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INFLUENCE OF FEEDBACK ON DISTRIBUTED PROBLEM BASED LEARNING

Enhancing Online Communities in Group Functioning and Well-Being

Abstract. This research examines two different kinds of feedback-mechanism to scaffold problem solving as well as interaction in an asynchronous PBL course. An automated feedback mechanism has been used to enhance interaction and group well-being during computer supported collaborative learning. We tracked individual contribution behavior as well as learners' motivation during collaborative problem-solving by means of an asynchronous communication platform. These data have been used to automatically generate visual aids, providing feedback about group members' participation as well as motivational clues. A second feedback mechanism has been applied by aggregating learners' problem solving discourse into a meta-document. This document revealed groups' problem-solving strategies as well as their progress during different problem solving stages. We examined how this scaffolding methodology based on a group's own behavior enhanced problem-solving outcomes. Results suggest positive influences of feedback mechanisms on problem-solving as well as motivational parameters.

1. INTRODUCTION

Research concerning issues on how to enhance computer supported collaborative learning is rapidly growing. There are two major approaches that refer to (1) technology, enhancing CSCL by means of technological design, and (2) instructional design, supporting online learning groups by didactical methods.

Both approaches are not necessarily separable because technology follows instructional design and vice versa. In this paper we want to discuss an approach that combines technological and instructional design. We hereby pursue a combination of a distributed Problem-Based Learning (dPBL) approach with Learning-By-Design as well as different kinds of technology based feedback mechanisms that enhance the learning environment.

Major problems concerning interaction, motivation and social awareness during CSCL are well known (e.g., van Gorp, 1997). Our approach has been designed in order to overcome certain problems that derive from limitations of computer-mediated communication (CMC). In contrast to common approaches that combine pre-defined argumentation structures (the instructional part, Jonassen & Remidez, 2002) with the communication platform itself (e.g., labeling of contributions according to type) we pursue a post-hoc structuring of contributions. Therefore, we use interaction data that arises from CMC, aggregate these data in order to focus on meaningful information, and provide this as feedback to online collaborators. In our study we differentiate between two kinds of feedback: Feedback based on interaction behavior and feedback based on problem-solving processes.

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The first type (interaction level) refers to communication and interaction as well as accompanying factors, such as motivation and emotion. The second type depends on the instructional approach itself: A problem-solving process is necessary in order to produce data that can be used for feedback purposes. PBL as well as Learning-by-Design are curricular models that enhance groups' problem solving.

In order to provide more details we first introduce our learning approach followed by an overview about how technology can enhance interaction as well as problem solving by means of feedback. Then we describe an empirical study that tests the effectiveness of the method.

2. DISTRIBUTED PROBLEM-BASED LEARNING AND LEARNING-BY-DESIGN

2.1. Distributed 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 complex 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, data-bases, experts, etc. in order to complete his or her objectives and to solve the problem. The individual's results are collected and discussed in a follow-up meeting moderated by a tutor. Then a new problem or case is provided.

During the last years there have been several approaches using the internet for distributed PBL (e.g. Björck, 2001; Cameron, Barrows and Brooks; 1999; Milter & Stinson, 1999a, 1999b; Steinkuehler, Derry, Woods & Hmelo-Silver; 2002). All these approaches have in common that small group discussion in the classroom is replaced by CMC.

2.2. PBL and Learning-by-Design: Own approaches

In addition to the common PBL-approach, we include a constructionist element: Learning-By-Design (LBD; e.g. Fischer, McCall & Morch, 1989; Kolodner, 1997). LBD requires that a problem is always linked to creation of an artifact (design product). This kind of learning requires students to externalize their knowledge, to discuss different possible solutions and to provide arguments for a single design product, all of which are effective learning mechanisms. Our approach combines Learning-By-Design, PBL and CSCL by means of internet technologies.

Students in such a course do not only have to discuss different aspects of and solutions to a problem. They also have to develop an artefact (plan, design-document) product that assembles representations of the original problem and possible solutions. To instantiate this methodology, we developed a course in Educational Technology realizing the above mentioned principles. Students in small groups are presented with authentic problems like the following one:

> The PFITZER CONSULT Corporation has its major business in consulting and training. The management is planning to invest in personal training in project management. Your team is responsible for the in-house training and for the new project management training. While the traditional philosophy of PFITZER CONSULT has been in to use lecture-based training you use the opportunity to introduce situated learning approaches. The situation is beneficial: your team has to develop plans and strategies for future in-house trainings following the new educational paradigm. For this purpose you develop a slide show as well as a one-sided hand-out for the management including your practical suggestions.

By means of referenced literature students have to discuss issues of different educational paradigms, and consequences for instructional design. As well, they have to develop practical conclusions considering the task and the needs and characteristics of the target groups (here: managers). Furthermore, they have to develop an artefact that represents all these features (here: the presentation and the hand-out).

This is only the introductory task. In subsequent problems students are faced with course planning according to different instructional design theories and they are required to develop courses on their own and evaluate them in a formative and summative manner.

3. ENHANCING ONLINE COMMUNITIES IN GROUP FUNCTIONING AND WELL-BEING

3.1. Effects of dPBL: Restrictions of CMC

In order to turn traditional PBL into dPBL it cannot be recommended to merely replace face-to-face communication with computer-mediated communication. More or less direct transfer leads to a number of problems. Cameron et al. (1999) mentioned usability problems in a synchronous dPBL-environment. Participants in their study were faced with difficulties in navigating and scrolling through their collaborators' contributions.

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 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? There seems to be a problem with communication itself. Verbal exchange between group members in face-to-face situations differs greatly from online learning groups. In many cases, the latter takes place only via text-based tools such as an online platform or other text-based internet technologies. Any forms of para- or non-verbal communication like gestures and facial expressions cannot be perceived by the other group members. Typewriting needs more time than talking to each other: correspondingly, text-messages addressing interaction issues are less likely to be sent. Hence, online groups have more difficulties with the maintenance of their member support and well-being functions (e.g. Kiesler und Sproull, 1987; Thomas, 2000).

The maintenance of a group's and its members' well-being is crucial to establish learning communities and successful, but also stable, learning groups like those prevalent in PBL. This has in particular been stressed by McGrath in his TIP-Theory (Time – Interaction – Performance; McGrath, 1991). TIP-Theory describes three functions a group has to fulfill at the same time: (1) working on the common task together (production function), (2) maintaining the communication and interaction among group members (group well-being), and (3) helping the individual member when necessary (member support). These three functions are connected with each other (McGrath, 1991).

From such a perspective, the most common variant of CMC, text-based communication, is a comparatively poor medium to support these three functions. Difficulties with typing, turn-taking and a minimum of social influence (and of course: social control) are often adverse to the production function. Furthermore, dedicated channels that support group well-being are missing. Para- and nonverbal cues that usually provide information for diagnosis and intervention regarding this function in face-to-face communication are cut off and only poorly substituted in CMC (e.g. by emoticons ;-)). Given these shortcomings of text-based CMC in supporting well-being and productive aspects, there will also be a lack of member-support because single group members will not be able to compare production outcomes of team mates or identify mates with motivational or emotional problems.

These difficulties can be summarized as follows: The lack of immediate and permanent feedback during CMC related to aspects of groups' production-function, well-being and member-support hinders establishment of successful learning groups and communities. A possible solution can be found in approaches that provide steady feedback as additional information resources in online groups.

3.2. Feedback in Online Collaboration

CMC itself provides the basis for feedback mechanisms in online collaboration. During computer-mediated communication data on interaction can easily be recorded, stored and re-used for feedback purposes. In addition, software interfaces designed for CSCL allow collecting individual quantitative data that can be used for further computations in real time. Both data sources combined can easily be used to analyze individuals' and groups' behavioral processes automatically. Thus, online learning groups provide the basis for feedback on their progress by just collaborating.

Research on this methodology is poor. Barros and Verdejo (2000) have been pioneers using their own collaboration platform with integrated analysis and feedback mechanisms. They describe an approach to provide feedback of group characteristics and individual behavior during CSCL based on a set of attributes computed out of data derived from learners' interactions. Their automatic feedback provides a qualitative description of group activities regarding three perspectives: the group's performance in reference to other groups, each member's performance in reference to other members of the group, and the group performance itself. Their DEGREE-approach (Distance Environment for GRoup ExperiencEs) allows for extracting relevant information from online collaboration at different levels of abstraction. Unfortunately Barros and Verdejo (2000) give no empirical evidence for the effectiveness of their asynchronous system.

Jerman (2002) describes another possibility of giving feedback based on interaction data. He provides feedback on quantitative contribution behavior as well as on learner-interaction during a synchronous problem solving task (controlling a traffic sign system). Jerman compared a first experimental group that received feedback about each individual learner's behavior. A second experimental group received feedback about the whole group's success. He showed that a detailed feedback containing each individual's performance data enhanced learners' use of meta-cognitive strategies regarding problem-solving as well as discourse compared with outcomes of a control group.

In an earlier study (Zumbach, Muehlenbrock, Jansen, Reimann & Hoppe, 2002) we also used a feedback mechanism during a synchronous problem-based learning task. In an experimental group with permanent visualization of group-members motivation and display of relative amount of each group member's contributions we found slightly positive effects of this visualization. Compared to a control group without feedback there was a higher amount of interaction between learners. Furthermore, we found a positive influence on intrinsic motivation. These effects were only slight because we used ad-hoc groups and treatment time was, at about three hours, relatively short.

Our approach continues this line of feedback research, combining feedback mechanisms in an asynchronous CSCL-environment with long time intervention.

3.3. Providing feedback to support a group's production function and well-being

An important characteristic of our approach is to use CMC, extract data from discourses and to provide abstract views as a substitute for missing communication and organization 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 be turned into histories of potential use for groups.

We chose two ways to analyze how such group histories can be used for learning purposes. Firstly, parameters of interaction such as participation behavior, learners' motivation, and problem solving capabilities were recorded and fed back in a computationally aggregated manner. This acts as an additional information resource for the group. These data could thus be used to structure and plan group coordination and to enhance group well-being (well-being function). Secondly, we tracked group members' problem solving behavior during the design tasks and provided feedback by means of problem-solving protocols. These protocols can be used to enhance a group's problem solving process in further tasks (production function). In order to establish these functions we developed a collaboration platform integrating interaction and problem-solving feedback (see Figure1).

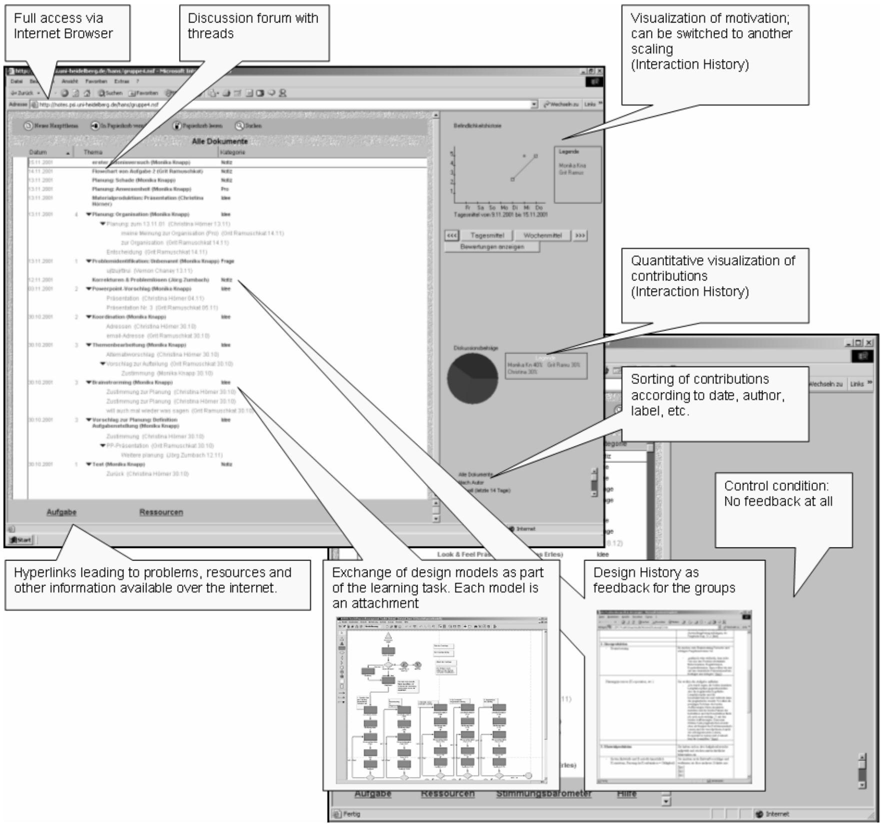

Figure 1. Asynchronous collaboration platform with feedback mechanisms.

Figure 1 shows the collaboration platform developed for our dPBL/LBD course (including a variant without feedback-mechanism in the background; see study below). The communication facility is based on a Lotus Notes platform, merging tools that can manage documents with automatic display possibilities for interaction parameters and problem-solving protocols. During collaboration each group member had to fill in a form stating his or her motivation in regular intervals. These data were aggregated over time and visualized in a line graph, showing all group members' motivation (one curve for each learner; see Figure 1, top right).

Contribution behavior of each learner was recorded by the system itself and, in relation to all other group members' contributions, quantitatively represented as a pie chart (Figure 1, right part).

Both of these feedback mechanisms (the "*interaction history"* of a group) can help to identify problems in motivation as well as participation. This provides a diagnostic base to give member-support and, by that, help to maintain the well-being of the group members.

Another type of support is given by means of aggregated problem-solving protocols that maintain groups' essential steps of solving previous design problems. These meta documents ("*design histories*") are produced manually by a tutor or instructor and provide an insight into the problem solving process of a group by showing them milestones of their previous work. By means of such feedback learners are able to identify strengths as well as weaknesses in their production function and can easily re-use existing solutions and modify them for further problems stated in a PBL-course.

In a dPBL course lasting over 4 months we evaluated our methodology concerning group-well being and production function.

5. EVALUATING OUR FEEDBACK APPROACH

In a controlled experiment we examined the influence of our feedback techniques on groups from three to five members – a total of 33 participants. These groups participated in a problem-based course about Instructional Design that was a combination of PBL and Learning-By-Design. Learners were required to design several online modules for a fictitious company. Tasks were presented as problems including a cover story. Each problem had to be solved over a period of two weeks (i.e., an Instructional Design solution including sample lesson blueprints had to be presented). All materials were accessible online and, additionally, tutors were available during the whole course to support the students. At the end of each task, the groups presented their results to other groups.

The groups were randomly assigned to one of four treatment conditions: interaction history only, design-history only, with both histories and without any feedback histories, i.e., a 2x2 design with the factors *interaction history* and *design history* was employed. Several quantitative and qualitative measures to access 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) and an adapted version of the critical thinking scale (Newman, Johnson, Webb & Cochrane, 1997). We tried to answer one major question: how far does the administration of feedback in the form of design and interaction histories, as well as their different combinations, have an influence on students' learning? Generally, we assumed that groups with any form of histories would perform better than those without, especially regarding the motivational and emotional aspects supporting the well-being function and the production aspects supporting the production function of a group.

The results are encouraging regarding outcomes in favor of the application of feedback within the group process. Groups with design present significantly better results in knowledge tests, created qualitatively better problem solutions, produced more contributions to the task, and expressed a higher degree of reflection concerning the groups' organization and coordination (see figure 2; all results are significant with $p<0.05$).

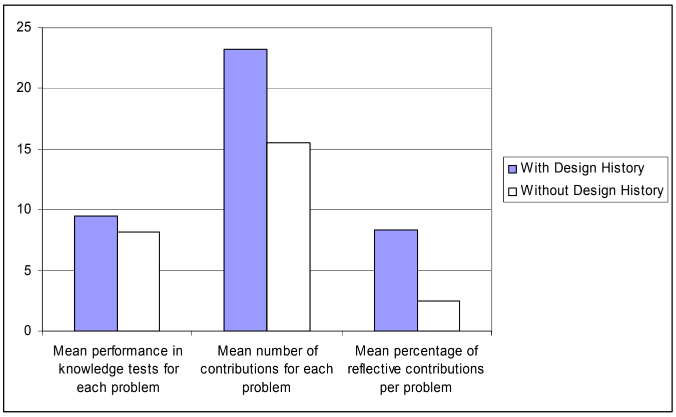

Figure 2. Results comparing groups with and without Design History.

At the same time, the presence of interaction histories influenced group members' emotional attitudes towards the curriculum and enhanced their motivation for the task (see figure 3; all results are significant with $p<0.05$).

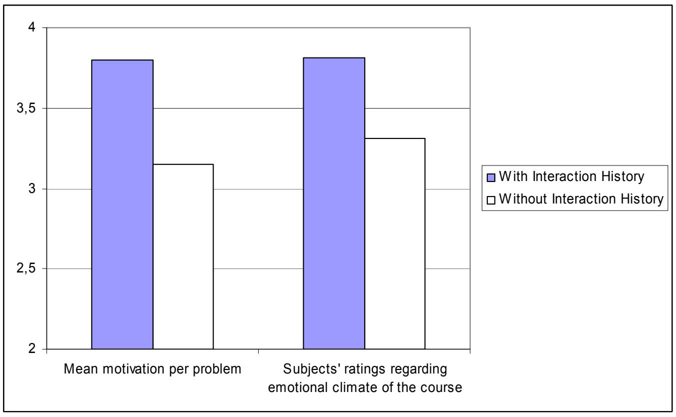

Figure 3. Results comparing groups with and without Interaction History.

So far, it seems reasonable to conclude that the different kinds of feedback positively influence different aspects of group behavior. Feedback in form of interaction histories seems to have an effect on the group's well-being function, whereas feedback in form of design histories seem to influence a group's production function according to McGrath's (1991) conception of group functions.

6. CONCLUSIONS

This research contributes to analyze different mechanisms that can enhance online learning by providing feedback to collaborators based on their own collaboration process.

Feedback is an important information source that helps learners in many aspects: In addition to feedback on a performance level, there are many other possibilities to provide feedback on interaction and on group members' well being. Especially in situations where there is a lack of visual cues – as in text-based CMC compared to face-to-face communication - many kinds of (automatic) feedback can be used to support learners.

Enhancing parameters that directly refer to a group's well-being, its member support and its production function are needed in order to improve distributed problem-based learning. By using learners' own design history and their interaction history we have overcome some disadvantages of a traditional asynchronous communication platform and established an enriched way of CMC that enables students to become successful task oriented groups.

New technologies related to knowledge management solutions could improve our approach in future by means of semantic document analysis. Meta documents like the design histories in our study can be generated automatically. This will reduce tutor's or instructors' work and thus, make this method more economic. Our contribution hopes to stimulate new areas of research on how to and enhance online learning communities by means of automatic generated feedback based on the communities' own collaboration outcomes.

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