Integration of Communication, Coordination and Learning Material – a Guide for the Functionality of Collaborative Learning Environments

Andrea Kienle; Thomas Herrmann
University of Dortmund
Informatics and Society
44221 Dortmund, Germany
{kienle, herrmann}@udo.edu

Abstract

For collaborative learning environments, the support of interaction is mainly focused on communication since directly experiencing a situation and learning by observing are mostly inapplicable. We describe communication based on a context-oriented communication model that focuses on the dialogical communication and mediation of context. The model leads to an abstract identification of general communication tasks and the use of learning material in collaborative learning processes. The difference between uploading material and communicative contributions has to be made distinct and different ways of combining both need to be supported. The prototype system "KOLUMBUS" which has been used for an experimental investigation in a university course and in a working group is used to demonstrate such features. The evaluation brought evidence that the concept of annotations to support context-oriented communication in collaborative learning processes is well received.

Introduction

In the area of electronic support for learning processes, there is an increasing number of developments which can be assigned to the paradigm of computer supported collaborative learning (CSCL). The most important characteristic of collaborative learning is the active role of the learner. Koschmann recognizes a paradigm change in this development towards a self-responsible learner [1]. Computer supported learning is focused on communication and the work on virtually presented learning material. This work is carried out to solve an artificial task which has to be provided by a teacher. The task has to be designed with the aim to initiate communication processes which support mutual learning and shared understanding. The CSCL-paradigm is related to constructivism where learning is an active process of constructing rather than acquiring knowledge [2, p. 171]. If this construction is a joint process of several students, it is the main role of the teacher to support and to inspire the communication processes for constructing knowledge. Thus, the support of communication is seen as a precondition for computer supported collaborative learning [3].

In this context the term "collaborative work" means, that the students who work together have an opportunity to get to know each other and to improve their knowledge about each other. Thus, they know to whom they can address their communication. Furthermore, they are aware of their main goal which is to enlarge their knowledge by collaboratively solving a problem. This problem is based on material being distributed on a network. Our approach is to improve communication support under these conditions by referring to those types of communication theory where communication is comprehended as symbolic interaction between identifiable persons who can be directly addressed in the course of dialogues. The mass distribution of instructions through electronic communication networks is not included in this perspective as there is no opportunity for the learners to realize what others are doing and how their understanding develops. One important aspect of communication theory is the differentiation between verbal and non-verbal expressions on the one hand and their completion by the context on the other hand, where context is understood as the physical and social setting in which the communication takes place. We suggest a design rationale for computer-mediated communication support which emphasizes this difference. This is the basic concept of the prototypical system called KOLUMBUS which is described in this paper. It offers the users two different perspectives on the items of content that are stored and displayed by the system: an item can be considered as context (e.g. the material that helps to solve the task) or as communicative expression (e.g. the description of the task or questions about it). An item which is contributed as a communicative act at a certain moment can become part of the context later. The following considerations are mainly focused on the question of how this dichotomy can be supported by appropriate software functionality and on their evaluation.

Section 2 of the paper presents this model of communication. Section 3 deals with existing collaborative learn-

ing environments, analyzed with regards to the requirements derived from the context-oriented model of communication. Furthermore, various systems are described, each of them realizing the comprehensive requirements only partially. Section 4 illustrates how the requirements derived from the context-oriented model of communication can be dealt with by features which are integrated into the functionality of a complete collaborative environment prototype. Section 5 describes the most important insights gained by the empirical evaluation of KOLUMBUS and section 6 summarizes the potential improvements.

A Context-oriented Model of Communication

In computer science, models of communication are generally characterized by the sender-recipient-model by Shannon and Weaver [4]. In this model, the transmission of a sender's message to a recipient by a channel is assumed, where the message is encoded before and decoded after the transmission. However, even if human communication acts are transmitted by a collaborative learning environment, they are more than only the transport of a coded message from A to B and a following decoding. Psychologically oriented research shows that both communication partners have to contribute if the mutual understanding and construction of ideas is to succeed in dialogues [5], [6]. The origins of this approach are closely related to neo-constructivism [7] and biological epistemology [8]. Maturana and Varela in particular point out that the models where something such as information is transported from a sender to a receiver are completely inappropriate [8]. Sender and receiver are closed systems with respect to information processing. Communication is a process that is influenced by a number of selections: a communicator selects from the universe of his/her beliefs what he/she wants to say and the recipient selects, with respect to his/her universe of beliefs what he/she wants to understand. In the course of social interaction, these selection processes cannot be determined in advance but only be influenced by the communication partners - the relation between the influencing activities and their results is contingent. This contingency is a basic characteristic of communication and learning processes. It has to be accepted for the design of collaborative learning environments.

Another basic characteristic of communication is the relevance of context: communication can only succeed, if the communicators' expressions are completed by the context which can be perceived by them and the recipients [9]. The term situative context can partially be referred to Ducrot's and Todorov's definition of the speech situation: "By this we mean at once the physical and social setting in which the act takes place, the identity of the interlocuters, their image of the act of enunciation, their views of each other (including the idea each has of what the other thinks of him), the events of what preceded the enunciation (especially the previous relations between the interlocuters ...)." [10, p. 333]. The situative context of the communicators is represented by what they perceive during communication and by what they have perceived before the moment of the communication act. Since context can refer to the past, an expression of the moment can become part of another expression's context in the future. The starting point or the boundaries of the context of a communication act cannot be defined deterministically. It belongs to the task of the communicators to encircle the scope of context which can support their communication.

By referring to the available context two essential advantages are achieved: on the one hand, the explicitness of the conveyed content does not need to be maximal, because only these pieces of information have to be given that are required to complete the context in such a way that the message can be reconstructed and understood by the recipient. For example "Where is the car?" can be answered with "behind the red house" if there is only one red house which is part of the perceptible context. The communicator has to anticipate the scope of context that is available for the addressee. This anticipation can be supported by knowledge about the communication partner. Eventually, the need for explicit communication can be reduced ("where is the car?" – "same place as yesterday"). On the other hand, the available context assists in finding out whether the communication partners understand each other: depending on how a situation evolves there are either indicators for the success of a communication task or an identifiable necessity to recheck the comprehension of the message or simply to improve the communication ("let's get up immediately" – ….. "why are you not getting up right now – don't you understand me?").

In computer-based collaborative learning environments, the provided material can and has to be used to serve as context. The combination and the distinction between communication on the one hand and the material itself on the other hand can be explained by using different constellations which can all be combined in one learning-scenario (as described later, see fig. 1):

A lecturer provides material as a base for the collaborative learning efforts of the students' workgroup. For example, a quite confused interview-transcription together with a process description may be provided – both documenting a client's requirements for a software development team. Students should learn in a joint discussion that these types of requirements could be interpreted and understood differently – therefore leading to different results. For documentation purposes, the discussion should be performed purely electronically. Providing the material is not a communication act itself – just the oppo-

site: it is not the lecturer's responsibility to provide non-ambiguous material, the attempt to do so is prone to provoke misunderstandings. The description of the actual task itself is certainly a communication act. Therefore, it is absolutely the lecturer's responsibility to make sure that all students understand the task.

The communication effort can be reduced by directly referencing the material. Thus, the description which communicates the task, should be related to the interview transcript. In this example, it is desired that the students have the opportunity to add their discursive comments as annotations that are directly linked to the appropriate part of the material where the provided comments are referring to. This contextualization simplifies comprehension in general. If the directly available material is not sufficient as context, references to other materials can be added, e.g. with hyperlinks in the case of web-based systems. For this reason, it is also difficult to determine the scope of the potential context in the case of electronic networks. Furthermore, previous messages or discussion threads which have already been entered into the system, can also be considered as context. It depends on the task and the phase of a cooperative process whether parts of the former discourse become a part of the material and are considered as context or not.

If someone modifies the material (e.g. edit, reorder, summarize) and these changes cannot be comprehended by other students (what exactly was changed and why?), further explanations can be added to appropriate parts of the material. These comments simplify cooperative work with the common material and therefore promote the reflections about the joint actions – overall an essential support of learning processes.

The design of a collaborative learning environment has to make the distinction between material and message obvious to the students – different ways of combining material and message need to be supported by the system.

Context-oriented communication in existing systems

In this section functionalities of collaborative learning environments are presented with regards to the requirements derived from the context-oriented model of communication. Furthermore, systems based on the concept of annotations are shown, because annotations can be used for enabling the integration of communicational contributions into material. Therefore they could be the key concept underlying the development of collaborative learning environments.

Collaborative Learning Environments

The *BSCW Shared Workspace System* [11] allows an easy upload of documents, however, the presentation of the content does not take place in the workspace, but in the system in which they were developed (e.g. Microsoft Word). Furthermore, communication is not supported sufficiently in the system; it mainly occurs outside the workspace (e.g. with e-mail).

CSILE (Computer Supported Intentional Learning Environment) allows all participants to add any desired information to the system, so that this content can be used as easily accessible context information. A disadvantage is that they have to use HTML-commands to add their content to the system if they wish to prepare a readable, pleasant presentation with different views which increase the possibility of understanding [12].

Gentle, an evolution of *Hyperwave* for the learning sector, makes readable versions of content possible which can be commented at various positions. Here material is used as context. References to this material can be made within the comment, any further additional explications are unnecessary. But only dedicated roles (and not students) can contribute material to the system. It is a major disadvantage of the system that the joint creation of materials by learners is not supported. Furthermore, it is neither possible to limit the group of recipients nor to extend the set of responsible authors [13].

WebGuide [14] offers the possibility to add statements or annotations to the content which can be found on the system. However, the students mostly did not relate these contributions to each other closely. There was a lack of convergence in the discussions. On the one hand, the students were not motivated to overcome this deficit but on the other hand, the system did also not offer sufficient functionality to do so, such as the facilitation of structured discussions or negotiation.

Annotations in other systems

So far, annotations are implemented in systems solely supporting either discussions on existing content or the joint work while creating and editing texts. Systems supporting the discussion on existing content are *CoNote* [15], *CaMILE* [16] and *WebAnn* [17]. All these prototypes focus on functionalities enabling annotations.

CoNote and *CaMILE* support annotations through linking discussion forums and material on existing web-sites. Therefore relations between the web-site and a discussion contribution are created. This relation can only be applied to the whole web-site and not to parts of them. Furthermore, material cannot be added by the learners.

WebAnn enables a differentiated annotation of websites´ content. The system enables the linking between the content itself and the annotation by simply marking selected content-parts. The displayed web-window is twofold: on the one side, discussion threads consisting of annotations are listed, the to-be-discussed content is shown on the other side. Annotations are made by selecting specific text in combination with inserting a message in an extra window. Other users can recognize the link between an annotation and the content by pointing with the mouse at the marked content – the related annotation is then highlighted. Currently, students can not add content. Furthermore, every annotation is perceivable by every user; therefore addressed communication is not possible.

Word processors like Microsoft Word enable the annotation of existing text by using the function 'insert-comment'. Annotations can be made directly within the text, therefore material and comments can be perceived simultaneously. No access rights are provided for these comments; therefore comments can be modified or even deleted by others.

Summarizing, we found that existing systems only support single aspects of integrating learning material and communication, e.g. the integrated presentation of material and annotation (e.g. *Gentle*, *WebAnn*), upload of material by all users (e.g. *BSCW*) or annotate existing annotations (e.g. *CSILE*). However, none of the considered systems support functionalities for determining recipients. These functionalities would support addressed communication and different phases of the collaborative learning process. We recommend the implementation of all mentioned features to support the whole process of collaborative learning within a single, integrated system resulting in an integration of material and communication.

The collaborative learning environment KOLUMBUS

KOLUMBUS was developed at the University of Dortmund, Informatics & Society. The central feature of KOLUMBUS is the segmentation of content into small units (called items) enabling the students to use and annotate the stored content in a very flexible way. Items can be represented by text, pictures, binaries, links or annotations. Communicative contributions are presented by annotations. The content can be presented as a hierarchical structure of items viewable in a web-browser. Items of material can be inserted at the same hierarchical level of another item or on the next lower level. In this way, the teacher as well as the students, can build a hierarchy of their contributions. All existing functions (e.g. annotate, rate, copy, shift, and change) can be applied to every item. Annotations can be inserted on every hierarchical level. The higher they are annotated in the hierarchy, the more general they are meant.

In the following, the main functions of KOLUMBUS are described. They are related to the four main phases of the learning process (see fig. 1): after the teacher has prepared the task and the material (1), the students have to be introduced into the usage of KOLUMBUS and the seminar's procedure. Then they start to prepare a text based on their individual research (2). This phase should be interwoven with exchanging the own contributions with the work results of others (3). Eventually, in the collaboration phase they exchange question and answers, develop a discussion thread or conduct a negotiation to find a consensus (4). These phases rely on the students' cooperation but should also be supported by the system's functionality. The whole process can be supported by activities of facilitating or giving hints by the teacher or the students.

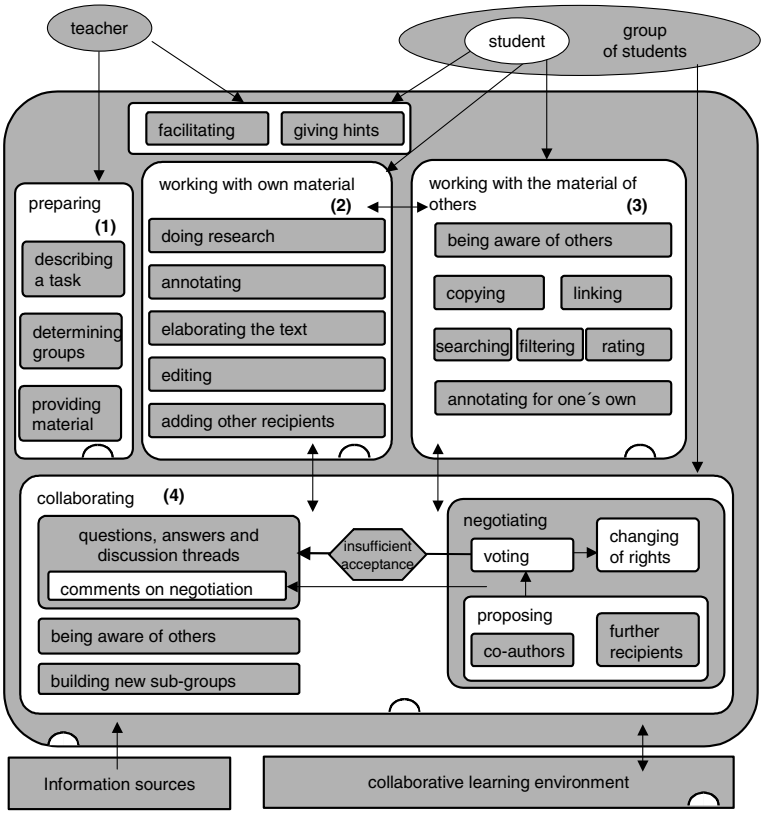

Figure 1. Collaborative learning process

The model of collaborative learning with KOLUMBUS in figure 1 uses a specific modeling language (SeeMe) where roles are presented by ovals, activities by rounded rectangles and entities by rectangles. Arrows are meant as relations and indicate that an activity

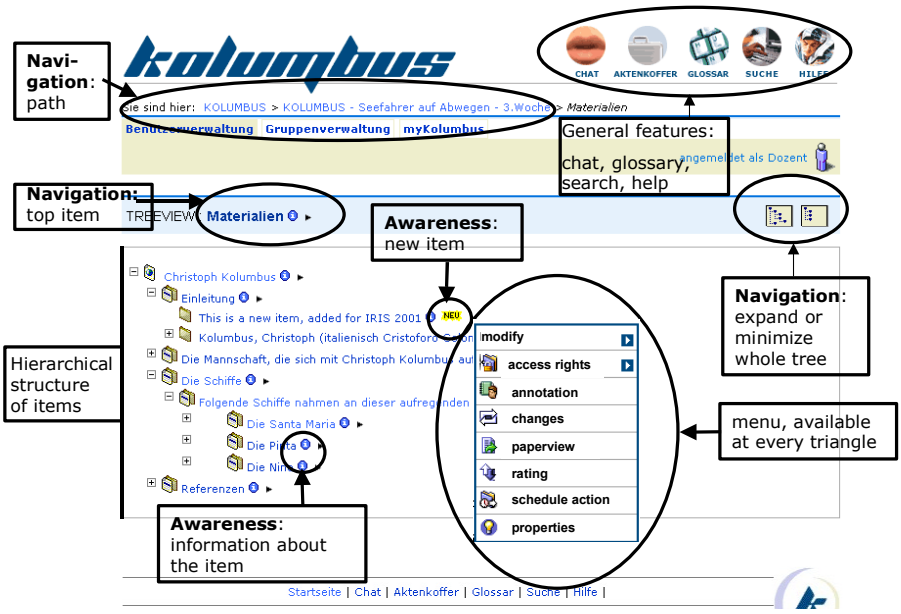

Figure 2: Treeview

uses an entity or – if pointing in the direction of the entity – that it is manipulated by the activity. Furthermore, they express that an activity is followed by another – if the arrow cuts the border of an activity it means that it does not habe to be completed before the next activity can start. Hexagons contain the conditions under which a relation is instantiated. Further details are described in [11]. The model of figure 1 is itself stored in KOLUMBUS and can be used to instruct the students.

Preparing a seminar

For preparing a seminar, a teacher can use KOLUMBUS to prepare a content structure and to upload a task description and its accompanying materials. Descriptions and material can be uploaded by different ways – a web-based form, a predefined DTD or a template for Microsoft Word. KOLUMBUS provides two different views of content. In the treeview, each item is represented as a node in a hierarchical tree-structure (see fig. 2). To support searching and focusing on relevant content, parts of the tree or the whole tree can be expanded or minimized. Furthermore, it is indicated whether an item has been inserted newly. By contrast, the paperview shows the content in a visually more attractive and readable way. Here, different types of presentations are combined to form a single document. Figure 3 shows a segment of a German content and gives an overview how different kinds of elements can be combined. Within the paperview, KOLUMBUS supports the perception of meaningful structures which are built up on a didactical basis. It belongs to the teacher's task of preparing material, to arrange the way of how the material is displayed in the paperview. In this view it is also possible to expand or reduce the scope of displayed items, and all functions of KOLUMBUS are available, e.g. to add material or annotations.

Working with one's own material

During this phase, the students are expected to do research and collect data that helps them to carry out their task. Possible sources for their research are the material as well as other information systems, especially the World Wide Web. The result of the research has to be documented in the individual content areas. These content areas can contain text, pictures, links, URLs, binary objects, uploaded documents etc. The design rationale is to offer all functions which are necessary to insert the results of a student step by step, to edit it, to re-order it and to insert links which refer to other items of the material. However, it is also possible that the whole collection of the research results is done outside the system and that it is then uploaded afterwards in a single step. In this case, the system will automatically create items from every paragraph of the text, every picture etc. Furthermore, the students can add annotations to selected items to help them organize their own work – for instance someone could insert a remark to a header of a text section to remind him or her that the structure of the text has to be remodeled. Other types of annotations can be inserted to prepare the communication with others, e.g. questions, explanations etc. The students can always edit the access rights of the material or annotations which they have inserted. Thus they can decide whether and when someone else should be able to see their contributions.

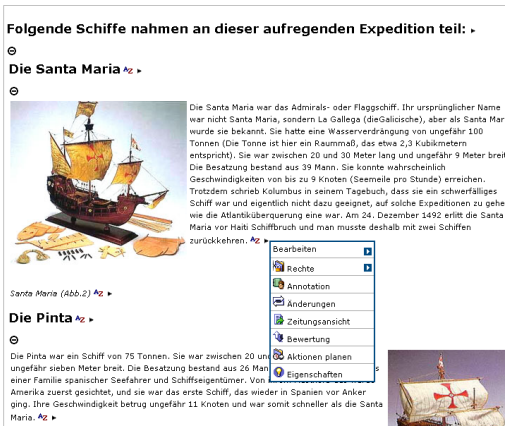

Figure 3: Paperview

Working with the material of others

Individually created items can be made readable for others by allocating access rights to the name of individuals or sub-groups. Sub-groups are introduced either by the teacher or by the students themselves. It is possible to build a hierarchy of groups and sub-groups. The students can switch between different perspectives: in one perspective, they only see their own items, in a second perspective they see what their sub-group has produced, a third one shows the work of the whole class and so on. This idea of supporting different perspectives for the various phases of the collaborative learning process is inspired by Stahl and Herrmann [14].

Not only a single item but also a (sub)tree of items can be published to others. On this basis, other students can read these items, they can annotate them or copy them to their own content area – physically or by a link. If they use a link, they inherit all future changes of the item they have copied. Since it would be awkward to constantly check whether something new or relevant has been added to the material, new or modified items are marked with a "new"-sign. Furthermore, the author of an item should carefully select and assign an access right exclusively to whom it is relevant. Furthermore, they can add messages by using annotations, e.g. to explain the relevance of an item. The recipients can use searching and filtering functions to see the new contributions at one glance and to identify those items which are especially relevant for their context of work or communication.

Both, the treeview and the paperview, can be used to work with the material of others. To differentiate between annotations and material, the treeview uses different icons while the paperview employs different colors. In the paperview, the communicative character of annotations is increased by placing the author's name in front of the annotation. This is similar to newsgroups. After changing the view from tree to paper, annotations are hidden behind a non-intrusive symbol to offer the possibility to perceive the material first.

Collaborating

During the phase of "working with the material of others", it is not required, that the "others" realize the usage of their material. However, the students can always switch to the phase of collaboration and vice versa. Collaboration includes intensive communication and discussion. By using the function "annotation" or "rating", participants give feedback or supplements on others' materials or ask questions. Here, annotating is meant as communicative activity (in contrast to annotating for one´s own). By searching for the type "annotation", it is possible to have all contributions to discussions at one glance. Chat rooms can be anchored at a certain point of the tree view and thus refer to the context of a selected item. Chatting is especially helpful to exchange information which is urgently needed.

Since the search functionality can use certain criteria such as content, author, type of items etc., a communicator can use it to understand what a recipient already knows, what context she or he is aware of and what has to be explicitly conveyed. A recipient might use the search function to complete the contextual aspects which are needed to understand a message (e.g. by searching all other contributions of a communicator).

The content structure can also contain an area for individuals to store information to describe themselves. This helps others to develop knowledge about the members of their learning group.

It is an advantage of the concept of fine-grained items that the discussion contributions can be directly linked to that part of the content to which they refer and which therefore provides the relevant context. Discussion threads can be developed by annotating other participant's annotations. From this point of view, it becomes obvious that the definition of context is relative to the communication act: context is everything to which an annotation is referring to.

A decisive design rationale of KOLUMBUS is that not only an individual can be the author of an item, but also a group. This requires that one student, who has created a certain item, invites others to be her or his co-authors. Consequently, the content area of KOLUMBUS can contain group results for which several students are responsible. Before someone becomes a co-author of an item, she or he has to agree upon this proposal. KOLUMBUS offers negotiation functionality [14] to enable this. The negotiation is initiated by proposing further co-authors. The proposed co-author as well as all the others who are already co-authors are invited to the negotiation process via e-mail. They can vote for or against the new authorship for the item in question, abstain or request more discussion.

In contrast to Stahl and Herrmann [14], the design rationale of KOLUMBUS is to keep the negotiation as simple as possible. Therefore, secret voting is used where the votes cannot be comprehended by others or explained to them. Once it is given, a vote cannot be changed. The idea behind this design decision is that the negotiation process is inserted as a special node into the content structure and that the students can add annotations to this node if they want to comment their vote or disclose their decision to others. In the case of KOLUMBUS, negotiation consists only of the possibility for proposing co-authors or additional recipients and of a voting mechanism. If a pre-determined percentage of voters agree upon the proposal, the group of authors will be extended as proposed. We assume that a student does only want to become a co-author, if she or he has understood the content of the item. This requirement should be enforced by

the characteristic of the task which is prepared by the teacher. Therefore, the building of sub-groups of co-authors supports the convergence of understanding of the material which is originated by different students. If a selected item has more than one author and someone of them proposes to extend the group of recipients, another negotiation process is initiated. An item can only become readable for others, if a pre-specified percentage of the co-authors agree in the process of negotiation.

The whole task can be considered as completed, if every sub-group has a result on which its members have agreed upon and if all of these results a made readable for the whole class and for the teacher after a process of negotiations. The overall result – material, annotations, and discussion threads – can be made available for other tasks of the same or other classes. In this case, this overall result plays the role of material or context. It is also possible to delete parts of this material for this purpose. However, it should be noted that an item cannot be deleted if other items refer to it as context – in this case, the item is transferred to an archive instead of being deleted.

Experiences with KOLUMBUS

In order to gather experience with KOLUMBUS and to convey potential for further improvement, we have conducted two case studies:

1. The first one used a course which is a mandatory seminar of the computer science program at the university of Dortmund (referred to as "seminar" in the text below).
2. The second case was arranged as a case study where four groups of scientists and students (with four members each) used the negotiation support to decide which topics they would like to discuss at a two days group meeting (referred to as "negotiation case study").

The seminar's topic was the impact of using information and communication technology on working and daily life. There is a seminar meeting where every student has to give a presentation on a selected theme. Before this meeting takes place, short documents and material to support the presentation have to be prepared by small groups of students. For this task, KOLUMBUS had to be used after an introduction to the system had been given. The students started their work at the end of April 2001. As a part of the first phase, the organizers of the seminar used KOLUMBUS to distribute documents and organizational information (e.g. meeting information etc.). Furthermore, the students were asked to use the system to declare which topic they would like to work on, and to solve conflicts if more than one student wanted to prepare the same theme. For the evaluation between April and September, the usage of the system was logged and observed. Finally, interviews with 16 participants of the seminar and the two organizers were conducted. We took those proposals for improvement of the system into account which were made by one or more interviewees and not opposed by others.

In the negotiation case study, additional data was gathered by the observation and logging of the usage process and by final group-interviews in December 2001. The group-interviews were especially helpful to identify proposals for improvement which are based on a consensus. The main subject of the case study was to find out how the negotiation mechanism is used and combined with the possibilities for discussion. This case study became necessary since it turned out that the task within the seminar did not necessarily requires negotation.

Working with material

Students mostly used the predefined template for Microsoft Word documents to prepare and add their material into the system. Tree view and paper view did both support the students in navigating the content structure and perceiving relations with the material of the other students. An archive providing materials of previous seminars' and the opportunity to observe other students' activities were very well received. Students confirmed that these functionalities supported them to learn more about the content presented by the others. Furthermore, they mentioned that it helped to improve their own way of working on their material.

It turned out to be a crucial success factor for the usage of the system, that the structure of the tree, where the content has to be filled in, is appropriately prepared. Both case studies revealed that it cannot be expected from users to create their own structures in the different content areas. Students required prepared content-structures and links between the different areas (e.g. themes) and even for the storage of their own material. This support was not planned for the process of collaborative learning with KOLUMBUS as described above (see fig. 1). The participants of the negotiation case study did also require predefined content structures. The large amount of discussion contributions caused an uncontrollable growth of the content-structure and problems with the users' finding the relevant information. However, the participants of the negotiation case study confirmed that possibilities for flexible adding of material are an advantage.

We also found in both case studies that the possibility to change the access rights for selected items was considered as valuable – however, it was required that the dialogue for changing these right should be much more user-friendly. On the other hand, the possibility to introduce newly built sub-groups was not used. This might be because the task did not urge the users to introduce new sub-groups, that the dialogue for doing so is too awkward, or that this feature is generally not very sensible.

Annotations

At first, most students were irritated by the integration of communication support and the working on material within a single system. Therefore, KOLUMBUS was at first considered more as a system for material storage than as a communication media. Furthermore, students tried to transfer their experience with the functions of text-based communication media – such as e-mail – to the usage of annotations.

Taking into account the experience with the whole process of the seminar, it became apparent that annotations in KOLUMBUS are a good vehicle for web-based contextual communication. Annotations were predominately used in the review-phase, where students were asked to comment the material of each other. By inserting the comments at the appropriate position of the content, not many additional explications were necessary. Therefore, the overall process of adding communication contributions was noticeable easier. During the negotiation case study, annotations were used for supporting the discussion process by exchanging arguments for or against proposed topics. This discussion process prepared the negotiation phase. However, the participants criticized that the system does not offer any support for building links between contributions in different discussion-threads. This kind of links could have allowed the users to bring together the heading nodes of different content areas and expand them if needed. We had to learn that the KOLUMBUS functionality of hyperlinks was not sufficient to meet this requirement.

The detection of annotations was described as difficult for the recipients. This problem is known from the evaluation of newsgroups. Because of the integration of material and communication contributions, the problem even increases. An overall improved way to become aware of new content, especially new contributions (annotations), was considered necessary by many interviewees. In the case of the negotiation case study, it was considered as a problem that new communication contributions were added at nearly every position in the content structure. This flexibility makes it more difficult to detect relevant discussion contribution than it would be the case if they all were collected in a special content area. The group discussions reveal that it might be a sensible solution if there is a choice to get all annotations displayed in a chronological order. This solution might be helpful for an easier understanding and combining of different discussion threads.

Negotiation

By supporting the negotiating step, KOLUMBUS is one of the very few systems providing support for the mutual agreement on a common result within an integrated collaborative learning environment. Our design rationale was to keep it as simple as possible. However, a secret voting was considered as less suitable for supporting negotiations in collaborative processes. Users criticized the lack of transparency during a negotiation procedure. They demanded a list showing all current negotiation-procedures together with their up-to-date conditions and transparency on the votes of the individual users. Additionally, users mentioned that possibilities to explain and change votes are necessary for negotiation, if shared understanding about the different positions should be achieved. It was criticized that the negotiation procedure does not offer an own area for exchanging comments and for discussion threads. The results reveal that users switch frequently between voting and discussion and that they consider the separation of both modes as awkward and as de-contextualization.

Awareness

In both evaluations, an improvement of the awareness of others' activities was demanded. This would not only ease the estimation of the recipients' knowledge but also supply the user with a feeling of learning in a community, and it would lower the threshold to use the chat channel for a more "direct" communication, e.g. for making comments if a quick reaction is needed. During the negotiation case study, it was particularly demanded that all users should be notified about changes made by other participants. The interviewees criticized, that the "new-icon" of an item does not disappear before it is explicitly confirmed that the item has been read. Furthermore, it was required that not only in the paperview but also in the treeview, the author and the date of origination of an item are immediately displayed. This requirement opposes our design rationale of keeping the amount of information which is immediately displayed without further request, as reduced as possible.

Coordination and facilitation

It became apparent during our interviews that the whole process of collaborative learning and development of shared understanding needs explicit coordination and facilitation. For example, the organizers of the seminar were considered as role models with respect to their way of using KOLUMBUS. Nearly all students mentioned explicitly that they learned the use of the system by observing the organizers, e.g. while doing the reviews. This is also relevant for the communicational use of KOLUMBUS. From the viewpoint of our interviewees, the most relevant tasks of the organizers with respect to KOLUMBUS were the already mentioned preparation of the content-structure, the facilitation of discussions during the seminar, and the construction of the archive prior to the seminar. During the negotiation case study, no dedicated role – such as an organizer – was pre-defined.

Therefore, we could observe difficulties in the organization of the process of discussion and negotiation. It was difficult for the participants to proceed to the next step in the course of the discussion process, e.g. to make a proposal or to start voting etc. It was also a problem that it hardly did happen that someone had tried to summarize the current state of the discussion. In the group interviews, it was demanded that one person should control the discussion and the negotiation process.

During the negotiation case study, the participants tried to help themselves by using annotations for the purpose of facilitation and coordination. However, for this purpose the concept of annotation is limited as long as there is no contextual material available to which a facilitation contribution could be linked to. There was no particular content area planned for inserting coordinating or facilitating communication acts. A special content-structure which supports the insertion of organizational and content-related contributions, was demanded to support the coordination of the communication process. The organizational and content-related contributions should be distinguishable. Special features should support both types of contributions, since there was a large amount of organizational contributions (ranging from 17% to 40% in the various workgroups). A large percentage of organizational contributions in learning processes is also mentioned in other studies [19].

Discussion and further research

With KOLUMBUS, a collaborative learning environment is offered which integrates the storage of multimedia material and communication contributions. The design rationale of KOLUMBUS is based on a context-oriented communication model. It is focused on the question of how mutual understanding can succeed and be facilitated in dialogues by building immediate relations between communication acts and the material which represents the context. For meeting this requirements, a special concept of annotations is used which is based on a very high granularity of the items which can be annotated and on an elaborated access philosophy of access rights which helps to alter the extend of visible material and annotations in accordance with the phases of the task completion and the learning process.

The evaluation of two case studies, a seminar with 16 students and a study in 4 work-groups, brought evidence that the concept of annotations to support communication in collaborative learning processes is well received. The material can be used as context information to support the communication between the learners. The participants confirmed that communication overhead - caused by extra explications - can be reduced, if messages can be suitably fitted into the content-structure. On the other hand, difficulties arose if new contributions had to be located, because they can be potentially stored at every place in the content-structure.

In the following conclusion, we discuss three main problems and further research questions. These problems are concerning the distinction between communicational contributions and stored materials, managing the learning process and the support of moderation tasks.

Distinction between communicational contributions and stored materials in collaborative learning environments: The evaluation revealed that users at first were irritated when confronted with the integration of material-storage and communication-media within one system. While getting used to it, participants demanded a higher variety of technical support. For example, with respect to the handling of material, the functionalities of flexible inserting and adding at any place were well received. For communicative contributions, the flexible insertion was problematic with respect to the comprehensibility of the relation between different annotations or discussion-threads, if they were related to each other but located at different places within the content structure.

We are convinced that the integration of material-storage and communication-support is a guiding model for the design rationale of future collaborative learning environments. Further research should deal with the questions to what extent the usage of material and communicational contributions has to be distinguished. Examples are different awareness-mechanisms, requirements for the content structure or the indication of meta-information about either communication contributions or materials.

Managing processes and transparency regarding these processes: Collaborative learning environments support various phases of the collaborative learning processes. KOLUMBUS´ users criticized the missing transparency regarding the process's progress and the missing support for switching phases. For the phase of collaboration, it should be supported that various contributions which are located at different places of the content structure, can be brought together by simple means. This supports convergence and the initiating of negotiations by making proposals. For the negotiation, a kind of open voting has to be supported – offering transparency and also allowing the users to add arguments to given votes. Further functionalities have to be developed to find possibilities how the technical system can support transparency and the management of processes.

Support for the facilitator's tasks: A facilitator of collaborative learning processes is supportive for the supplement of or as a corrective to the technical system. Examples are the support of the collaborative process by creating an appropriate content structure and activities like summarizing the actual state of discussions or leading over to the next process phase.

Further research is necessary to support the tasks of the facilitator and to understand how this support can be

technically provided. This could also include technical functionalities for flexibly enabling a group's member taking over the task of moderation. This could be, for example, a distinction between organizational and content-related contributions to enable a sufficient facilitating of the communication process.

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