Multi-Dimensional Tracking in Virtual Learning Teams An Exploratory Study

J. Zumbach[1], M. Muehlenbrock[2], M. Jansen[2], P. Reimann[1] & H.U. Hoppe[2]

[1]University of Heidelberg, Germany, [2]University of Duisburg, Germany

zumbach@uni-hd.de

Abstract

In this paper we discuss how group processes can be influenced by designing specific tools in computer supported collaborative leaning. We present the design of a shared workspace application for co-constructive tasks that is enriched by certain functions that are able to track, analyze and feed back parameters of collaboration to group members. Thereby our interdisciplinary approach is mainly based on an integrative methodology for analyzing collaboration behavior and patterns in an implicit manner combined with explicit surveyed data of group members' attitudes and its immediate feedback to the groups. In an exploratory study we examined the influence of this feedback function. Although we could only analyze ad-hoc groups in this study, we detected some benefits of our methodology which might enrich real life Learning Communities' collaboration processes. The data analysis in our study showed advantages of this feedback on processes of a group's well-being as well as parameters of participation. These results provide a basis for further empirical work on problem solving groups that are supported by means of parallel interaction analysis as well as its re-use as information resource.

Keywords

Co-Construction, Motivation, Learning Communities, Shared Workspaces, Action Analysis

INTRODUCTION

Collaborative learning can be organized and orchestrated in a number of ways (e.g., Slavin 1995). For instance, Learning Communities (LCs) are groups that focus on building shared knowledge and, in doing so, also gain individual knowledge (Bielaczyc & Collins, 2000). Further characteristics of LCs are the sharing and discussing of knowledge, the support of learning by doing, the enhancement of metacognitive (group) processes, and the formation of an group identity. A famous example of support for virtual LCs is the system CSILE (Scardamalia & Bereiter, 1994; Scardamalia, Bereiter & Lamon, 1994).

In contrast to work-related groups or communities of practice, the central aim of a LC is common knowledge construction, i.e. the socially shared sense making (Dillenbourg, Baker, Blaye & O'Malley, 1995). The most important way to reach this goal is dialogue, e. g. a sequence of questions and answers. This basic communication process can be divided into three parts (Fischer, Bruhn, Gräsel & Mandl, 1998): (1) *Externalisation*: Learner A shares his or her task-related knowledge with others; (2) *Elicitation*: Learner A arranges that learner B or others contribute their knowledge related to A's externalisation (e.g. learner A asks another learner or the whole group); (3) *Consensualisation*: Deviant opinions and understandings are regarded as triggering learning processes, i.e. a conflict raises the need for a consensus. This consensus could be an extension of individual or shared knowledge or a restructuring of existing knowledge structures. External representations play an important role, because they are an excellent opportunity to reflect a group's actions.

Learning communities that work together for weeks and months have to maintain a certain level of coherence and stability (Bielascyk & Collins, 2000). This means that, in addition to task completion, psychological factors concerning the well-being of the group as a whole and the well-being of their individual members have to be considered. From a social psychology perspective, McGrath (1991) suggested in his TIP theory three success factors for learning communities, i.e. 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 low-bandwidth channels such as chat tools or discussion boards. In particular, social cues are lost when communication is limited to media which do not convey non-verbal information about other users' behavior and appearance (Kiesler &

Sproull, 1992). A success factor for a virtual LC is to attend to its well-being, which requires first of all to be aware of the members' motivational and emotional state This awareness is a prerequisite for adapting to individual and/or collective problems.

In our approach we experiment with techniques to (a) dynamically *elicit* emotional and motivational state of the group members and (b) 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. In other words, we focus on turning individual motivational and emotional states into knowledge that is shared by all group members. We are furthermore interested in how groups make use of such information once it is available to them. Finally, we are interested in the effects of supporting group well-being on the outcomes of the learning or work.

Although our long term goal is the support of learning communities, we based our exploratory study on ad-hoc groups which worked together for only a number of hours. For such groups, well-being may not be a primary concern. However, in this study we were mainly concerned with methodological considerations: How can implicit and explicit collaboration parameters be tracked, used in order to analyze interaction and, by means of feedback, be used to support collaborative learning?

This paper is organized as follows: In the next section, a shared workspace system based on a replicated architecture will be presented that can be used to analyze user actions and group interactions. In the following section, an exploratory study with this workspace environment is described for investigating the interaction patterns that take place during a co-constructive design task and for investigating the influence of feeding back a group's socio-emotional parameters. Finally, we address conclusions for further studies and system development.

SUPPORTING AND ANALYZING CO-CONSTRUCTION IN REPLICATED SHARED WORKSPACE ENVIRONMENTS

We seek to advance the state of art of computer science methodologies with respect to computer-based analysis of cooperative activities in the context of CSCL and knowledge communication (Jermann, Soller, & Muehlenbrock, 2000; Barros & Verdejo, 1999; Soller, Linton, Goodman, & Lesgold, 1999; Tedesco & Self, 2000). Contrary to well-known linguistic approaches such as discourse analysis, here the focus is on the analysis of *directly observable* operations on visualized objects in shared workspace environments. Making knowledge communication and collaboration systems more transparent and "well informed" should provide several opportunities for enhancing those environments. Moreover, an action-based approach is advantageous to dialog-based analyses by making use of the logic of a problem space, thus leading to principles of "operational semantics" for the analysis and support of collaboration.

A framework system for user interface synchronization and intelligent support

In traditional application sharing systems, usually a server process (master) owns the data that may be shared (i.e. visualized) by clients (slaves). Clients therefore only get a view on the common data, they never physically own the information. This has serious drawbacks for the stability and flexibility of such systems: e.g., if the master crashes for some reasons, the information is lost. Furthermore the structure of data that has to be distributed over the network has a loose relation to the real semantic data. In contrast, replicated architectures are based on self-contained applications in which components of the user interface are synchronized. The JavaMatchMaker server (Tewissen, Baloian, Hoppe, Reimberg, 2000) is a very flexible system by providing dynamic and partial synchronization of user interfaces. It is possible to start and stop the synchronization at any point of the application’s lifetime and to synchronize each component of an application’s interface individually with a component of another application’s interface, thus allowing the synchronization of applications with completely different interfaces. The MatchMaker server is a core component of open distributed learning environments (Muehlenbrock, Tewissen, Hoppe, 1998), which are characterized by the provision of opportunities for group interaction, the combination of intelligent support with interactive learning environments, and a distributed component-based architecture.

In this framework system, a shared workspace is a special type of synchronized object of the user interface. Of particular interest are collaborative learning environments which are based on shared workspaces using two-dimensional visual representations. The common characteristic of these types of systems is that they support both spatial metaphors and direct manipulation with objects that may differ in the degree of symbolic abstraction. The formal structure underlying these visual representations is usually a directed graph with labeled links. A shared workspace based on visual languages facilitates the definition and the cooperative creation and manipulation of networks of surface objects called cards (Hoppe, Gassner, Muehlenbrock, Tewissen, 2000). Cards can contain specific content information in the form of text, images, or other media, and they can be linked visually by creating edges. In addition to workspaces, any other user interface object can be coupled. For instance, synchronizing text input objects in distributed user interfaces establishes a simple chat tool.

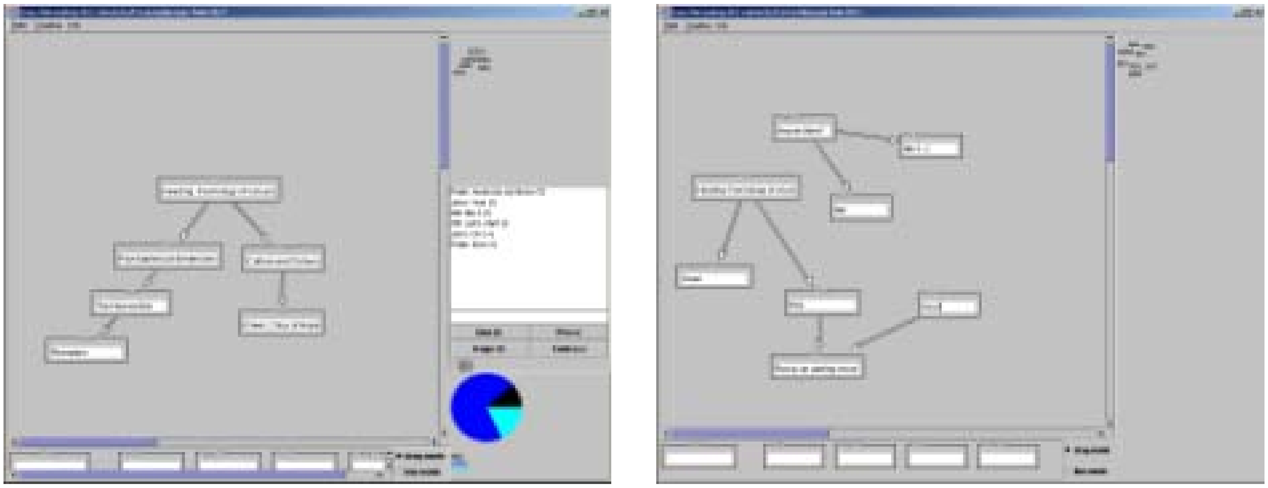


Figure 1: EasyDiscussing in experimental condition (left) and in control condition (right)

The application EasyDiscussing (figure 1, left) is based on JavaMatchMaker and has been developed for the study in this paper. Its main component is a shared workspace with a set of typed cards that can be dragged from a palette below the workspace and dropped at an arbitrary position within the workspace. In this application, cards are text cards or are annotation cards according to the IBIS notation (Conklin, 1993), and they can be linked by means of directed edges. Further components of the application are an overview panel providing a bird's eye view on the workspace, 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. For the control condition, the chat interface and the feedback component can be switched off (figure 1, right). In addition, the feedback component also includes visual representations of qualitative aspects such as an interpretation of constructive and destructive effects of user actions as described in Muehlenbrock & Hoppe (1999). These have not yet been used in the empirical investigation. Furthermore, all user actions are logged to a file in a XML-based format (see table 1). The protocol represents the type of action such as adding, deleting or changing nodes or edges together with further parameter that represent the objects involved, the user, and the time and date among others. This protocol is particularly useful for an offline analysis of the user activity.

Table 1: Action protocol in XML format


```
<?xml version="1.0" encoding="ISO-8859-1"?>

<!DOCTYPE EasyDiscussingModel SYSTEM
'file:/Y:/dfg/dfg/udui/main/dtd/EasyDiscussingLog.dtd'>

<EasyDiscussingLog>
 <TextNodeAdded>
  <id>73e4b32acf5b3b94:37c60d:e72bbdc51f:-7fc8</id>
  <label>//2/5/14</label>
  <user>Martin</user>
  <date>Mon Jun 18 15:36:53 GMT+02:00 2001</date>
 </TextNodeAdded>
 <EdgeAdded>
  <id1>73e4b32acf5b3b94:37c60d:e72bb36206:-7fe5</id1>
  <id2>73e4b32acf5b3b94:37c60d:e72bb36206:-7faf</id2>
  <user>Anne</user>
  <date>Mon Jun 18 15:37:04 GMT+02:00 2001</date>
 </EdgeAdded>
 <Chat>
  <label>//3</label>
  <text>Martin: What is the main concept (?)</text>
  <date>Mon Jun 18 15:38:15 GMT+02:00 2001</date>
 </Chat>
 <AnnotationNodeChanged>
```

```
<AnnotationNodeAdded>
  <type>1</type>
  <id>73e4b32acf5b3b94:37c60d:e72bb36206:-7faf</id>
  <label>//2/5/16</label>
  <user>Anne</user>
  <date>Mon Jun 18 15:37:00 GMT+02:00 2001</date>
</AnnotationNodeAdded>
…
  <type>1</type>
  <text>Main Concept</text>
  <id>73e4b32acf5b3b94:37c60d:e72bb36206:-7fdd</id>
  <label>//2/5/10/11</label>
  <user>Anne</user>
  <date>Mon Jun 18 15:41:37 GMT+02:00 2001</date>
 </AnnotationNodeChanged>
</EasyDiscussingLog>
```


Automatically analyzing the shared workspace interaction

The analysis of collaborative activity in shared workspaces is based on the idea of observing and recognizing user actions and indicating specific patterns of activity and interaction (Muehlenbrock & Hoppe, 1999). Activity recognition (Muehlenbrock, 2001) is formally grounded in the situation calculus for planning and based on approaches to plan and task recognition. The recognition and interpretation of user and group actions is organized hierarchically, starting from basic actions in the shared workspaces and successively deriving higher-level activity. This is achieved by observing user actions in the context of the problem solving product as well as by relating actions to preceding and potentially subsequent actions.

In activity recognition, actions are conceptualized as occurring in the context of some state (situation) and in the context of other actions. Taking a stream of action messages from the shared workspace and a set of operators as an input, activity recognition automatically and incrementally infers abstract notions of group activity and interpretations of problem-related conflicts and coordinations. Recognized activities are fed back as an input to the recognition mechanism to derive even higher concepts (see figure 2). In addition, activity recognition maintains a description of relevant aspects of the current workspace state (situation) and a set of action sequences (pendings) that have already been initiated but have not yet been completed. In each situation, pendings represent a set of potential interactions. Activity recognition does not rely on domain and task knowledge, though it can use possibly available information (backgrounds) to improve its results.

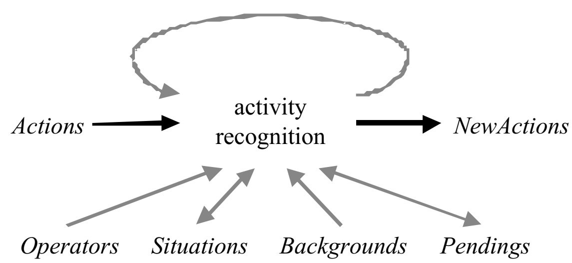


Figure 2: Principle of activity recognition

With specific problem-oriented card representations, domain-dependent background knowledge can be included to enhance the analysis of user actions as shown in Muehlenbrock (2001). In a user interface which is mainly based on free text input, no background information is available without an expensive natural language analysis. However, actions related to the graph structure and the contribution types can nevertheless be analyzed. Principally, different actions can be related through

- *temporal sequence*, i.e. a set of successive actions can be interrelated,
- *graph reference*, i.e. a single node or a set of nodes is involved in a number of actions, and
- *type reference*, i.e. some type of contribution is considered as a response to another type of contribution, e.g. question and answer types.

From these heuristics, sequences of related actions can be defined formally to be automatically recognized. The underlying idea is that when a sequence of related actions is performed by more than one user, it may indicate some form of coordinated activity or cooperation. Table 2 gives a number of sequence-based activities that have been defined for analyzing interaction in EasyDiscussing. For instance, the activity "node_reference" is performed by some users if one user adds a node to the shared workspace and another user subsequently adds an edge that is partially based on this node (and could not have been created without that node). There are two variants of the formal definition depending on the fact whether the new node is the source or the destination of the edge. Another type of interaction is indicated by some user adding a node and a different user putting in some text in that node ("node_labeling", see table 2). A further example is the adding of a node by one user and the deletion of that node by a second user ("node_rejection"). The activity "inverse_ambiguity" refers to the directedness of the edges and is to indicate inverse edges between the same nodes. In contrast to the other formal definitions, it refers to a precondition that a certain edge has been added but does not presuppose an immediate sequence. Finally, a sequence of adding a chat contribution classified as a question followed by adding another text classified as an answer would be characterized as a "question_answer" activity.

Table 2: Formal indicators for cooperation sequences

Activity	**Action sequence**	**Comment**
node_reference(User1, User2)	add_node(Id1, User1), add_edge(Id1, _Id2, User2)	2 variants
edge_reference(User1, User2)	add_edge(Id1, _Id2, User1), add_edge(_Id3, Id1, User2)	4 variants
node_edge_reference(User1, User2)	add_node(Id1, User1), add_node(Id2, User2), add_edge(Id1, Id2, User2)	2 variants
node_labeling(User1, User2)	add_node(Id1, User1), change_node(Id1, User2)	
edge_rejection(User1, User2)	add_edge(Id1, Id2, User1), delete_edge(Id1, Id2, User2)	
node_rejection(User1, User2)	add_node(Id, User1), delete_node(Id, User2)	2 variants
reference_rejection(User1, User2)	add_edge(Id1, _Id2, User1), delete_node(Id1, User2)	2 variants
inverse_ambiguity(User1, User2)	add_edge(Id2, Id1, User2), *precondition:* edge(Id1, Id2, User1)	
question_answer(User1, User2)	add_chat('?', User1), add_chat('!', User2)	3 variants

A sample analysis of a multi user session taken from the empirical study is shown in table 3. The overall action count shows that 88 sequences have been recognized. From these, seven sequences involved more than one user and hence are interpreted as indicating some interaction. The evaluation of these interactions shows that one user dominates the initiation of the sequences, whereas another user tends to complete the interaction. The evaluation also shows that a certain dyad is involved in almost all of the interactions in this session.

Table 3: Example analysis of a multi user session

Overall action counts	**Recognized interaction sequences**	**Evaluation of the sequences**
add_edge-50	interaction(edge_referenc2, [christian, julia])	initiator(christian, 5)
add_node-98	interaction(edge_reference3, [christian, julia])	initiator(julia, 1)
annotation_node_added-17	interaction(node_reference1, [julia, christian])	initiator(carina, 1)
change_node-2979	interaction(edge_referenc2, [christian, julia])	completor(christian, 1)
delete_node-56	interaction(edge_reference3, [christian, julia])	completor(julia, 6)
edge_added-50	interaction(node_labeling, [carina, julia])	dyad([christian, julia], 5)
interaction-7	interaction(node_labeling, [christian, julia])	dyad([christian, carina], 0)
sequence-88		dyad([carina, julia], 2)
text_node_added-81		
text_node_changed-2979		
text_node_deleted-56		

COMBINING SOCIO-EMOTIONAL AND TASK-ANALYTIC PARAMETERS IN THE EVALUATION OF A COLLABORATIVE ENVIRONMENT

This study was designed to examine parameters influencing group processes during a co-constructive learning task using the shared workspace environment as described above. The main idea of the study is the investigation of how groups can be influenced by feedback of their own socio-emotional parameters and what kind of interaction patterns take place during a co-constructive design task. We use here a combined top-down/bottom up analysis: On the one hand, we collect data by using traditional psychometric methods. On the other hand, the collaboration platform itself allows a detailed tracking of user behavior and a semantic analysis of interaction patterns during collaboration. We wanted to examine the effects of the combination of collecting data about collaborative behavior and socio-emotional data in real time as well as its re-use as direct feedback for supporting small group interaction. Beyond the specific experiment, there is also a methodological interest in exploring the potential of combining different techniques of tracking and analysis.

Learning Task: Information Design

Learners have to develop an online screen version of a linear text. Basically this task requires to chunk the linear text into coherent parts, add or delete parts, provide adequate headings and develop a navigation structure. As usual in design tasks, there is no single “right” solution, but it is possible to solve the task in different ways. The overall objective is to get to know and apply basic principles of information design. As our learners had no previous experience in this kind of task, we provided them with an informative hypertext with the required information.

Design of the study

Subjects were randomly assigned to small groups of three members each. Nine subjects (= three groups) participated in an experimental condition with the tracking of interaction as well as motivational and emotional parameters directly displayed as feedback to each whole group. The other nine (also three groups) subjects in the control condition 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 linear text into a didactically structured online-text. This design task had to be fulfilled by using the EasyDiscussing tool. In order to provide further information a hypertextual information base for didactical screen design was available online. All subjects had to perform a multiple-choice pre- and a post-test regarding knowledge about didactical screen design.

Materials and Tools

As collaboration platform for the study the application EasyDiscussing as described above has been used. While the experimental group (EG) could use the full functionality of EasyDiscussing, the control group (CG) had the same interface but without the feedback component and chat interface. In the CG, only annotation cards which had to be erased after their use were available for discussing decisions. Parallel to their collaboration task subjects emotions and motivation have been surveyed. In intervals of 30 to 40 minutes they 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?”. The values of each entry and each subject were displayed to experimental group members using a dynamic graph. These graphs were not shown to the control group. Figure 3 shows a typical diagram. In order to assess subjects knowledge concerning the task we developed a multiple choice test with 16 items that was used as a pre- and post-test.

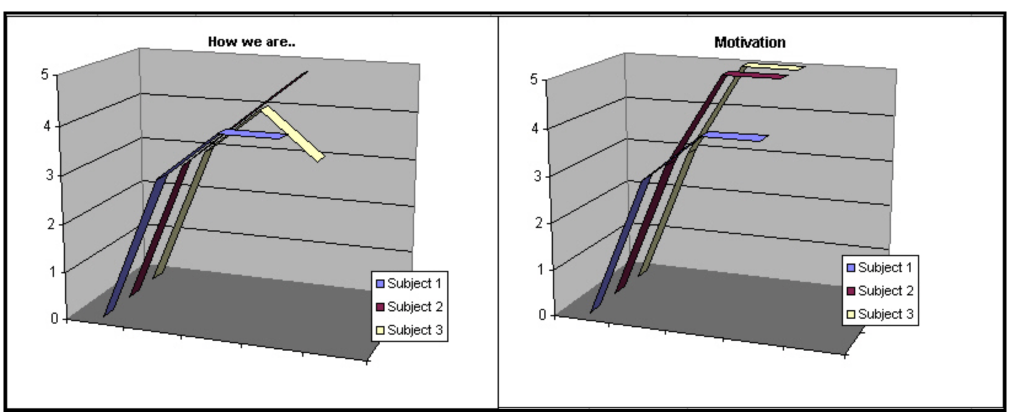


Figure 3: Emotional and motivational feedback

Procedure and Sample

The experiment started with a general introduction into the handling of Easy Discussing and the internet browser. After the introduction the pre-test was administered and a and 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, connected with the others only by means of the EasyDiscussing 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 (mean = 26,2, s =. 5,46; 11 female and 7 male). Each subject received 40 DM (~ 20 US$) for his or her participation.

Hypotheses

We expected influences of the feedback we provided for the experimental groups in this experiment. In particular, we expected that providing dynamic feedback on the members participation behavior should lead to an increased and equally distributed participation. Furthermore we expected that the feedback of emotional and motivational parameters should influence how intensively the groups reflected on its well-being and on problems specific members might have.

Results

The results of subjects' performance in the pre-test concerning domain knowledge revealed no significant differences. There were also no difference between both groups in post-test performance (see table 4 for detailed results). Both groups mastered the post-test significantly better than the pre-test. Interaction between both tests and groups was not significant (F (1, 16) = 0,19, p = 0,67; see figure 4, left).

Table 4: Pre-Post Analysis

Comparison	**Mean EG (s)**	**Mean CG (s)**	**F (1, 16)**	**p**
Knowledge pre-test	4 (3,08)	5,11 (3,33)	0,54	0,47
Knowledge post-test	8,89 (3,76)	9,11 (5,25)	0,1	0,92
Knowledge pre-post			19,42	**<.001**
Mood pre-test	3,56 (0,88)	3,67 (0,87)	0,7	0,79
Mood post-test	3,67 (0,25)	3,67 (0,5)	0,0	1
Mood pre-post			0,8	0,78
Motivation pre-test	3,33 (1)	4,1 (0,67)	3,38	0,09
Motivation post-test	3,89 (1,11)	3,44 (0,78)	0,94	0,35
Motivation pre-post			0,5	0,83

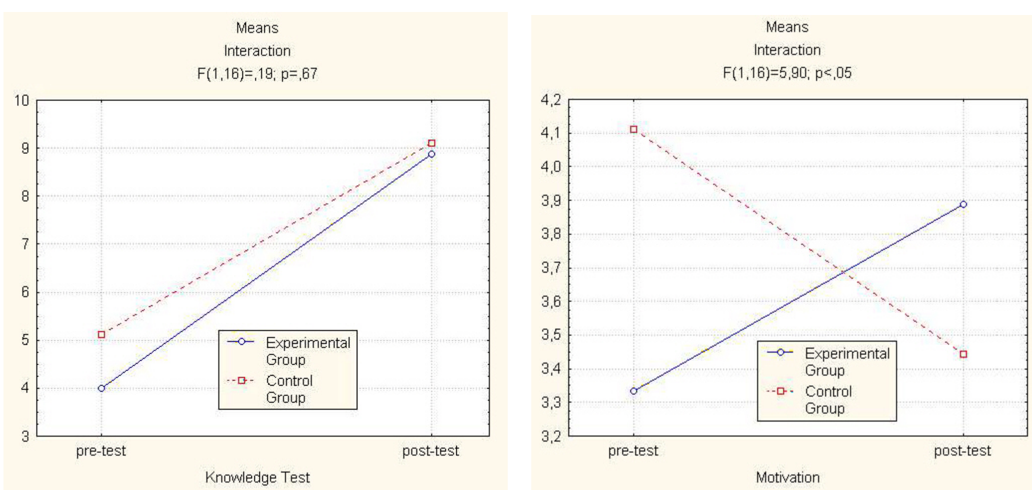


Figure 4: Performance in knowledge assessment (left) and analysis of motivation in pre and post test (right)

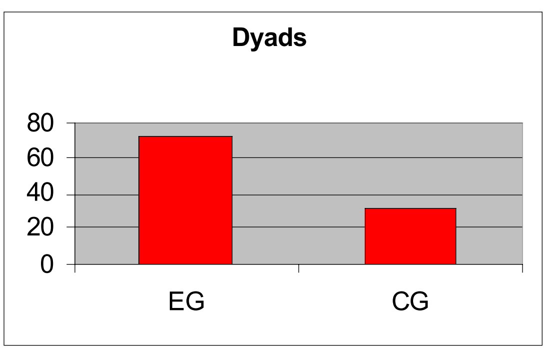
We found no significant differences between both groups in pre-test and post-test regarding the emotional state (see table 4: mood). There was not pre-post effect as well as no significant interaction between repeated measurement and experimental condition (F (1, 16) = 0,8, p = 0,78). The groups also showed no differences in pre- and posttest regarding the motivational parameter. There were also no differences between pre- and post-test. The interaction of repeated measurement became significant (see figure 4, right).

For analysis of group communication patterns an overall value of all objects ("cards") created in EasyDiscussing was computed and compared. This includes in the EG all postings in the chat-window and the shared workspace, in CG all nodes created in the shared workspace. An ANOVA revealed no significant difference between overall number of postings in both conditions (see table 5). Additional analysis concerning links between cards showed also not significant results.

Table 5: Analysis of communication patterns

Comparison	**Mean EG (s)**	**Mean CG (s)**	**F (1, 16)**	**P**
Number of contributions	32,67 (17,36)	29,87 (13,47)	0,16	0,70
Number of added edges	8,78 (9,98)	11 (10,62)	0,22	0,64
Added pro-statements	6,11 (6,31)	1,1 (1,54)	5,33	**<0,05**
Added contra-statements	3 (3,64)	0,11 (0,33)	5,62	**<0,05**
Added *ideas*	6,55 (3,97)	4,78 (7,98)	0,36	0,56
Added *questions*	8,22 (7,14)	8 (10,39)	0,02	0,96
Distribution of contributions	-0,44 (4,38)	1,67 (4,49)	1,02	0,32
Initiating a collaboration	4 (3,32)	1,78 (2,33)	2,7	0,12
Completing a collaboration	4 (3,54)	1,78 (2,28)	2,51	0,13
Dyadic interactions	8 (4,58)	3,56 (3,28)	5,59	**<0,05**

A more detailed view on subjects' discussion structures showed a more frequent use of *pro* and *contra* postings in the experimental group. There were no significant differences in use of *idea* and *question* postings (see also table 5). The analysis of subjects' distribution of contribution behavior was computed by subtracting each individual's number of postings from the corresponding group mean. Subjects in EG showed a more equally distributed contribution behavior than those in CG although the difference became not significant. The automatic detection of interaction patterns in subjects' discussion yielded a significant difference in the number of dyadic interactions (see table 5). Figure 6 (left) shows the values in dyadic interactions for both groups. Figure 6 (right) shows the percentage of interactions in automatically detected sequences; i.e., the ratio of elementary actions that could be interpreted as part of a dyadic inter-action.



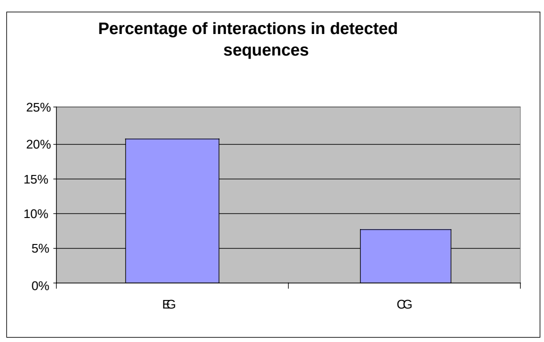


Figure 6: Total participation in interaction dyads and percentage of interactions in sequences

A view on correlations between participation in dyadic interaction revealed significant correlations between use of the pre-structured argumentative icons of "pro" (0,82, **p<,05**) and "contra" (0,71, **p<,05**). In addition, we found a significant correlation between initiating a dyadic interaction and the use of questions (0,74, **p<,05**).

SUMMARY AND DISCUSSION

Computer supported collaborative learning is influenced by many parameters. In this paper we stressed the role of external representations as a result of a group's natural interaction. These interactions can be recorded and by means of graphical representation used as immediate feedback to a group. In our experiment we investigated the role of feedback on different parameters of collaboration and group processes. We used a design task to figure out how explicit and implicit protocolling and its re-use for subjects' information resource influences subjects' group behavior, problem-solving, knowledge acquisition as well as emotional and motivational parameters. We did not find significant effects of the experimental conditions on subjects' knowledge acquisition. We found that both experimental conditions have been a powerful way to learn the basic principles of knowledge design concerning instructional hypertexts. Furthermore we detected no influence of feeding back individuals' emotional state to the whole group. This may be due the short time the experiment was running. In this time the emotion might have been to stable to be influenced by the task and the problem-solving process. We found an influence of feeding back groups motivational parameters. 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 some processes in computer-supported collaboration can be influenced in a positive manner by means of a steady tracking of parameters outside the task itself and immediate feedback of these to a group. Regarding contribution behavior we found slight advantages of the feedback of each subject's number of postings. Although the difference became not significant mean deviations in-between groups reveal a more equally distributed contribution behavior in EG. Similar results have been found in communication patterns where subjects of the experimental group showed more interactive behavior. Interesting results derive from analysis of interaction sequences and use of explicit discussion structure: The more argumentative processes happen, the more dyadic interactions take place. This stresses the role of computers supported collaborative argumentation processes for collaboration (e.g. Buckingham Shum, 1999).

Overall we could show some effects of tracking parameters of group interaction and feeding it back to the group members. Further analysis of this experiment and additional experiments are needed to investigate the role of this kind of protocols and their feedback in detail. In further research, we will increase and refine the number of parameters utilized to assess and visualize group well-being. For instance, we will also include socio-metric measures such as centrality of a member in a group. In addition, we will record not only traces of emotional-motivational and interaction aspects of group work, but also trace the work on the task (e.g. design histories). From the methodological perspective, the concrete experiment is an example of what can be achieved by combining different analytic measures to gain more insight into group processes and to feed those parameters back to the group. The technical prerequisites are flexibly definable shared workspace environments, mechanisms for protocoling and analysis, and appropriate feedback techniques including visualization. Whereas the example system used in this study was essentially based on a standard communication architecture and analysis framework, future applications will be based on a generic user interface for collaborative visual languages ("JavaCardBoard"). In this framework (Pinkwart, Hoppe & Gassner, 2001), domain-specific language elements are arranged on multiple palettes which can be combined with semantic components to interpret the "models" created in the workspace. On this basis, visual models of different types (e.g., Petri Nets, system dynamics, business processes) can be flexibly supported. This will enable us to extend the analytic approach to collaborative modeling tasks.

ACKNOWLEDGEMENTS

This research has been supported by grants of the German Science Foundation (DFG) to Ulrich Hoppe (HO 2312/1-1) and Peter Reimann (RE 814/11-1). We thank Johann Pixner for his support.

REFERENCES

Barros, B., & Verdejo, M. F. (1999). An approach to analyse collaboration when shared structured workspaces are used for carrying out group learning processes. In S. P. Lajoie & M. Vivet (eds.), *Artificial Intelligence in Education: Open Learning Environments* (pp. 449-456). Amsterdam: IOS Press.

Bielaczyc, K. & Collins, A.M. (2000). Learning communities in classrooms: A reconceptualization of educational practice. In C.M. Reigeluth (Ed*.), Instructional design theories and models* (pp. 269 - 292). Mahwah, NJ: Erlbaum

Buckingham Shum, S. (1999). *Computer Supported Collaborative Argumentation*. Workshop at the CSCL99 conference, December 1999, Stanford University, USA.

Conklin, E. J. (1993). Capturing organizational memory. In R. M. Baecker (Ed.), *Groupware and computer-supported cooperative work* (pp. 561-565). San Francisco: Morgan Kaufman.

Dillenbourg, P., Baker, M., Blaye, A. & O'Malley, C. (1995). The evolution of research on collaborative learning. In P. Reimann & H. Spada (Eds.), *Learning in humans and machines: towards an interdisciplinary learning scienc*e (pp. 189-211). Amsterdam: Elsevier.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (1998). *Strukturangebote für die gemeinsame Wissenskonstruktion beim kooperativen Lernen*. Universität München, Lehrstuhl f. Empirische Pädagogik und Pädagogische Psychologie. Forschungsbericht Nr. 97 (Oktober 1998)

Hoppe, H. U., Gassner, K., Muehlenbrock, M., & Tewissen, F. (2000). Distributed visual language environments for cooperative learning: Applications and intelligent support. *Group Decision and Negotiation, 9(3),* 205-220.

Jermann, P., Soller, S., & Muehlenbrock, M. (2001). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *In Proceedings of the European conference on Computer Supported Collaborative Learning, EuroCSCL-2001* (pp. 324-331). Maastricht, The Netherlands, March.

Kiesler, S. & Sproull, L. (1992). Group decision making and communication technology. *Organizational Behavior and Human Decision Processes, 52,* 96-123.

McGrath, J. E. (1991). Time, Interaction, and Performance (TIP). A Theory of Groups. *Small Group Research., 22*, 147-174.

Muehlenbrock, M. (2001). *Action-based Collaboration Analysis for Group Learning*. Amsterdam, The Netherlands: IOS Press.

Muehlenbrock, M. & Hoppe, H. U. (1999). Computer-supported interaction analysis of group problem solving. In C. Hoadley and J. Roschelle (eds.), *Proceedings of the conference on Computer-supported Collaborative Learning, CSCL-99*, (pp. 398-405). Mahwah, NJ: Erlbaum.

Muehlenbrock, M., Tewissen, F., & Hoppe, H. U. (1998). A framework system for intelligent support in open distributed learning environments. *International Journal of Artificial Intelligence in Education*, 9, 256-274.

Pinkwart, N., Hoppe, H. U., & Gassner, K. (2001). Palettes, In *Proc. of 7th International Workshop on Groupware*, CRIWG-2001. Germany, October.

Scardamalia, M. & Bereiter, C. (1994). Computer Support for Knowledge-Building Communities. *The Journal of the Learning Sciences, 3 (3),* 265-283.

Scardamalia, M., Bereiter, C. & Lamon, M. (1994). The CSILE Project: Trying to bring the classroom into World3. In K. McGilly (ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 201-228). Cambridge, MA: MIT Press.

Slavin, R. E. (1995). *Cooperative Learning* (2nd ed.). Boston: Allyn and Bacon.

Soller, A., Linton, F., Goodman, B., & Lesgold, A. (1999). Toward intelligent analysis and support of collaborative learning interaction. In S. P. Lajoie & M. Vivet (eds.), *Artificial Intelligence in Education: Open Learning Environments* (pp. 75-82). Amsterdam: IOS Press.

Tedesco, P. & Self, J.A. (2000). Using meta-cognitive conflicts to support group problem solving. In G. Gauthier, C. Frasson, and K. VanLehn (eds.), *Proceedings of the 5th International Conference on Intelligent Tutoring Systems, ITS-2000* (pp. 232-241). Berlin: Springer.

Tewissen, F., Baloian, N., Hoppe, U., & Reimberg, E. (2000). "MatchMaker": Synchronising Objects in Replicated Software-Architectures, In *Proc. of 6th International Workshop on Groupware*, CRIWG-2000 (pp. 60-67). Madeira, Portugal, October, IEEE CS Press.