Supporting Distributed Problem-Based Learning:

The Use of Feedback Mechanisms in Online Learning

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SUPPORTING DISTRIBUTED PROBLEM-BASED LEARNING: THE USE OF FEEDBACK MECHANISMS IN ONLINE LEARNING

ABSTRACT

In this chapter we discuss possibilities and shortcomings of internet usage for distributed Problem-Based Learning. Several problems with the use of computer-mediated communication for collaborative learning online are identified. In our approaches we use data that is automatically tracked during computer-mediated communication and extract relevant information for feedback purposes. Partly automatically partly manually prepared the feedback is a rich resource for learners to manage their own collaboration process as well as subsequent problem-solving processes. In a synchronous and an asynchronous distributed Problem-Based Learning environment we show how we applied this methodology to support learners' motivation and problem-solving. Analyses show encouraging benefits of our approach to overcome common problems with computer-mediated communication.

INTRODUCTION

When James Cook started his last journey to find the Northwest Passage in the North of America, his wife was angry with him because he had promised her that he would never go on a long voyage again. During the whole trip he was supposed to be in an ill-tempered mood totally different from his normal style, badly collaborating with his crew and behaving harshly and unfairly to the native people he met. No wonder that he was killed on the islands of Hawaii in 1779. What he did not know was that his wife had already forgiven him, so some might say that if he had seen her smile this would have changed the whole course of history. Is this true? Does such a form of emotional feedback have an impact on people's performance in a group situation? Did Cook die due to a lack of feedback?

Nowadays, most of the white spots on Earth have been explored and internet technologies have made the world smaller. People communicate, collaborate and even learn together using the Internet. There is much ongoing research about how to use computer-mediated communication (CMC) for task oriented groups. Actually, little research is dedicated to the use of technology for feedback purposes during online collaboration, especially in distributed Problem Based Learning. There are also many studies exploring feedback mechanisms in individual computer based learning, especially for knowledge acquisition purposes. Research concerning Intelligent Tutoring Systems (ITS) has provided evidence for a meaningful use of individual feedback based on learner-program interaction (Wenger, 1987). Unfortunately, this tradition has yet not reached contemporary learning approaches using computer supported collaborative learning (CSCL).

Besides the use of computer generated feedback on a task level, there is hardly any exploration of its effects on a group's interaction level. Although interacting and communicating is crucial to Problem Based Learning (PBL) most approaches transferring PBL into a network-based learning environment do not pursue approaches to give learner support on this level.

Some earlier research, for example Mandl and Fischer (1985), discusses some computer-based feedback mechanisms and functions, but do not specifically refer to a group context. So far, these investigations have not been carried further. Possible reasons might be a lack of underlying theoretical assumptions and derivations of specific hypotheses.

Our investigations so far let us assume that different kinds of feedback mechanisms can influence online learning groups in a positive manner. We examined the influence of providing groups with feedback about their members' interactions as well as their problem-solving processes. These selected feedback mechanisms have a positive impact on an online collaborative learning group's motivation, interaction, problem-solving abilities, and learning.

If these findings can still hold in future replications, questions about how to use feedback approaches in the most appropriate form and quantity, as well as when and why to use them will be of great interest. For the beginning, however, we first need to find out more about feedback effects in the online group situation in general. In this paper, we (1) provide a theoretical background to explain feedback effects within groups, (2) explore techniques of how to provide feedback in a CSCL environment, and (3) give two concrete examples of empirical studies (including our own) showing how to implement different kinds of feedback into online learning environments and investigate their effects on groups' performances.

BACKGROUND: PROBLEM-BASED LEARNING GOES INTERNET

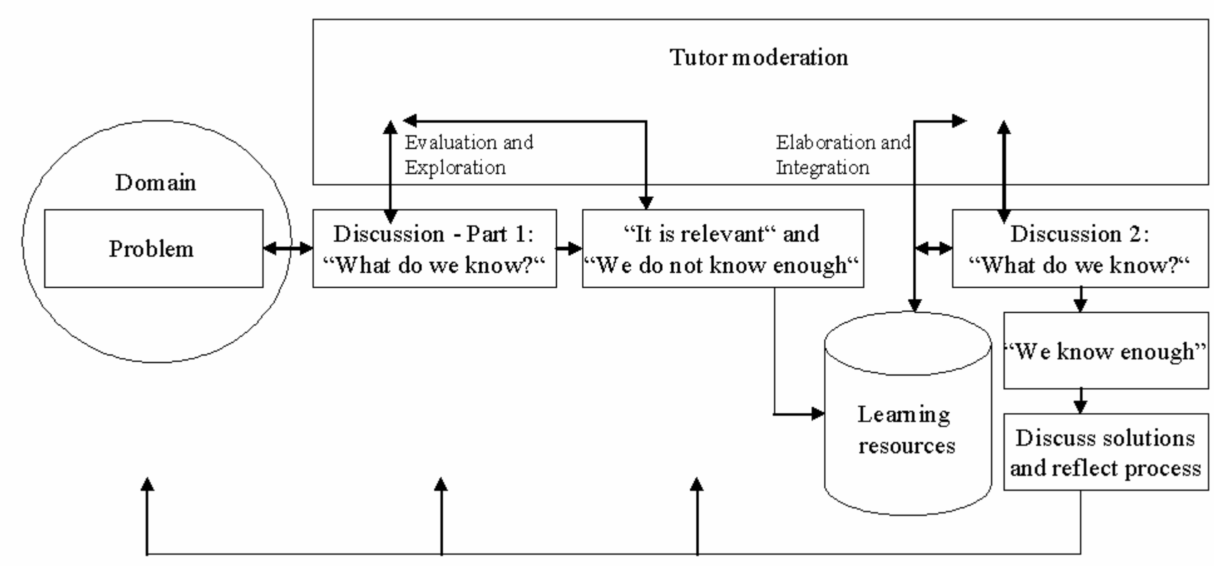
Our hypotheses about feedback effects in CSCL are mainly derived from two research areas: Problem-based Learning (PBL) (e.g. Barrows, 1985; Thomas, 1997) and the Time Interaction and Performance Theory (TIP) by McGrath (1991). PBL is related to the CSCL-paradigm with regard to its philosophy (Koschmann, 1996): Both approaches regard learning rather as a distributed process than a result. Knowledge acquisition happens in an implicit manner. When using PBL as a distributed learning approach over the Internet (dPBL; e.g. Björck, 2001) both approaches merge together.

Problem-Based Learning

The basic principles of PBL can be summarized as follows (e.g., Barrows, 1985; Thomas, 1997): learning in small groups is initiated through authentic and mostly ill-structured problems. Students discuss these problems in order to identify their state of knowledge and what they need to know. This leads them to the definition of learning objectives and the organization of each individual's tasks and learning steps. Afterwards, each student gathers problem-relevant information from literature, databases, experts, etc. in order to complete his or her objectives and to solve the problem. The individual results are collected and discussed in a follow-up meeting which is also moderated by a tutor. Then a new problem is given.

The small group discussion among students and tutor is crucial to the PBL-Process (Viller, 1991). Small group discussions are important to identify learning issues resulting from the problem in the initial phase of a PBL session and the problem-solution phase. While students are discussing, they define what to learn, distribute tasks, apply previous and newly collected knowledge and discuss solutions to the problem (Dolmans, Schmidt & Gijselaers, 1994). Small group discussions enhance knowledge acquisition and deepen students' understanding by means of social knowledge construction. Taking a look at a single PBL unit, that is students working on one single problem taken out of a complete curriculum, we often find the following typical process (see figure 1).

Figure 1: The process of working on a single problem during a PBL course or curriculum.



At the beginning of a PBL unit there is a problem that should initiate discussion among learners about what they actually know about the problem, what caused the problem, and how to solve it. Students have to identify learning objectives and to collect all information they already have (Dolmans et al., 1994; Gijselaers, 1996). Providing a well-designed problem, the group members have to discuss (a) which problems should be addressed, (b) which possible learning objectives can be identified, (c) how a problem could be solved, (d) how to distribute single tasks among group members, and (e) where to locate possible resources for the collection of relevant information. As this collaborative task is a crucial phase in the whole process it should be supported by a tutor supervising the learners' progress (e.g., Schmidt & Moust, 1995). After the initial discussion process, students have to seek and collect necessary information to solve the problems in order to reach the objectives. This information can be found in textbooks, libraries or by asking experts from the faculty. Usually this phase of individual study lasts from one day to several weeks and depends on the organization of the curriculum.

A PBL-unit ends with a final discussion of the problem including recommendations for one or more possible solutions. At this point, the results should be presented in a structured and organized way combined with an argumentation resolving the results. Each student should present his or her own work concerning the learning objectives. Learners should also reflect critically on a) their own and others` contributions, b) the process, c) experiences during the problem-solving process, d) possible other solutions, and e) what they have actually learned (Koschmann, Feltovich, Myers & Barrows, 1995). The role of the tutor is crucial to the PBL-process because he or she is guiding students during the problem solving process. While research provides no clear evidence whether a tutor should be an expert in the field of the problem or not, he has to guide small group discussion and to lead students in accomplishing their learning objectives.

In addition to the already mentioned PBL-principles, we pursue an approach that combines Problem-Based Learning with a more constructionist approach: Learning-By-Design (LBD; e.g. Kolodner, 1997). LBD implies that problem-solving always demands creation of deliverables. This kind of learning requires students to externalize their knowledge, to discuss different possible solutions and to provide a design rationale. In our approaches we combine Learning-By-Design, PBL and CSCL by means of internet technologies.

Bringing together PBL and CSCL: Distributed Problem-Based Learning

During the last two decades there have been some attempts to combine PBL with CSCL. In early approaches (e.g., Koschmann, Myers, Feltovich & Barrows, 1994) local area networks have been used to foster a technology based PBL. Nowadays, internet technology allows us to export collaborative problem solving out of the classroom into the digital world. There are several reports about synchronous as well as asynchronous PBL-courses accessible over the internet. One example for distributed Problem-Based Learning (dPBL) is provided by Cameron, Barrows and Brooks (1999). In their study they reported a synchronous computer-mediated PBL-scenario. Students and their facilitator communicate during small group problem discussion via conferencing software (they used Microsoft's NetMeeting). Their qualitative analysis shows advantages of CMC regarding students' participation: CMC led to an equal distribution of comments among all participants. That means, technology allows an answer of each group member to facilitator's questions. During face-to-face sessions only one student is able to provide an answer to a question (if this answer is correct and exhaustive). All other participants have to remain passive until another question comes up. Furthermore, CMC provides an automatic storage of all students' as well as facilitator's contributions in problem discussion. This is not always advantageous as Cameron et al. (1999) showed: especially navigation and scrolling e.g. in long chat protocols can influence students' concentration and/or their focus on discussion.

Although research on dPBL is growing, there are rarely studies with controlled experimental groups. Most authors remain on a qualitative level (e.g. Milter & Stinson, 1999a, 1999b; Steinkuehler, Derry, Woods & Hmelo-Silver (2002). There are few studies comparing dPBL and PBL. Thomas (2000) reported higher drop-out rates in a MBA-program using a dPBL-Course (65%) compared to a face-to-face course (10%). He also mentioned several technical problems. Such difficulties are also reported by Björck (2001). Technological problems (e.g. getting connected or usability problems) are not the only obstacle in online learning. Dobson and McCracken (1997) mention problems resulting from insufficient group facilitation. What are the causes for these problems reported from many collaborative online courses? An answer can be found at the interface of theory and technological restrictions of CMC.

A useful theoretical framework to explain determinants of successful and less successful (online learning) groups is the Time, Interaction and Performance Theory (McGrath, 1991). Besides many other propositions about the nature of groups it states that groups always undertake three functions at the same time: One is working on the common task together (production function), another is maintaining the communication and interaction among group members (group well-being), and the last is helping the individual member where necessary (member support).

Performance and success of a group depend on how well it can reconcile its functions and tasks with the help of its members' activities. Therefore, methods are needed to support group members in all three functions as well as possible in order to use the group's potential in the best possible way and to obtain best results[1].

Another crucial element that has to be discussed in regard to the background of a group's functioning is communication. Communication among group members in face-to-face situations differs greatly from online learning groups. In many cases, the latter communicate only via text-based tools such as an online platform or other text-based internet technologies. Any forms of non-verbal communication like gestures and facial expressions cannot be perceived by the other group members. Typing on a keyboard needs more time than talking to each other: corresponding text-messages discussing well-being are less likely to be sent.

Hence, online groups presumably have more difficulties with the maintenance of their member support and well-being functions (e.g. Kiesler und Sproull, 1987; Thomas, 2000).

Several studies support findings that the kind of media that is used for the group interaction has an impact on group performance and outcomes on various dimensions. Some studies show that groups that communicate via computer are less productive than face-to-face groups, though some task performances like overall effectiveness do not show differences (e.g., Straus & McGrath, 1994).The picture still remains unclear. Questions concerning methodologies are still not, or are only insufficiently answered, especially in regard to how best to provide cognitive, emotional and social support to online groups.

Supporting Online Learning Communities by means of feedback

Recent research is dedicated to finding support mechanisms for online collaborators. Many authors discuss possibilities of scaffolding by structuring computer-mediated communication (e.g. Dobson & McCracken, 1997; Jonassen & Remidez, 2002; Reiser, 2002). Common to all these approaches is the provision of a structure for discourse and/or problem-solving. Instead of pre-structuring we pursue a way of post-hoc structuring interaction in online learning groups.

CMC itself provides the basis for this possibility. During computer-mediated communication all data can easily be stored and re-used for feedback purposes. In addition, software interfaces designed for CSCL allow the collection of individual quantitative data that can be used for further calculations in real time. Both data sources combined can easily be used to analyze individuals' as well as groups' behavioral processes automatically. In this way online learning groups provide the basis for feedback on their process by just collaborating.

So far, there has been only little research on this methodology. Barros and Verdejo (2000) describe an approach to provide feedback of group characteristics and individual behavior during computer-supported collaborative work based on a set of attributes that are computed out of data derived from learners' interactions. Their automatic feedback gives a qualitative description of a mediated group activity concerning three perspectives: a group's performance in reference to other groups, each member in reference to other members of the group, and the group by itself. Their DEGREE-approach (Distance Environment for GRoup ExperiencEs) allows extracting relevant information from online collaboration at different levels of abstraction. Although this approach seems to be very advantageous for enhancing online collaborators, Barros and Verdejo (2000) give no empirical evidence for the effectiveness of their asynchronous system. Jerman (2002) describes another possibility of providing feedback based on interaction data. He provides feedback on quantitative contribution behavior as well as learner-interaction during a synchronous problem solving task (controlling a traffic sign system). In an experiment, Jerman compared a group that received feedback about each individual learner's behavior. Another experimental group received feedback about the whole groups' success. He could show that a detailed feedback containing each individual's data enhanced learners' use of meta-cognitive strategies regarding problem-solving as well as discourse.

Our research group follows this line of feedback research. We conducted two studies to examine feedback effects on online collaborators during CSCL. One purpose of these investigations is to provide post-hoc scaffolding for subsequent problem solving. Another purpose is to use CMC, extract data from discourses and to provide abstracted views as a substitute for missing communication cues. In particular we investigated how the interaction in, and the performance of, small problem-based learning groups that cooperate via internet technologies in a highly self-organized fashion can be supported by means of interaction feedback as well as problem-solving feedback. Since the possibility of tracking and maintaining processes of participation and interaction is one of the advantages of online collaboration, ephemeral events can easily be turned into histories of potential use for the groups. We chose two ways to analyze how such group histories can be used for learning purposes. First, parameters of interaction like participation behavior, learners' motivation (self-ratings) and amount of contributions were recorded and fed back in a computationally aggregated manner as an additional information resource for the group. This data could thus be used in order to structure and plan group coordination and group well-being. Second, we tracked group members' problem solving behavior during design tasks and provided feedback by means of problem-solving protocols. These protocols can be used to enhance a group's problem solving process for further tasks. Both studies testing our methodology in a synchronous and an asynchronous setting shall now be introduced more deeply.

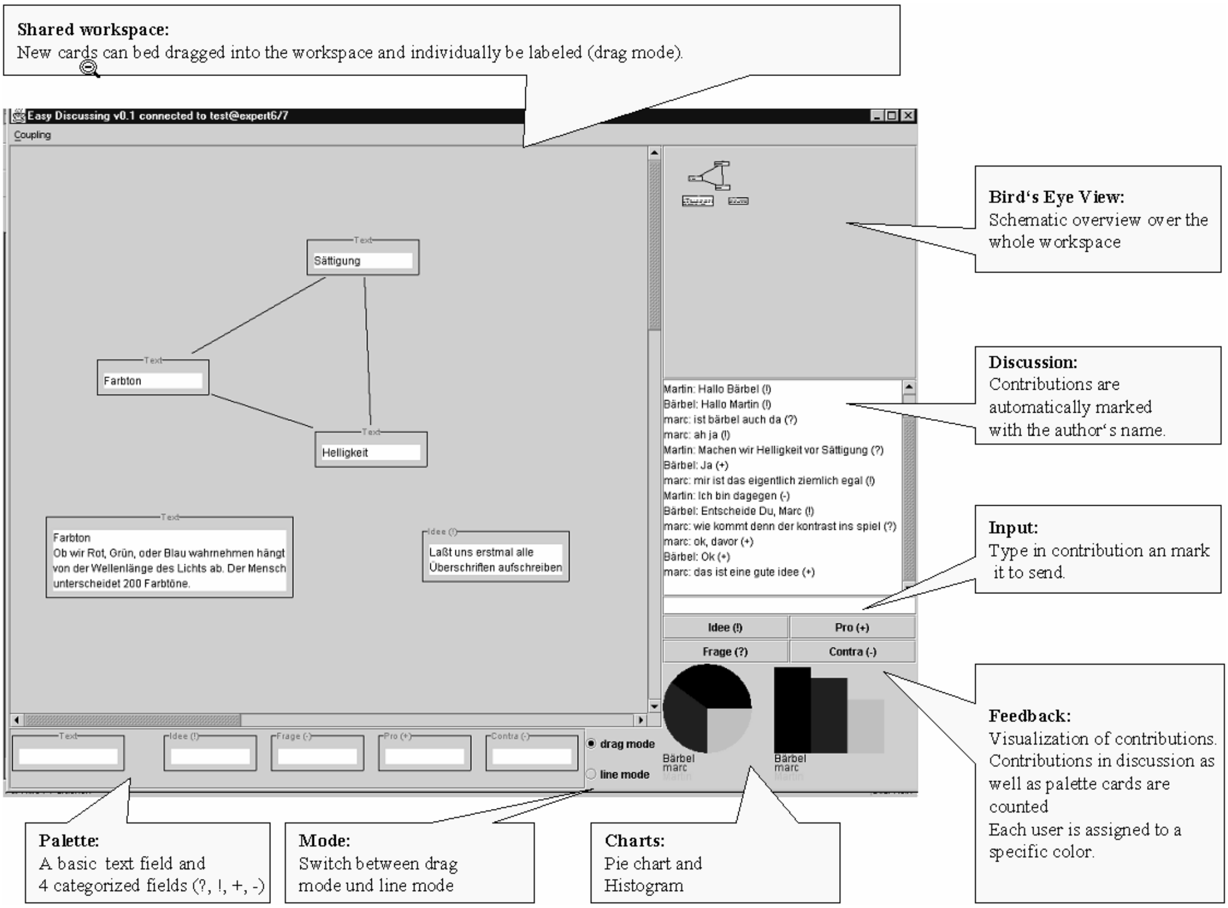
STUDY 1: AUTOMATIC FEEDBACK IN SYNCHRONOUS DISTRIBUTED PROBLEM-BASED LEARNING

Our first laboratory experiment (Zumbach, Muehlenbrock, Jansen, Reimann & Hoppe, 2002) was designed as an exploratory study to test specific feedback techniques and their influence in an online collaboration learning environment.

For this purpose we designed a dPBL-learning environment. In a sample of 18 students of the University of Heidelberg we evaluated six groups of three members each. All students worked together synchronously via a computer network solving an information design problem. Each group was collaborating for about 2,5 hours (synchronously in one session). The task - strictly consistent for all groups and presented as a problem - was to design a hypertext course for a fictitious company. All necessary task materials were provided online. In addition, all learning resources related to online information design were accessible as hypertext.

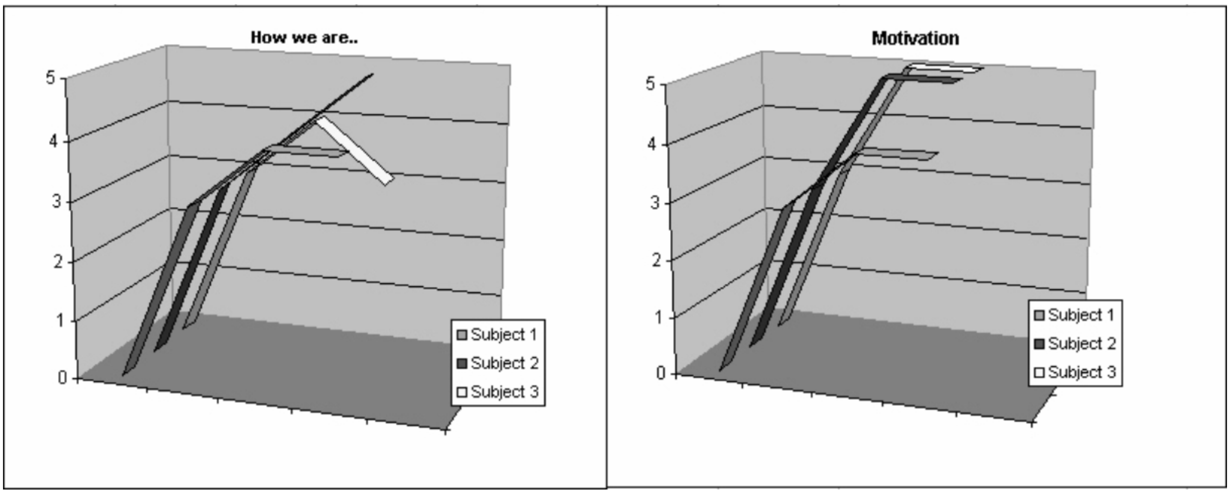
As a communication platform, the software EasyDiscussing was specifically developed for this experiment in cooperation with the COLLIDE-research group at Duisburg University, Germany. This Java-tool makes it possible to display a shared workspace to the whole group that can be modified by each member simultaneously. It contains drag-and-drop functions, thematic annotation cards like "text" (for general comments or statements), "idea", “pro” and “con” to structure the discussion, and it offers a chat opportunity as well (see Figure 1). All parameters are recorded in so-called "action protocols" and analyzed either directly or after the study. This makes it possible to check certain argumentative structures that become obvious during the course work, and also opens up the possibility to provide feedback based on the data produced.

Figure 2. The design of the communication platform EasyDiscussing



Feedback parameters were gained in the following way: every 20 minutes students were asked about their motivation and their emotional state on a five item ordinal scale (parameters relating to the well-being function: “How motivated are you to work on the problem?” and “How do you feel actually?”). These were displayed to the whole group by means of dynamic diagrams (see Figure 3), showing each group member's motivation and emotional state with the help of a line graph. As a quantitative parameter supporting the production function two diagrams showed each group member's absolute and relative amount of contributions.

Figure 3. Feedback on emotion and motivation



In order to test feedback effects we divided the groups into experimental groups that received feedback and into control groups that did not receive any feedback. Both groups had to do a pre- and post knowledge test, a test about attitudes towards cooperative learning (Neber, 1994), as well as some questions about their current motivation and emotional state. We assumed that the experimental groups would be more productive since they were given parameters that would enable them to fulfill their well-being and production functions more easily. That means, they were assumed to contribute more ideas in an equally distributed manner, and show a greater amount of reflection, as far as interaction patterns were concerned, as opposed to the control groups.

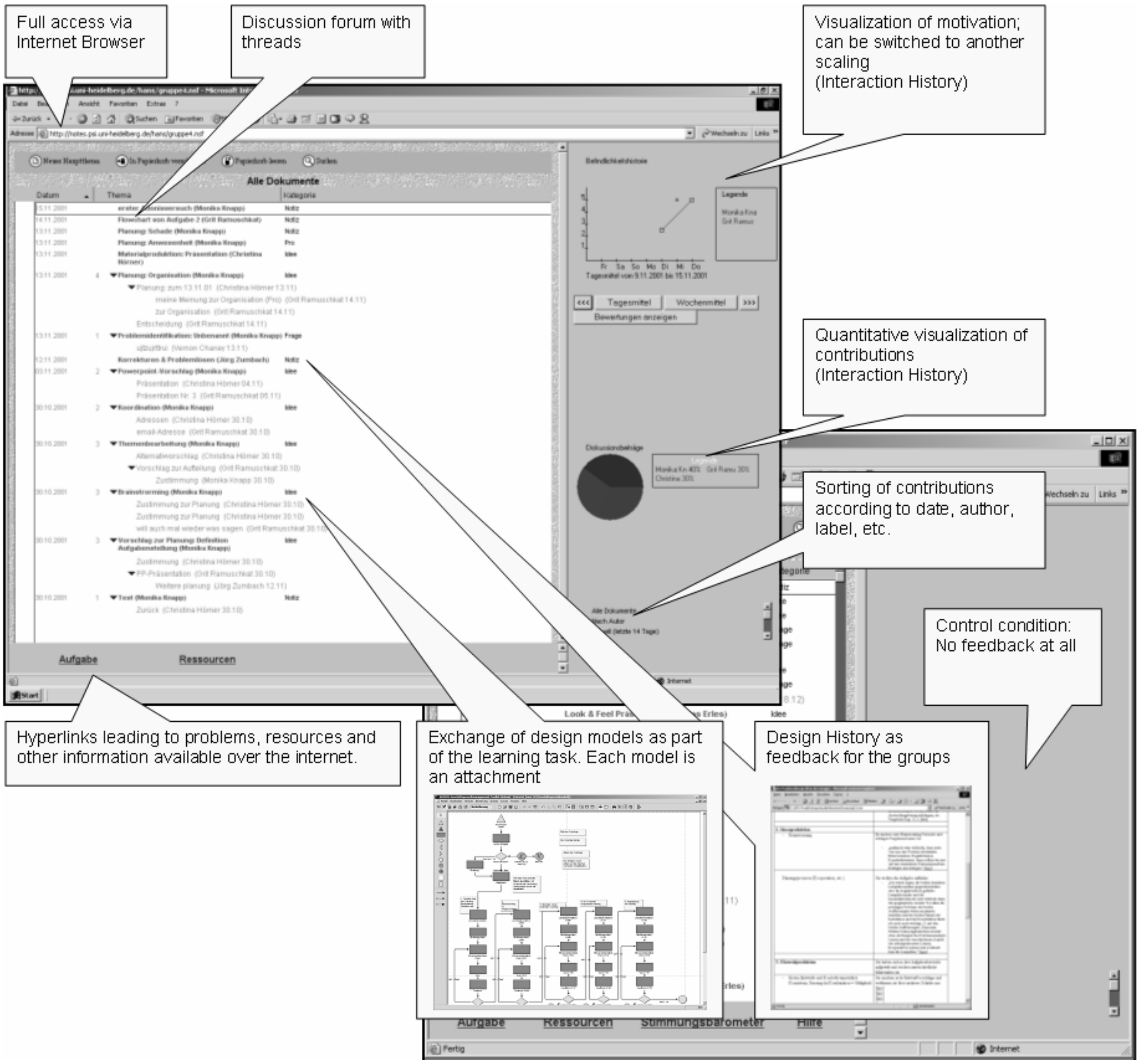
The results of subjects' performance in the pre-test revealed no significant differences concerning domain knowledge. There were also no differences between both groups in post-test performance. Both groups mastered the post-test significantly better than the pre-test. There was no significant interaction between both tests and groups. We also found no significant differences regarding subjects' emotional data. The groups also showed no differences in pre- and post-tests regarding motivation except a significant interaction between groups and time of measurement. While subjects in the control condition without feedback did not show differences in motivation, experimental groups had an increase from pretest to post-test. A closer view on interaction patterns in subjects' discussions also yielded a significant difference in the number of dyadic interactions in groups that received feedback on their contributions.

Overall, the effects of this study indicate 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 by immediate feedback of these to a group. Although intervention time in this experiment was short, we found positive influence of motivational feedback as well as feedback on contributions: communication patterns showed more interactive behavior for subjects of the experimental group. As a consequence of these effects, which indicate that our mechanisms have a positive influence on groups' production-function as well as well-being, we decided to examine these feedback strategies further. For that purpose we arranged a long-time intervention study containing the same kind of visual feedback.

STUDY 2: INVESTIGATING THE ROLE OF FEEDBACK MECHANISMS IN LONG-TIME ONLINE LEARNING

Our main target of this study was to test different treatment conditions concerning feedback with groups that collaborated solely through an asynchronous communication platform over a period of four months. In this study we examined groups from three to five members – 33 participants on the whole. These groups participated in a problem-based course about Instructional Design that was a mixture of PBL and Learning-By-Design. Learners were required to design several online courses for a fictitious company. These tasks were presented as problems within a cover story. Each problem had to be solved over periods of two weeks (i.e. an Instructional Design solution had to be presented for the problem). As in study one, all materials were accessible online and, additionally, tutors were available during the whole course to support the students if questions emerged. At the end of each task, the groups presented their results to other groups. The asynchronous communication facility was based on a Lotus Notes® platform merging tools that can manage documents with automatic display possibilities for interaction parameters and problem-solving protocols (see Figure 4).

Figure 4. Asynchronous collaboration platform with feedback mechanisms.



All created documents as well as attachments were accessible over the collaboration platform. Provided meta-information showed when a document was created and who created it, so that interaction patterns became obvious and could be recorded. With the same technique of diagrams as in study one, motivational and quantitative production parameters can be fed back to the user, referred to as interaction histories. Students' problem-solving behavior, however, had to be analyzed by the tutors themselves and had to be provided as text documents (design histories) on the group's workspace. Invisible for the students, many detailed action protocols were recorded in the background and could later be used for exploratory or hypotheses testing analyses, depending on the research design.

In our study, the groups were randomly assigned to one of four treatment conditions: with interaction history only, with design-history only, with both histories and without any feedback histories, i.e. a 2x2 design with the factors interaction history and design history. Several quantitative and qualitative measures to assess motivation, interaction, problem solving, and learning effects were collected before, during and after the experimental phase on different scales, such as the student curriculum satisfaction inventory, (Dods, 1997) or an adapted version of the critical thinking scale (Newman, Johnson, Webb & Cochrane, 1997). We tried to answer the following question: What kind of influence does the administration of feedback in form of design and interaction histories, as well as their different combinations, have on students' learning? Generally, we assumed that groups with any form of histories would perform better than those without, especially as far as the motivational and emotional aspects supporting the well-being function and the production aspects supporting the production function of a group are concerned.

The results show encouraging outcomes in favor of the application of feedback within the group process. Groups that were shown design histories on their workspaces presented significantly better results in knowledge tests, created qualitatively better products in the end, produced more contributions to the task, and expressed a higher degree of reflection concerning their organization and coordination. At the same time, the presence of interaction histories influenced the group members' emotional attitude towards the curriculum and enhanced their motivation for the task. Slight influences of the interaction history's visualization regarding the number of contributions were also found on the production-function: Learners receiving this feedback produced more contributions than their counterparts without feedback. So far, it seems reasonable to conclude that the different kinds of feedback influence different aspects of group behavior. Whereas feedback in the form of design histories seem to influence a group's production function according to McGrath's (1991) conception of group functions, feedback in the form of interaction histories seems to have an effect also on the production-function, but mainly on the group's well-being function.

PROBLEMS AND FUTURE TRENDS

Since research on feedback effects in online environments is still in its infancy, our studies also struggled with some problems that need to be solved for future investigations. In particular, difficulties occurred with regard to technical aspects of the software equipment, data organization, statistical analyses, and the practical implementation of the learning environment. Besides the problem that the Lotus Notes platform would be unstable at times, some features could also be made user-friendly as far as the communication features are concerned. Moreover, the program created a large amount of informational data that needed a long time to be disentangled for further usage. An early filtering that already takes place during the information collection as well as further programs to structure the data pool is needed. For future research, it is desirable and necessary to carry on with analyses that take into account the sequential nature of the observations.

Given that the - just outlined - improvements can be put into practice, there are multiple perspectives for future research in the area of feedback effects. Questions can range from whether there are even more kinds of feedback supporting different aspects of group behavior, over which techniques can be used in an online learning environment, to the theoretical foundations of feedback effects in general. From our point of view, the most attractive question is whether there is an optimal combination of the two kinds of feedback we explored to support students in a group environment as well as possible? Or should they just serve as separate measures? The aim must be to increase the benefits of feedback while not overloading students with too much superfluous information. This is what we tried to do by extracting data out of all available information and presenting these extractions as feedback.

CONCLUSION

Feedback in general has an impact on a group's performance, enhancing both qualitative and quantitative parameters of students' achievement. Due to the short history of research in the area of feedback in group-based computer-supported collaborative learning environments, the groundwork for more specific applications and the derivation of more precise hypotheses has still to be continued to reach more validated results on a larger scale.

In Cook's case, he would probably have liked to see that his wife had forgiven him. But whether a line diagram of his wife's positive emotional state towards him would have changed Cook's negative behavior will still remain a mystery.

NOTES

[1]In this chapter we try to provide possibilities to enhance the production function and the group well-being by means of enriching computer-mediated communication (we do not directly focus the member support function here).

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