, results suggest that our monitoring and feedback strategies, examples for the management-based scaffolding approaches, had positive effects on students' interaction behaviour, problem-solving processes, and group climate. However, the small sample size in both studies sets limits to generalisations. The results are stable but should be considered as first tendencies which have to be replicated.

More generally, our research indicates that the analysis of interactions, collaboration, and other processes summarized under the label "social grounding" appears to be essential for learning but also for meta-learning. If learners are to be empowered to reflect upon their learning behaviour (or production-function), their member-support, and their group well-being and to become strategic collaborative learners, they need to be provided with concepts and tools for analyzing their collaborative learning process. Our approach contributes to such advances and can be extended to include further parameters that enhance online learning groups on their way to sable learning communities.

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Figure 1: Approaches to scaffolding collaboration.

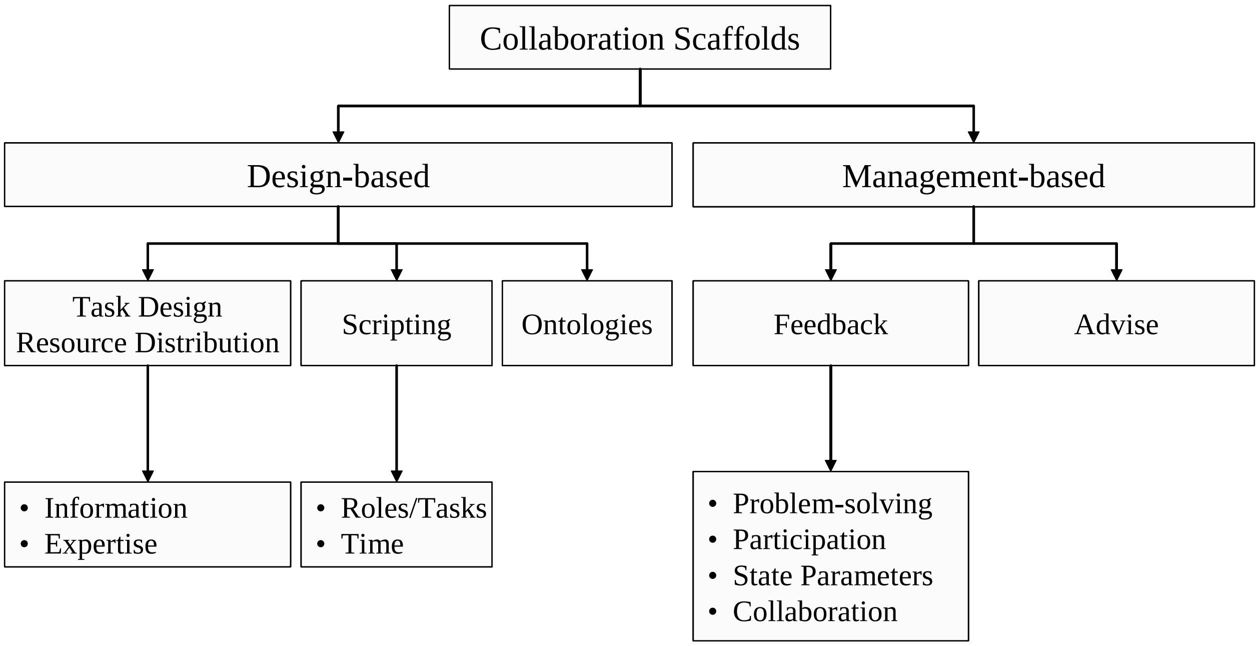

Figure 2: The synchronous collaboration platform in experimental condition (left) and in control condition (right).

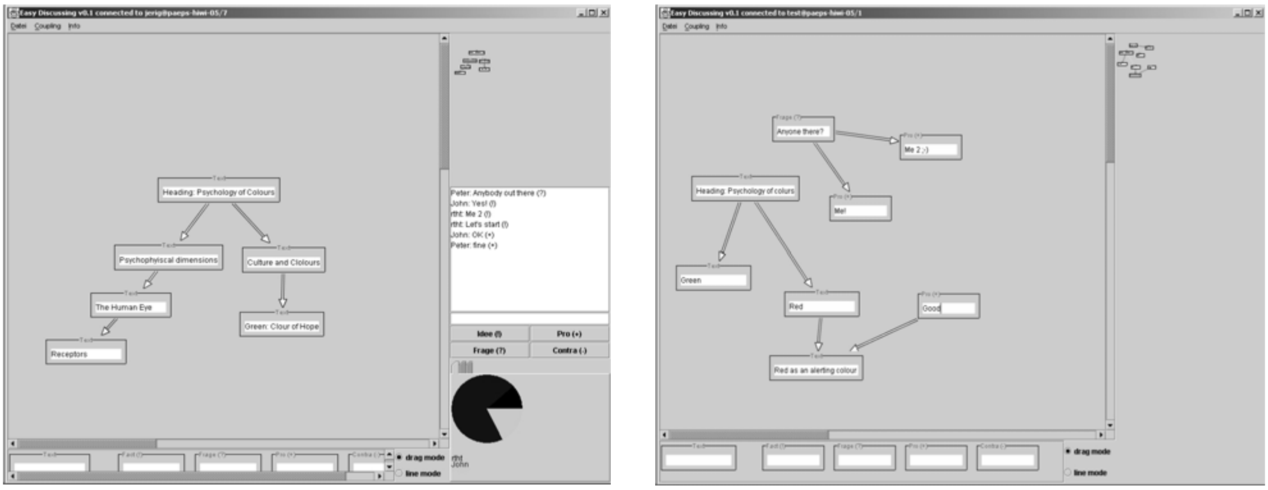

Figure 3: Dynamic emotional and motivational feedback visualization.

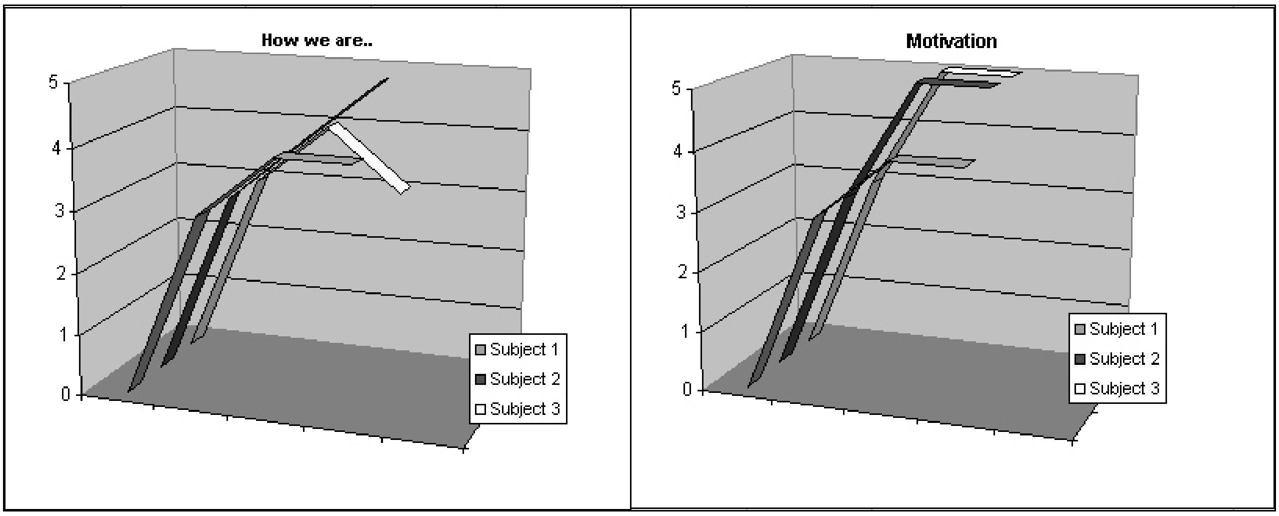

Figure 4: Interaction of treatment condition and time of measurement in participants' motivation.

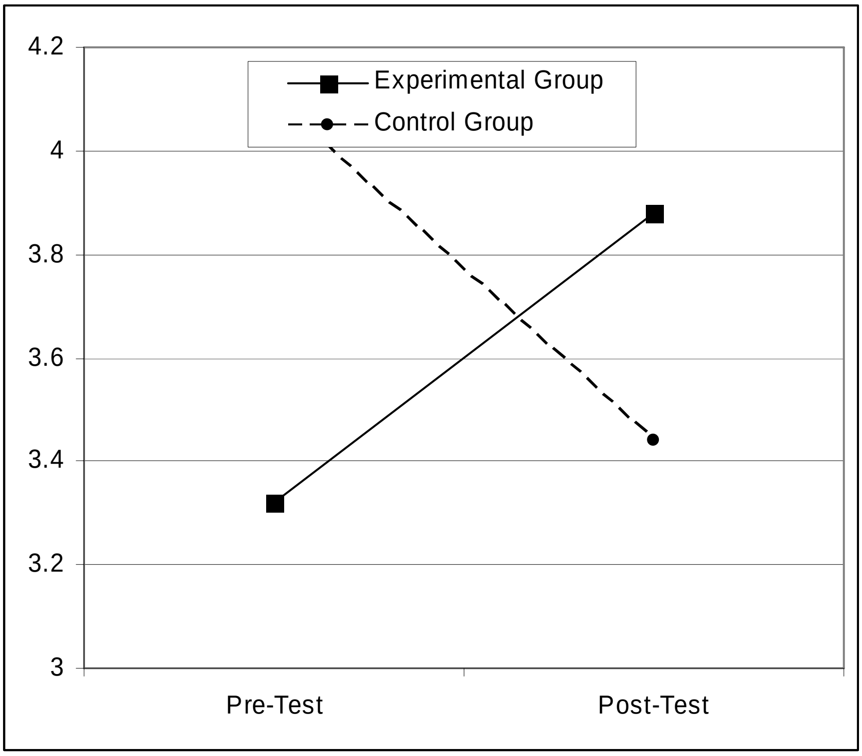

Figure 5: User Interface for individual and cooperative learning.

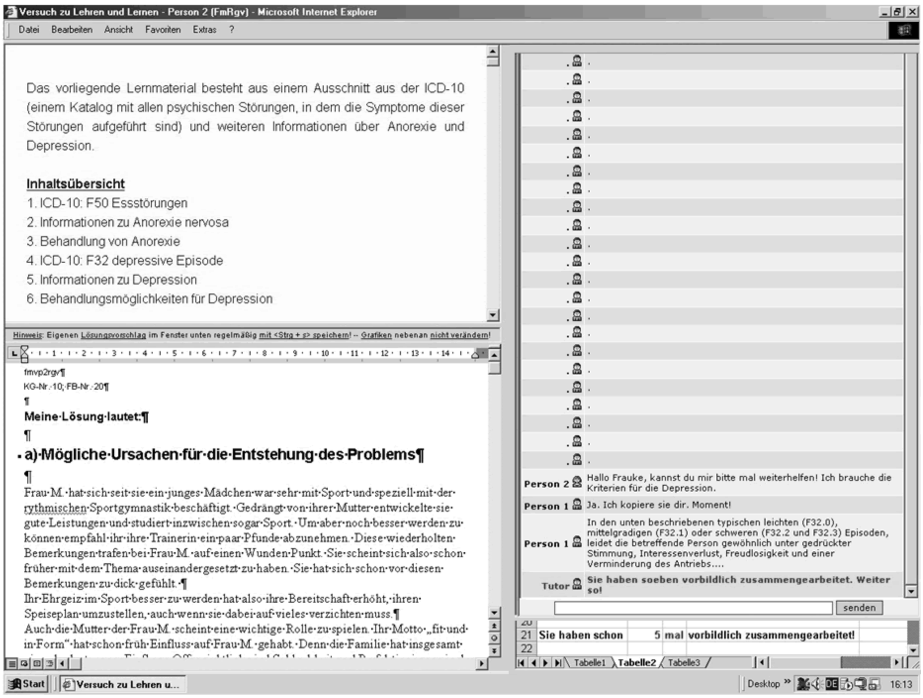

Table 1: Means and standard deviation of dependent measures in study 1.

Dependant Measure	**Mean Experimental Group (SD)**	**Mean Control Group (SD)**
Knowledge pre-test	4 (3.08)	5.11 (3.33)
Knowledge post-test	8.89 (3.76)	9.11 (5.25)
Mood pre-test	3.56 (0.88)	3.67 (0.87)
Mood post-test	3.67 (0.25)	3.67 (0.5)
Motivation pre-test	3.33 (1)	4.1 (0.67)
Motivation post-test	3.89 (1.11)	3.44 (0.78)
Number of contributions	32.67 (17.36)	29.87 (13.47)
Number of added edges	8.78 (9.98)	11 (10.62)
Added pro-statements	6.11 (6.31)	1.1 (1.54)
Added contra-statements	3 (3.64)	0.11 (0.33)
Interactions chains	8 (4.58)	3.56 (3.28)

Table 2: Operationalization of collaborative events.

	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] cf. Barron & Sears (2002); [2] cf. Soller & Lesgold (2000); [3] cf. Barros & Verdejo (2000); [4] cf. Barron, Martin, Roberts, Osipovich & Ross (2002); [5] cf. Johnson & Johnson (1996); [6] cf. Kneser, Fehse & Hermann (2000); [7] cf. Clark (1996); [8] cf. Reinmann-Rothmeier & Mandl (1999); [9] cf. Welch & Tulbert (2000).

Table 3: Means and standard deviation of dependent measures in study 2.

Dependant Measure	**With Collaboration Feed-back Means (SD)**		**Without Collaboration Feed-back Means (SD)**	
	Homogenous Resources	**Distributed Resources**	**Homogenous Resources**	**Distributed Resources**
Knowledge pre-test	15.2 (6.12)	13.1 (9.03)	15.1 (10.77)	15.45 (11.50)
Knowledge post-test	30.95 (3.48)	28.35 (9.06)	32.6 (12.53)	29.1 (9.87)
Group Climate pre-test	3.51 (0.34)	3.63 (0.42)	3.63 (0.40)	3.52 (0.49)
Group Climate post-test	4.01 (0.36)	4.17 (0.29)	3.86 (0.40)	3.91 (0.28)
Problem-solving results	34.78 (11.20)	34.9 (7.36)	31.71 (12.95)	24.18 (7.63)
Number of collaborative events	3.8 (3.29)	7.4 (4.60)	0.0 (0.0)	1.6 (3.37)