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Context-oriented communication and the design of computer supported discursive learning

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Abstract Computer supported discursive learning (CSDL) systems for the support of asynchronous discursive learning need to fulfil specific socio-technical conditions. To understand these conditions, we employed design experiments combining aspects of communication theory, empirical findings, and continuous improvement of the investigated prototypes is employed. Our theoretical perspective starts with a context-oriented model of communication which is—as a result of the experiments—extended by including the role of a third-party such as a facilitator. The theory-driven initial design requirements lead to the CSCL-prototype, KOLUMBUS, emphasizing the role of annotations. In KOLUMBUS, annotations can be immediately embedded in their context of learning material. Practical experience with the prototype in five cases reveals possibilities for implementing improvements and observing their impact. On this basis, we provide guidelines for the design of CSDL systems which focus on the support of asynchronous discursive learning.

Keywords Communication · Facilitation · Design of CSCL-systems · Evaluation

Introduction

A wide range of collaborative learning is based on and mediated by the communication amongst students and between them and their teachers. We call those settings where the communicative exchange of beliefs and arguments has the deciding role for the success of collaborative learning *discursive learning* and the phenomenon that computer-based environments help to enhance it *computer supported discursive lear*ning (CSDL). We consider discourses to be a kind of talk that can also be represented by text and that has

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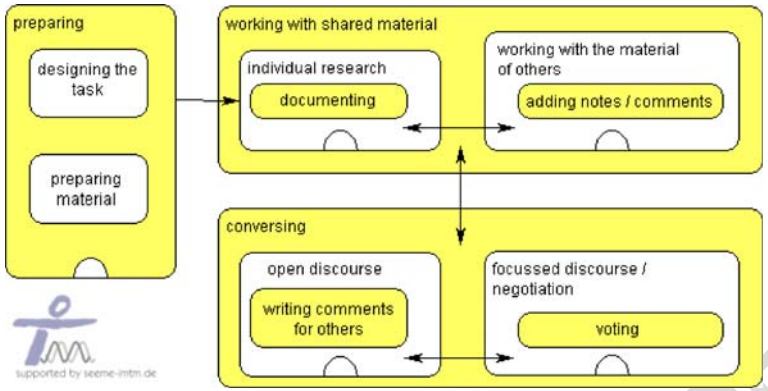

Fig. 1 Process map of discursive learning

crucial relevance for learning and for the development of thinking (Arnseth and Ludvigsen 2006). This view of discourse is supported by 'exploratory talk' (Mercer and Wegerif 1999). Discourses can be triggered by misunderstandings and breakdowns (Stahl 2000) or by opportunities and problems (Herrmann 2003)—all of them promote the reinterpretation and articulation of the concepts and beliefs underlying the discourse.

We intend to present an in-depth analysis of those aspects of computer-mediated communication that mainly support deliberate reflection in discourses. This intention is based on a constructivist approach that is often used as "a motivating theory in CSCL literature" (Suthers 2006). Constructivist learning can be supported by processes where students work together on a problem which they can only solve if they develop and acquire knowledge which is new for them. We suppose that discourse can have—depending on the problem to be solved—a positive impact on the intensity of knowledge construction. The more the solution of the problem cannot be directly checked against the constraints of the real world, the more is its appropriateness a matter of deliberate discussion. This in particular is the case with problems where more than one answer is appropriate.

Working on this kind of task intertwines certain types of activities as shown in Fig. 1[1]. It displays on the one hand the switching between individual work (on prepared or newly found material, such as text, pictures and other types of media) and communication, and on the other hand the switching between mere information exchange (notes, comments) and focused discussion threads about certain topics. These switches characterize the challenges to be met by CSDL since they imply phases where it is more or less relevant that the students make themselves understandable to each other.

Appropriate design of CSDL therefore has to meet the particular requirements of enabling mutual understanding. For this reason we suggest trying out a design approach that is guided by communication theory. We are interested in synthesizing those aspects of communication theory which help to explain how mutual understanding—and subsequently the convergence of ideas and beliefs—is possible. It becomes obvious that the appropriate interrelation between communicative utterances and their context make a decisive contribution to the success of mutual understanding, and that—however—this relevance

[1] The modelling notation which is used in Fig. 1 and in the other diagrams in this paper is explained in (Herrmann 2006). The white semi-circles in Fig. 1 indicate that an activity may include more sub-activities than are depicted in the diagram.

of communicative context is usually neglected in CSCL research (for exceptions see Stahl 2002; Enyedi and Hoadley 2006).

Many other CSCL concepts and experiments are focused on helping students to improve their communication for the purpose of constructive learning. The most prominent approaches are those which attempt to achieve improvement by contributing to the structuring of communication. Typical examples are the application of categories of speech act and argumentation theory (Ludvigsen and Morch 2003) or the guidance of the students through predefined communication threads that are represented by scripts (Kobbe et al. 2007). However, the scripting approaches are not sufficiently oriented to the problem, which is that the students need to learn and to gain practice in how they can produce computer-mediated statements that can be easily understood by others. The uploading of statements with a computer makes it difficult for students to anticipate how hard it may be for others to understand and share the idea that is underlying these statements. Therefore, our approach aims to support communicative behavior that takes knowledge about the communication partners and their perceptible context into account.

The following section starts with the theoretical derivation of a model of communication that puts the relevance of context into its foreground and reveals the relevant activities to be technically supported. The third section describes the practical settings of courses for which the prototypes were designed and where they were tested. The next section represents the theory-related features of the prototype and their experience-driven improvement. The structure of this section starts with theory-based design, and is followed by the demonstration of its usefulness and also some shortcomings; they are the basis for proposing the new design of technical features, which are illustrated by examples. Subsequently, the essential findings with respect to technical design and theory are discussed and related to the literature in the fifth section, which is followed by concluding remarks.

A context-oriented model of communication

This section outlines the theoretical approach which guided the design experiments. It starts with an overview of relevant communication theories and points out the difference between technical and human–human communication. It is argued that with respect to most communication theories, human communication partners are only loosely coupled and that therefore the context of communication plays an important role in supporting their coupling during their efforts to achieve mutual understanding. Consequently, the "The context of a communication" section describes and differentiates the phenomenon of "communicative context" and represents the details with the help of a graphical diagram which can serve as guidance for design. The next step (the "Activities of communication" section) describes the activities during communication to provide a basis for the design of the technical functionality needed to support communication. In particular, the requirements which have to be met by the participants in the case of computer-mediated communication are described. Finally it is outlined how the context-oriented communication theory differs from those approaches which are widely applied in CSCL research and design.

The wealth of theories on communication (for an overview, see e.g., McCarthy and Monk 1994 or Littlejohn 1999) demonstrate that we can draw on a multiplicity of scientific approaches when explaining human communication. McCarthy and Monk (1994) point out that conversation analysis (…), speech act theory, and common-ground oriented psychological theory have mainly influenced the field of CSCW. These approaches

recognize—or at least imply—that acts of human communication cannot be explained with a model of encoding an item of information, conveying or transporting it from a sender A to a receiver B through a channel, and subsequently decoding it. The transportation-oriented models refer to Shannon and Weaver's seminal work on communication engineering and are very helpful as a scientific base for data exchange between machines (Shannon and Weaver 1949). However, these models are based on the concept of a determined coupling between technical systems where the coupling mechanism can be understood by referring to physical relations of cause and effect. Therefore they cannot cover the phenomena of loose coupling between psychological or cognitive systems, as is the case when humans communicate. The engineering-oriented models are also not appropriate if students' exchange of messages is mediated by computers. The coupling becomes even looser if it is mediated between non-co-located communication partners and different slots of time, as is typical in asynchronous discursive learning. As an example we can refer to situations where people answer emails by merely reacting to the text of the message but not actually to the person who has written it or to the situation in which the message was generated.

The loose coupling between the communication partners can also be understood by referring to the concept of contingency. The German sociologist Luhman builds his theory of social systems on a notion which refers to a social system as a web of communication (Luhmann 1995). By referring to Maturana and Varela (1998), he understands communication as being characterized by *double-contingency*, which describes that not only the speaker is undetermined in his way of selecting what he/she wants to share with others from his flow of thoughts, but also the listeners, as they follow an utterance and make interpretations which resonate with their own flow of thoughts. Within communication, the concept of contingency means that the listener's interpretation is neither independent from nor determined by the utterance of the speaker. Therefore, it is appropriate to consider communication as a loose coupling. "The phenomenon of communication depends on not what is transmitted, but on what happened to the person who receives it. And this is a very different matter from »transmitting information." (Maturana and Varela 1998, p. 196). Instead of being just in the role of a decoder, "The receiver of a piece of language, be it a word, a sentence, or a text, faces a task of interpretation. A piece of language directs the receiver to build up a conceptual structure, but there is no direct transmission of the meaning the speaker or writer intended. The only building blocks available to the interpreter are his or her own subjective conceptualizations and re-presentations." (von Glasersfeld 1995, p. 141). The phenomenon of "loose coupling" helps to understand why students' contributions are sometimes not very closely related to each other even if they try to achieve a convergence of their ideas.

Because of the contingency of communication, Ungeheuer (1982) emphasizes the relevance of *context* in the course of building shared understanding via communication. The problem of decontextualization and recontextualization in Ackerman and Halverson (2004) is well known in the domain of knowledge management and is also relevant to explaining the potentials and limits of communicative understanding in CSCL systems when students exchange messages and the results of their work.

At first glance one might argue that a communicator's expression should contain as much information as possible about the idea which he wants to share. Thereby a recipient who follows the expression receives extensive guidance to reconstruct what is meant. This expectation runs counter to a basic assumption of communication theory: "a maximum of explicitness leads to a minimum of understandability" (Ungeheuer 1982, p. 328, translated by the authors). With respect to this assumption, the form and extent of an expression have to be specifically adapted to what the recipients already know and the extent of an expression should be reduced to what is needed by the recipients in order to reconstruct

what the communicator wants to share with them. Therefore the sharing of information via a computer system has to take into account what the recipients of this information can perceive in the actual moment or may already have perceived on other occasions—consequently their way of having experienced the world has to be considered as context which backs the communication. This is only feasible in CSDL if the participants are able to realize which parts of the available content have been actively received.

It is not only the expressions in a communicational dialogue which contribute to the loose coupling between the communicators and their recipients, but also the context which they share. In the case of discursive learning, for example, the material provided by the teacher and investigated by the students can serve as a context and support the coupling between the students and between their communication processes. This effect can be emphasized if a facilitator highlights the most relevant parts of the content.

The context of a communication

The "context of an expression" can be defined by referring to all phenomena in the environment of the communication partners which they can perceive or can have perceived, and which help to reconstruct the thoughts which were referred to by this expression. Context can cover the physical dimension of a situation as well as the social and informational dimension. It should be noticed that the behavior of the communication partners itself is part of the context (Ducrot and Todorov 1987). Besides the directly perceptible behavior (*perceptible con* in Fig. 2), those events which occurred in the past (*perceived con* in Fig. 2) are also relevant. These past events also cover expressions which were uttered before the current situation. With respect to the relevance of past events, it becomes evident that context can refer to all types of events in everyday life—in as far as the communication partners assume that they share these experiences. The relevance of context can be recognized with respect to the expectations that are developed during the course of the students' asynchronous communication and that give them a feeling of how fast the others will probably react to their contributions. If these expectations are not met, they may interpret this as evidence that a misunderstanding has taken place that has to be solved. CSDL has to support the detection of misunderstanding by facilitating the comparison between contributions and the expectations which can be derived from the context.

Another example refers to the spectrum of possible reactions to a question such as "Do we have evidence for this statement from the literature?" The question may simply be answered with "Yes!" or this confirmation may be completed with a concrete bibliographic indication, or the question will be interpreted as a request to provide the details that can be extracted from the literature. The appropriate reaction is mostly chosen by referring to the context of such a question. Furthermore, to detect misunderstandings we can use those overarching social activities in which communication is embedded and whose aim is not primarily the development of understanding. We call these activities *extra-communicative* behavior[2]. For example, if a student receives a message which asks him to submit an outline about his work on a task by a certain deadline, and if he meets this requirement, it

[2] By this distinction between communicative and extra-communicative we disagree with Watzlawick et al. (1967) who take as an axiom that one could not non-communicate. This might be helpful to explain pathological behavior where people cannot differentiate between whether an act of behavior is meant as communication or not. However, it is not helpful for the design of collaborative learning environments in which participants usually have to decide—and are able to do so—whether a contribution is meant as an act of communication (such as an email message) or is mainly an interaction with the system which contributes to collaborative task completion (e.g., the act of adding an attachment to an email).

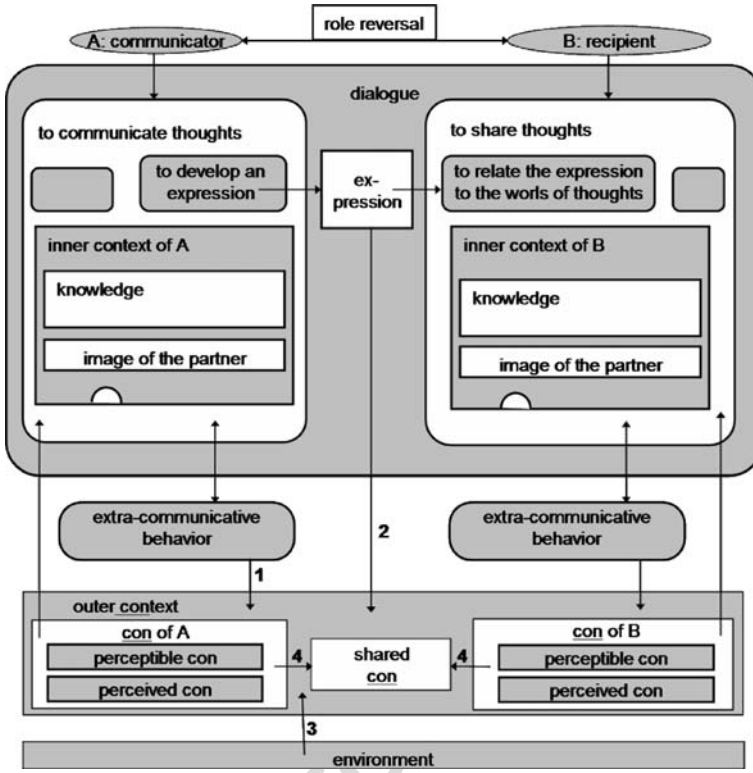

Fig. 2 Differentiation of context

can be assumed that he has developed an appropriate understanding of the message with respect to the thought and expectation that were behind this message.

The positive effect of context can only be achieved to the extent to which the experiences overlap and are shared by all participants. Clark and Brennan (1991) refer to this phenomenon of shared context as the "common ground" of communication acts. With respect to Fig. 2 "common ground" is represented by the intersection of the inner contexts of the communication partners. However, their shared outer context also plays an important role since only by referring to it can common ground be built and be extended.

It also has to be taken into consideration to what extent mass media or the World Wide Web, for example, contribute to the development of shared context. When a task description is developed to be dealt with within CSDL, it is questionable whether the students have certain knowledge about what is going on in the world, e.g., whether they know or not that a new computer virus is currently discussed in the daily press. Therefore links to public material should be an extra type of content item which can be adequately processed with a CSDL system.

The communication model in Fig. 2 takes the differentiation between varying types of context into account. It differentiates between the communicator A (referred to as "he") and the recipient B (referred to as "she"), who tries to share thoughts with A.

The communication model shows that results of extra-communicative behaviour (1) as well as of communicative activities—the expression (2)—and parts of the environment, e.g.

mass media, (3) become parts of the context. It also should be noticed that the contexts which are perceptible or could have been perceived by the different participants of a communication (con of A vs. con of B) only partially overlap, and only this shared context (4) (as represented in Fig. 2) can be used to complete the current expression or to ensure the success of understanding. In the case of CSDL this shared context can be built by data which has been uploaded or by the log files of the students' communication threads. The system can help to retrieve context by representing uploaded content by links which refer to earlier discussion threads or to material which is somewhere available in the Web. Awareness (Dourish and Belotti 1992) functions can also help to detect relevant parts of context.

Furthermore, only a part of the perceptible or previously perceived context in fact leads to impressions or experiences and becomes parts of the inner context of the recipient. Even if the communicator shares context with the recipient he cannot positively conclude that she will relate the same elements of the shared context to the ongoing communication act as he does. This can be typically observed in CSCL chats when the reader references other parts of the chat log than the writer had in mind. Therefore, the depiction of a cutting arc (cf. Fig. 2), which starts inside the box of an individual's context, indicates that the context is only partially employed to support communication. CSDL should allow the communicator to direct the attention of the potential recipients to those parts of the context which are related to his contribution.

Therefore, the differentiation between outer and inner context is helpful. The inner context represents all of those aspects of the available context (i.e., the outer context) which have found their way into the web of experiences—or world of thoughts and feelings—which are represented or available within a person. Designers as well as students have to be aware of this difference between inner and outer context. A typical problem is that not every statement that has been displayed on a screen has really been read and not every statement which has been read has been understood. With respect to CSCL it can be stated that the inner context also includes knowledge which is acquired by (collaborative) learning. Figure 2 presents "knowledge"—as an important basis of communicative understanding—and the image of the (communication) partner as parts of the inner context. "Knowledge" can also include information of how the relevant context can be identified and retrieved (cf. the "Meta-data of annotations" section on meta-data). The semi-circle at the bottom of the "inner-context" box indicates that it can also contain further elements such as feelings or self-image. An important part of students' knowledge which supports communication within learning processes is—for example—that the goals of a learning phase are known. The "image of the partner" is recognized as relevant in many communication theory based analyses. It is crucial for successful communication that the communicator's "concept of communication" (cf., Fig. 3) takes into account what the recipient may already know. The image of the communication partners must also include an estimation of the outer context which is accessible or has been accessible to the communication partner and their influence on the inner context.

We describe this differentiation between outer and inner context because it is particularly relevant to computer-mediated communication. With respect to a CSCL system, for example, its technical features belong to the outer context of the participants; however, the communicators must understand that not every participant is familiar with all of these features and that they have to take into account whether a certain functionality is known or not. For instance, knowledge about awareness functions or explicit references between chat contributions has an impact on communication processes.

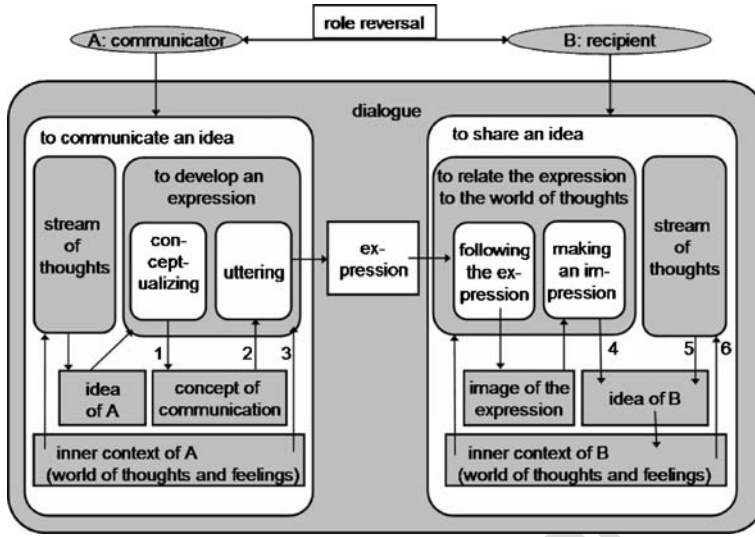

Fig. 3 Activities in the course of communication

Activities of communication

Communication consists of cognitive activities to which the technical support of discursive learning should be related. Based on his image of the recipient, the communicator develops (1)—mostly subconsciously—a communication concept which prepares (2) the uttering of an expression (the numbers in parentheses refer to Fig. 3). The communicator's concept of how to formulate the expression represents a plan (Ungeheuer 1982) of how the recipient can be guided to reconstruct an idea. With the differentiation between *stream of thoughts* and *idea* we want to indicate that something has to be separated from the permanent flow of cognitive activities to become a subject of communication. This differentiation emphasizes that the communication can be continuously influenced by the ongoing stream of thoughts. In situations where the communication partners are not co-present, the distortion by the stream of thoughts is higher than in face-to-face situations and focussing on the needs of the recipient is more difficult.

The communicator's "concept of communication" has to consider what has to be made explicit by the expression and what can be presumed to be part of the recipient's inner context. Effective communication tries to express only those aspects that are needed to reconstruct the idea. The hint "click here for further details," for example, presupposes that the recipient is aware of the context of Web technology features; a more explicit phrase such as "position the cursor over this spot and click to trigger the display of a new webpage which shows further details" would appear awkward to most users. Being less explicit does not only save time but helps to focus the recipient's attention on those aspects which are really intended to be shared. "No representation is either complete or permanent. Rather any description is a snapshot of historical processes in which different viewpoints, local contingencies and multiple interests have been temporarily reconciled." (Gerson and Star 1986, p. 257).

It is obvious that every idea can lead to a variety of different concepts and expressions in order to communicate it. The relation between the idea to be communicated and the expression can be indirect and incomplete since the main purpose of the expression is to

guide the recipient when she tries to imagine what the communicator may have in mind. The phrase "google it!" is a shortcut for referral to a series of activities and can be understood even if being heard for the first time, as long as the recipient is familiar with the context of search engines on the Web.

In many cases, the expression includes direct or indirect hints to the context which has to be taken into account by the recipient. In face-to-face communication, participants can be aware of the physical situation, which is perceptible and serves them as context for their communication. They can refer to their environment by gestures. The references to the context have to be made an explicit part of the expression if the relevant context is part of the past or cannot be perceived since the communication is computer-mediated. In CSDL, awareness-features can make the detection of relevant context more feasible. The content which represents the context has to be broken into small units so that it is easier to refer to specific parts of it and to direct the users` attention to them.

The recipient has to follow the expression to achieve a mental representation ("image of expression," see Fig. 3). This representation is a prerequisite to the development of an idea ("making an impression") about what the communicator may have meant. To "make an impression" is only possibly if the recipient interprets the expression in relation to her own stream of thoughts and to her inner context (5 and 6, Fig. 3). The interpretation has to be related to the recipient's knowledge of the communicator ("image of partner", see Fig. 2). "Making an impression" leads to a new idea (4, Fig. 3) which is—but need not be—correlated to what the communicator has meant. The new idea can—but again need not—partially become a new part of the inner context. With respect to awareness mechanisms, CSDL designers should differentiate between the users' merely displaying some content (of a message, an annotation, etc.) and those actions (e.g., sending a reply, editing a text, etc.) with which the reader of the content reacts to it. In the latter case it is more probable that the reader has made the content a part of her inner context. This difference should be mirrored by the awareness mechanisms within CSDL.

Both—communicator as well as recipient—have to contribute to the identification and avoidance of misunderstandings within the activities "conceptualizing" and "making an impression." This aim can be pursued by a permanent comparison of the ongoing dialogue with the context, in particular with the ongoing extra-communicative behavior. This behavior mirrors whether the expectations connected to the communication are fulfilled or not. For example, if the majority of the students of a class are not able to answer a question or to react appropriately to the description of a task, the possibility of a misunderstanding should be checked. The more direct a dialogue is, the more immediately the misunderstanding can possibly become a subject of the ongoing communication. In CSDL, misunderstandings can remain undetected if the recipient fills gaps in information with their own imagination (i.e., by referring to their own world of thoughts), instead of taking the incompleteness as a reason to ask for further information (Herrmann 1993).

The activities of communication become more difficult to perform in the case of computer-mediated communication. The possible extent of variations of the expressions to be conceptualized is reduced, for example, if the expression can only be represented by text. If the communication is asynchronous, the dialogues are more indirect and the detection and correction of misunderstandings becomes less probable since the feedback is slowed down. Our communication model emphasizes the relevance of context if one attempts to understand the advantages and disadvantages of a medium. Text, for example, reduces the variety of possible expression but is easier to search when the reconstruction of context takes place. We suggest that the complexity of the activity "conceptualizing an expression" is increased in those cases where the variability of selectable expressions is

reduced, the role reversal between communicator and recipient becomes slower and more indirect, or the extent of perceptible shared context is decreased. In these cases, the communicator should be supported to increase the redundancy of his communicative expressions and to offer more than a single clue (e.g., by the combination of text and pictures, cf., the so-called paper view as described in the "Integration of material and communicative contributions" section) which help the recipient to reconstruct the idea. Larger parts of the communicator's context have to be made explicit or at least be explicitly referred to, since it is difficult for the communicator to anticipate which parts of his context will be shared by the recipient or not. His anticipation of the recipient's available context has to take into account the possibility of temporal delay as well as differences with respect to locations, cultural habits, physical situations, availability of mass media, etc. For example, it is a typical phenomenon in the context of knowledge management and collaborative learning that the participants find it difficult to formulate questions about complex issues when these questions are submitted to other, unknown users (Kienle and Herrmann 2004, p. 47). For the recipient, the understanding of computer-mediated expressions becomes easier the more possibilities she has to identify and add additional context to her process of transforming the expression into an impression. She has to become active to reconstruct context or to find further context that is necessary to complete an expression.

Functionality which provides awareness is particularly helpful for both communication partners for creating context clues since awareness can be related to what we have described as extra-communicative behavior. Awareness makes those interactions with the system which are not *per se* meant as communicative acts visible, such as the up- or down-loading of data, editing of material, etc. Awareness data gives additional information to the communicators and their addressees about the overarching effects of their communication. In general, it should be considered in CSDL design that the usage of the system leaves traces which help to assure the success of communicative understanding. Both—communicator as well as recipient—have to be aware of the ongoing extra-communicative behavior to check on the success of the achieved understanding.

Context-oriented communication theory in comparison to other concepts

Highly relevant in CSCL research are concepts which refer to speech act theory and conversation analysis to support the structuring of collaborative learning processes. Speech acts are used to categorize the activities or steps in the process of collaboration. Once they are categorized, rules can be specified to determine which category should follow another one, such as an answer should follow on a question or a contra-argument after a pro-argument. Conversation analysis can help to find appropriate sequences. However, the decision to which category an expression can be assigned and how the conversation is appropriately continued after this expression is extremely dependent on the context. Above, we demonstrated with the expression: "Do we have evidence for this statement from the literature?" that it can be considered as a simple question or a request. There are numerous examples in the literature (e.g. McCarthy and Monk 1994, p. 53) which clarify that determination of categories and sequences cannot be context-free.

CSCL also refers to Clark and Brennan's concept of common ground to explain under what conditions understanding is possible and why misunderstandings can happen. The notion of common ground can lead to the misconception that it consists of a set of identical beliefs and experiences which are shared by the communication partners. By contrast, context-oriented communication theory only claims that there are experiences on both sides

which refer to the same perceptible outer context, which only implies that these experiences are partially congruent so that misunderstandings can be detected. The difficult questions with respect to common ground are how it is built and expanded, and how do the communicating partners know whether they share common ground to a sufficient extent. We suggest that referring to the interrelationship between inner and outer context can help to deal with these questions.

The problems with computer mediated communication are widely discussed in theories on the selection of the appropriate type of media. Media richness theory (Daft and Lengel 1986) evaluates the appropriateness of a medium with respect to a task by considering the spectrum of possible representations of information such as text, audio, video, etc. Media feature theory (El-Shinnawy and Markus 1997) refers to the functions which are offered to handle the mediated information. Media synchronicity theory (Dennis and Valacich 1999) differentiates between phases of divergent and convergent communication. Roughly described, this theory relates asynchronous media to the phase of divergence and synchronous media to convergence. We assign the exchange of arguments, the negotiation of positions and the making of decisions to the phase of convergence (Stahl and Herrmann 1999). We found some evidence in our explorative practical usage of CSCL systems that students prefer synchronous media—such as chat—for more intensive discussion. However, we assume that more deliberate exchange and negotiation of differing beliefs is—in the context of learning—better supported by asynchronous media. This assumption is backed by studies (e.g. Armitt et al. 2002, p. 157) that found that asynchronous discourses stimulate reflection more than synchronous communication. Therefore we focus our theory-driven design experiment on asynchronous support of discursive learning. Since media-oriented theories neglect the interrelation between communication and context, we refer to more basic communication theories to derive functionalities that support students in intensifying their mutual understanding in the course of communication.

Methodological and practical background of the empirical exploration

From a methodological point of view, this paper describes a theory-driven design experiment. “Theory-driven” means that we intend to check out certain features and characteristics which are derived from communication theory, and have therefore built CSDL prototypes (KOLUMBUS 1 and 2) to add these features to the typical functionality which is usually found in CSCL systems for teams of students who work on mutual, discussion-oriented tasks of knowledge construction. Typical examples of those kinds of systems, which we adopted as role models, are Webguide (Stahl and Herrmann 1999) and CSILE (Scardamalia et al. 1994). We found that communication theory approaches are relatively neglected in the CSCL community in contrast to psychological theories or learning theories, and that the difference between working on content and human–human communication is not well represented in models of online learning (as is exemplified in Figure 2.5 in Anderson 2004). We are aware of the general limits of a theory-driven approach (Wilson 1999) and that it may narrow our view on the necessities of an appropriate design. Therefore we planned to check our prototypes against the requirements of real, practical usage in classes and to be ready to modify the theory if necessary.

The bridge between theory and design is built by models—in our case graphical diagrams as shown in Figs. 2 and 3. These models detail the activities and relevant entities that characterize communicative endeavours to achieve mutual understanding. The graphical models display the requirements that guide the technical design and can conversely be

influenced by the technology and its usage if it becomes apparent that the theoretical model has to be altered since it does not mirror the reality of human behaviour.

The prototypes were not tested in laboratory experiments but practically applied in classrooms. Thus we have conducted a design experiment (see, e.g., Brown 1992). The experimental design can be characterized by the features summarized by Barab and Squire (2004). Consequently, our study is oriented toward qualitative data, observing the interdependency of a set of variables instead of only a single parameter, and toward singular temporal events which cannot be repeated. We involved a variety of participants in the design including the perspective of several students and we flexibly reflected on our design decisions and ran through several cycles of improvement which were inspired by the practical experience. The subjects of our design were the socio-technical settings which covered the technical support, the organizational procedure, and the prepared content of courses. We see it as an advantage that the theory-driven design experiment refers to real settings since it increases the chances that those influencing variables which are neglected by the underlying theory become apparent. On the other hand we have to accept the limitation that this kind of experiment makes it impossible to control the influence of single parameters and therefore can only lead to results at an exploratory level. However, we found substantial evidence at this level of how students can be technically supported during discursive learning to overcome the difficulties with computer-mediated communication. We describe technical features with which they can increase mutual understanding by relating their communicative statements to the relevant context as it is built by material or by the contributions of others. We "…draw connections to theoretical assertions and claims that transcend the local context…" (Barab and Squire 2004, p. 8) of our settings by emphasizing the role of a third party in communication models, which has a meta-function with respect to the increase in understandability.

In order to gather experience with KOLUMBUS and the interplay of material (as context) and annotations (as communicative acts), KOLUMBUS was used in different settings. Experiences in a first round of evaluation were a basis for further improvements that were again used in different settings. In an initial round, two case studies were conducted with the aim of detecting potential for improvement:

1. *Seminar in computer science*: The first study used a course which is a mandatory seminar of the computer science program at the University of Dortmund. The topic of the seminar was the impact of using information and communication technology on working and daily life. The organizers of the seminar used KOLUMBUS to distribute documents and organizational information (e.g., meeting information, etc.). The 16 participating students used KOLUMBUS during their work in subgroups to develop, review and discuss their own material.
2. *Discussions in groups of researchers*: The second case was arranged as a case study where four groups of scientists and students (with four members each) used discussion and negotiation support to decide which topics they would like to discuss at a 2-day group meeting (referred to as "negotiation case study").

Experiences with the redesign of annotations are mainly based on three different settings that were organised as blended-learning scenarios. In more detail the courses are:

1. *Student project group in e-business*: The project group of 11 students and one tutor took place at the University of Applied Sciences in Fulda (Germany). The task was requirements analysis, design and implementation of a web-based e-business application. The group met regularly each week in a face-to-face meeting. KOLUMBUS 2, more

concretely the collection of their own material and its discussion with annotations, was used during the requirements analysis (1 month) to discuss the design features during the time between the two face-to-face meetings.

2. *Student project group in computer science*: This project group of 12 students and two tutors took place at the University of Dortmund (Germany). This 1-year project was a software engineering project that included all steps from requirements definition to software testing and documenting. KOLUMBUS 2 was mainly used to collect and discuss requirements for the system (at the beginning of the project) and to discuss and write the documentation of the group work (at the end of the project).
3. *Seminar in pedagogy*: The seminar took place at the University of Dortmund (Germany), Education Institute. Fourteen students were arranged into four subgroups of three or four students. The topic of the seminar was the concept of and experiences with e-learning on a non-detailed level given by the tutor and with space provided for student research questions and solution ideas in the four groups. KOLUMBUS 2 was used by the subgroups for the discussion and development of a talk and final documentation of their research.

For the collection and analysis of data, a mix of quantitative and qualitative methods was used in all settings. The quantitative part was based on log files: the different events in KOLUMBUS 2 were recorded (e.g., add or download material or annotations). The evaluation of the log files was partly conducted using a prototyped KOLUMBUS module (Kienle and Ritterskamp 2007) that supports the analysis of logged events in the KOLUMBUS content area. On the one hand, the qualitative part of the study is based on regular verbal group interviews with the students and the tutors. All interviews were recorded, typed and analysed in order to add reasons to the quantitative findings and evaluate the concepts of KOLUMBUS 2. On the other hand, all annotations of the created content structures of the mentioned courses were analysed with respect to the types of annotations.

Design usage and cyclic improvement of a CSDL system

The insights into context-oriented communication theory as well as the system usage in seminar settings were the basis for the construction of the requirements in the design of a prototype CSDL system. Its main characteristic is to offer functionality which combines communication as well as context support. In the following we concentrate in those functionalities which support context-oriented communication. For details regarding other functionalities see Kienle (2006).

Integration of material and communicative contributions

To meet the requirements derived from the context-oriented model of communication, we built the CSDL system KOLUMBUS. The crucial feature of KOLUMBUS is to support the segmentation of content into small units. This allows the learners a highly flexible intertwining of content as context with acts of communication in the form of annotations. An advantage of the concept of the fine-grained item-structure is that communicative contributions can be directly linked to that part of the content to which they refer and therefore provide the relevant context. Because participants share the content in KOLUMBUS, it provides a basis for shared context as defined in the "Activities of communication" section.

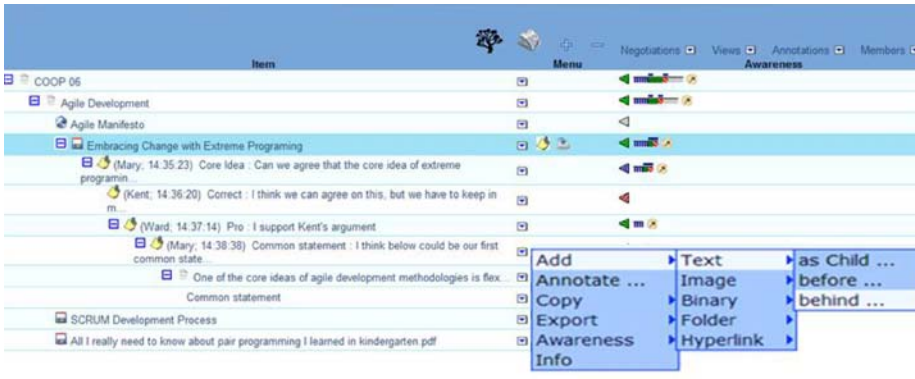

Fig. 4 Integrated tree view with magnified context menu and awareness tool (*blue*, *green*, *red bar*)

The design of communicative contributions in the form of annotations is inspired by systems for the joint creation and editing of text like CoNote (Davis and Huttenlocher 1995), CaMILE (Guzdial and Turns 2000), and WebAnn (Bernheim Brush et al. 2002). All these systems focus on functionalities enabling annotations, but do not support the linkage of fine-grained material (CoNote and CaMILE) or material that is added by the learners (WebAnn). Therefore the material cannot be used flexibly as context like in KOLUMBUS. Similar ideas that include the adaptation of annotations for collaborative learning are also reported in other current studies (see, e.g., anchored discussions; van der Pol et al. 2006).

KOLUMBUS[3] provides two different views of content. In the tree view, each item is represented as a node in a hierarchical tree-structure (for details see Kienle 2006, see Fig. 4). To focus on relevant content, parts of the tree or the whole tree can be expanded or minimized. Each user decides which content is relevant for him and which parts he wants to perceive. Furthermore, newly inserted items are indicated as new. The menu can be activated at every single item (see Fig. 4). It allows users to add communicative contributions (in form of annotations) or material. While the structure of a set of interrelated annotations represents a dialogue-oriented discussion thread, the hierarchical structure of the material depends on the logical relationships within its content.

The tree view offers an overview of the items and helps the user to view possible content at a glance and therefore to identify those parts of the available context which are new and also relevant to him or her. By contrast to the tree view, the paper view shows content in a visually more attractive and readable way. Here, different types of presentations are combined to form a single document. Within the paper view, KOLUMBUS supports the perception of meaningful structures built up on a didactical basis. It helps the user to perceive the directly surrounding context of an annotation and allows him or her to perceive details of the context. All functions of KOLUMBUS are available in both types of representation (paper or tree view), e.g., to add communicative contributions (in form of annotations) and material (all other item types).

An advantage of the concept of fine-grained item-structure is that communicative contributions can be directly linked to that part of the content to which they refer, which therefore provides the relevant context. From this point of view, it becomes obvious that the

[3] KOLUMBUS has gone through several cycles of improvement—further information can be found under http://www.imtm-iaw.rub.de/projekte/k2/index.html.

definition of context depends on the communication act itself; context is everything to which an annotation refers. Other studies have confirmed that a link between learning material and communication "increases the communicative efficiency" because the integrated communication support allows communication that is "more straight forward and to the point" (van der Pol et al. 2006).

Figure 5 shows the paper view of an authentic part of the content structure of the seminar in computer science; a title and some sections of material and two annotations (communicative contributions). Annotations are marked with an "A" and with the name of the author in front. Because the communicative contributions are placed in direct context, the author does not need to include hints for further context. This leads to relatively short contributions and the usage of direct references (in both annotations in Fig. 5 the word "hier" (German for "here") are used to reference the context).

Discursive learning is supported by the possibility of discussion threads that can be developed by annotating other participant's annotations. These threads can be handled in the same manner as in newsgroups; threads can occur in parallel and they can be expanded or minimized (as all items in KOLUMBUS); Fig. 6 shows an example of discussions in the researcher groups. Items are signed with the pencil and post-it icon. Since the tree view should only give an overview, only the beginning of the annotations (as well as text-based material) is presented in one row. The whole content can be read in a tool tip that appears with the mouse-over. The integration of material and discussions are also required in other publications. Hmelo-Silver, for example, mentions this requirement with respect to computer-supported problem-based learning: "There needs to be a mechanism for the facilitator and other students to negotiate and discuss the contents of the whiteboards in an integrated fashion" (Hmelo-Silver 2002, p. 207). Q2

Taking into account the experience within the design experiment, it became apparent that annotations in KOLUMBUS were an appropriate vehicle for contextual communication and discursive learning. Students tried to transfer their experience and habits with the functions of text-based communication media—such as email—to the annotations.

Annotations were predominately used in the review-phase of the seminar where students were asked to comment on each other's material. By inserting comments as annotations in the appropriate position in the content, not many additional explications were necessary.

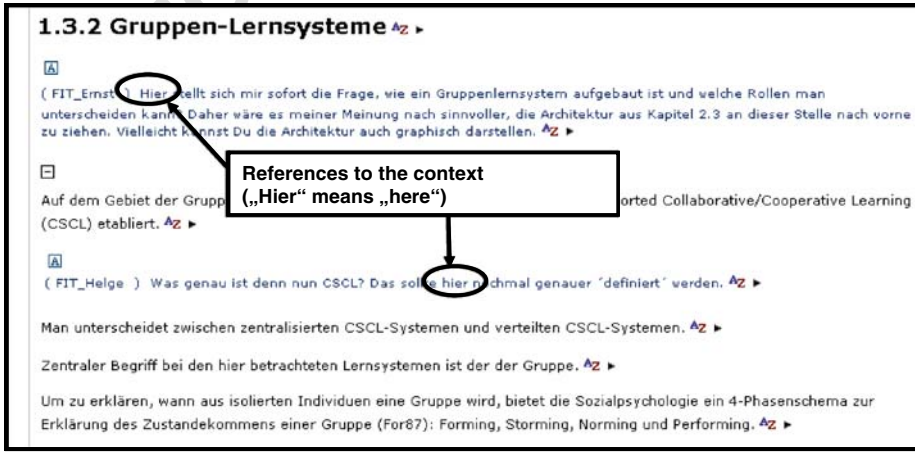

Fig. 5 Communicative contributions in context

Fig. 6 Discussions by using annotations

Therefore, the overall process of adding communicative contributions was noticeably easier than in situations without direct relations to context (e.g., email or newsgroups). During the negotiation case study, annotations were used to support the discussion process by exchanging arguments for or against proposed topics.

Presentation and handling of annotations

This subsection deals in more detail with the presentation and handling of annotations. The initial design of KOLUMBUS offers the users the possibility to easily differentiate between annotations and material: the tree view uses different icons, while the paper view employs different colours. The differentiation between annotations and material helps the user to distinguish which content is meant as communicative contributions by others and which not. With respect to the communication model, this means a differentiation between the expression of a communication and its context. The context of an annotation is not only represented by material; other already existing annotations can also take on the role of context (being built by preceding communication) which helps one to understand an annotation which is under consideration at a certain moment. In the paper view, the communicative character of annotations is increased by prefixing the annotation with the author's name, similar to the convention with newsgroups.

Organizational and content-related annotations

The usage of the initial design reveals some need for improvement regarding the types of annotations. Students mentioned that they recognize two different purposes of communicative contributions which should be easily distinguishable. The first kind are organizational annotations that have a coordinative character (e.g., "please insert here more information about…"), the second kind are content-related annotations that bring the discussion and the common artefacts as a result of collaborative learning respectively one step further. From the theoretical point of view, these types are related to context information concerning the intention of the contribution writing and the relevance of the contribution for the overarching cooperation process (organizational) or the discussion of contents (content-related). This differentiation is realized in KOLUMBUS; when adding a new annotation, it has the property "content-related" by default, but can be labelled as "organizational" by the author. The different labels correspond to different colours in all

views, which help the reader to differentiate the annotations at a first glance. Figure 7 shows the differentiation between organizational and content-related annotations.

A content analysis of the annotations (see Kienle 2007a for details) in the different settings revealed that a high percentage of all annotations were incorrectly categorized. This means that they are marked as content-related although they include only organizational issues. Some annotations marked as content-related include both organizational and content-related issues.

From these findings we conclude that participants wrote many annotations without reflecting and explicating their type respectively. This results in a high number of incorrect content-related annotations because the default is "content-related" as whenever an annotation is written it is content-related except in those cases where the author explicitly chooses 'organizational'. This default is also the reason why no annotation was found that had been typed incorrectly as organizational.

Although the interviewed users expressed a wish to be able to label the annotations differently (as content or as organisational), this differentiation was not used properly after the possibility had been introduced into the system. Even in studies with mandatory selection of a category it was found that members of a group need a long time when they try to develop a common understanding of the meaning of certain categories (Ludvigsen and Morch 2003).

On the other hand, the findings showed that both types are relevant for collaborative learning. This is especially true in long-period scenarios that do not include weekly face-to-face meetings because all organizational issues are discussed with the help of the CSDL system and this requires organizational contributions. The studies showed that in short-period scenarios the organizational effort is not that high and in settings with weekly face-to-face meetings a lot of organizational issues were discussed in the meetings.

With respect to the context-oriented model of communication we can state that the authors of an annotation do not use the appropriate type for the annotation as additional context information. Therefore the recipients have the major burden of reconstructing the real aim of the annotation. It becomes apparent that the need for structuring communicative contributions in asynchronous communication has first to be learnt by the communicators. It may also be the case that the students have not understood that the categorizing of their

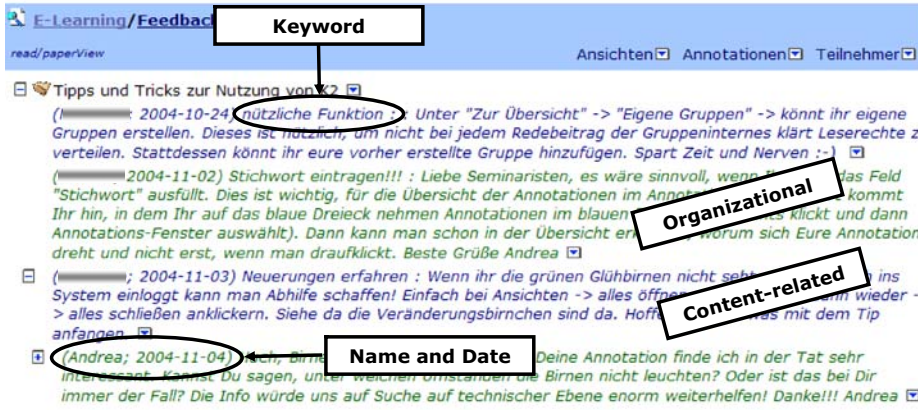

Fig. 7 Presentation of annotations (paper view) names are hidden due to privacy reasons

statements has a communicative relevance and is not just some additional task being imposed on them by the teacher.

Meta-data of annotations

A second improvement deals with the presentation of meta-data such as keyword, author, and date in front of annotations in tree and paper view. This helps—in terms of the context-oriented communication theory—to identify the context in which the annotation has been conceptualized. In KOLUMBUS, a keyword for the annotation can be added in a similar way to the specification of a subject-field of an email. This keyword summarizes the annotation and helps the reader to recognize the content of the annotation at a glance. The keyword as well as the author and the date are prefixed to the annotation itself. Figure 8 also shows the presentation of meta-data.

Regarding the usage of keywords, more annotations with keywords than without were added in the experimental fields. An interesting fact could be found while analyzing the relation between keyword usage and the discussion process. We determined for each annotation the time span which passed before a follow-up annotation (of other authors) was written. This time span varies from less than 1 min to 4 days. The average of time span between annotations with keywords and their previous annotation is approximately twice as high as for annotations without keywords and their previous annotation.

We conclude that the authors assume that the context of their own annotation is clearer when annotations are made shortly after one another with little time in between and that they consequently do not summarize their annotation with a keyword. This is additionally supported by the fact that annotations made with little time between them are often related

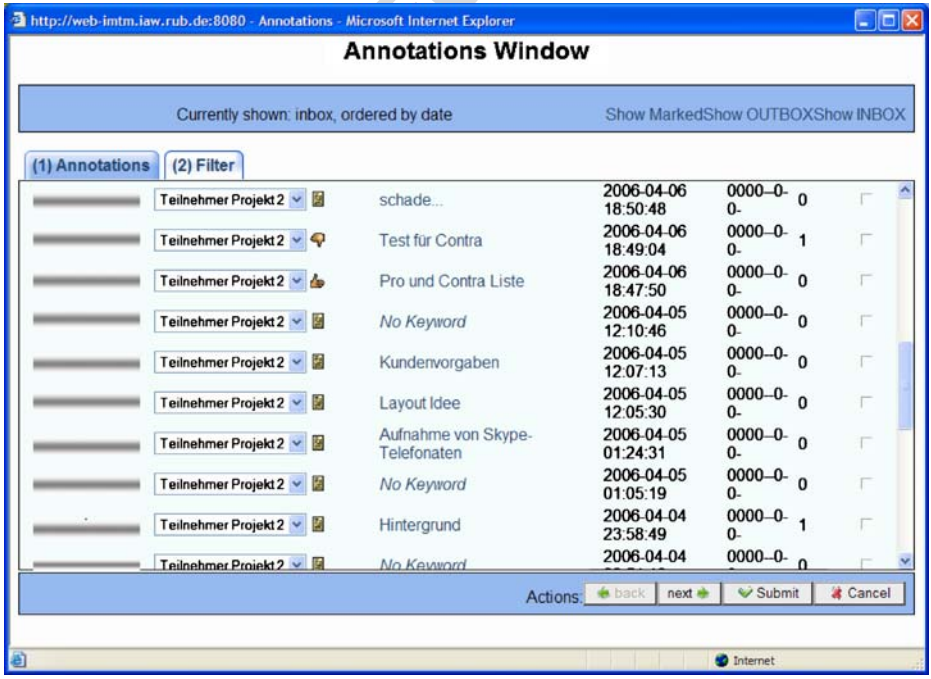

Fig. 8 Annotation window as an overview of new contributions names are hidden for privacy reasons

to the same discussion thread, which can also be interpreted as context. On the other hand, if a longer period of time passes before a new annotation is written, the context has often switched and the author explicates more information by adding a keyword. An automatically generated "reply-to" entry in the keyword field (like for example in discussion forums or email applications) could support the user in explicating the context.

Overview of annotations

The detection of annotations in both integrated views was described as difficult. This problem is already known from the evaluation of newsgroups. Due to the integration of material and communicative contributions, this problem was further exacerbated. Many interviewees considered a generally improved way of announcing new contributions (annotations) to be necessary. In the initial case studies, new communicative contributions were added at nearly every position in the content structure and this is what was considered to be a problem. This flexibility makes it more difficult to detect the relevant context than would be the case if they were all collected in a special content area. Group discussions revealed that a sensible solution might be an option to display all annotations in chronological order. This solution has two advantages. On the one hand, the access to new annotations and the awareness of them are eased. In terms of the context-oriented model of communication, the annotation window supports the activity "following the expression" (see Fig. 3 of the context-oriented communication model). On the other hand, the understanding of an annotation is supported because it can be easily related to past contributions and (different) discussion threads—both are also kinds of context information.

The KOLUMBUS annotation window is shown in Fig. 8. It is comparable to an email inbox that gives an overview of all annotations in the chosen content area. The entries in the list are links which guide the user to the position of the annotations in the integrated view. The list can be sorted by different meta-data (e.g., author, date, subject) and filtered (e.g., only content-related annotations). This window helps to perceive the annotations in chronological order and to be aware of new annotations.

Experiences with the annotation window revealed that its usage depends on the underlying scenario and the level of interweaving between communicative contributions in the form of annotations and context in the form of other material. In the analyzed settings we can differentiate between two levels:

- *Low interweaving between communicative contributions and material as context information*: in this case KOLUMBUS 2 is used more as a discussion forum than as an integrated platform. Discussion threads are not integrated with other forms of material (text, figures, etc.). For the participants, the detection of new annotations is possible without the annotation window because the tree view itself does not grow as fast as in settings with rapidly expanding material, and gives a good overview of the discussion threads.
- *High interweaving between communicative contributions and material as context information*: in this case KOLUMBUS 2 is used as a platform for an integrated development of material and discussions. The content structure grows very quickly because of many new items of different types (e.g., text or figures as material and annotations as communicative contributions) and the detection of new annotations is quite difficult. Here the annotation window serves as a kind of awareness feature to find those annotations that were placed "somewhere" in the integrated view.

Coordination and facilitation of the communication process

An underestimated problem found in initial studies concerns the coordination and facilitation of the communication process to support the discourse in the sense that the contributions of different participants referred more closely to each other. It became apparent during the interviews that the whole process of collaborative learning and development of shared understanding needs explicit coordination and facilitation. One problem was that almost everyone hesitates to summarize the current state of the discussion. There was a strong request in the group interviews that one person should control the discussion (and the negotiation) process. Participants tried to help themselves and those within the group by using annotations for the purpose of facilitation and coordination. Here again, the above-mentioned easy distinction between organizational and content-related contributions was required. It should be noticed that the number of identified organizational contributions mirrored this request (ranging from 17% to 40% in the various workgroups). This finding is in line with findings from other studies (Lakalla et al. 2002).

Alongside the requirement for organizational annotations, these findings give hints that the model of context-oriented communication theory has an insufficiency with respect to the roles participating in communication processes; not only communicator and recipient and their activities but also a third role, the facilitator and his activities, should be included. The role of the facilitator can be either taken on by one person (like a tutor in seminars) or by alternating persons (like group participants in self-organized discussions similar to the case study). From our findings we can derive the following activities of a facilitator (see Fig. 9 in the "Discussion of design and theory" section). These findings include activities for the discussion process and activities to support the understanding of the participants.

With respect to the discussion process a facilitator has the following activities:

- *Initiation*: starting discussions; switching to the next topic or phase of a discourse
- *Stimulation*: encouraging participants to make contributions from varying perspectives and to articulate consent and dissent.
- *Coordinating*: proposing an appropriate temporal structure and sequencing of a discourse.

With respect to the support of understanding we state the following activities:

- *Building bridges*: pointing out similarities and relationships between contributions and opinions.
- *Summarization*: mirroring the results of a phase of the discourse to the participants.
- *Directing attention*: if contributions or relationships are neglected in the discourse or have been forgotten, the facilitator can redirect the attention to them.
- *Avoiding misunderstandings*: giving hints if misunderstandings are undetected, or if people are in different semantic spaces.

For these activities, technical support was realized in KOLUMBUS. In a discussion thread, the facilitator's contributions are highlighted with bold type, directing attention of the discussion's participants to the facilitator's inputs. The bold type of the facilitator's statements also visually structures the discussion and reduces the necessity of reconstructing the course of a debate when working asynchronously. By this structuring, the initiation, transition over to the next phase, and the summarization are supported.

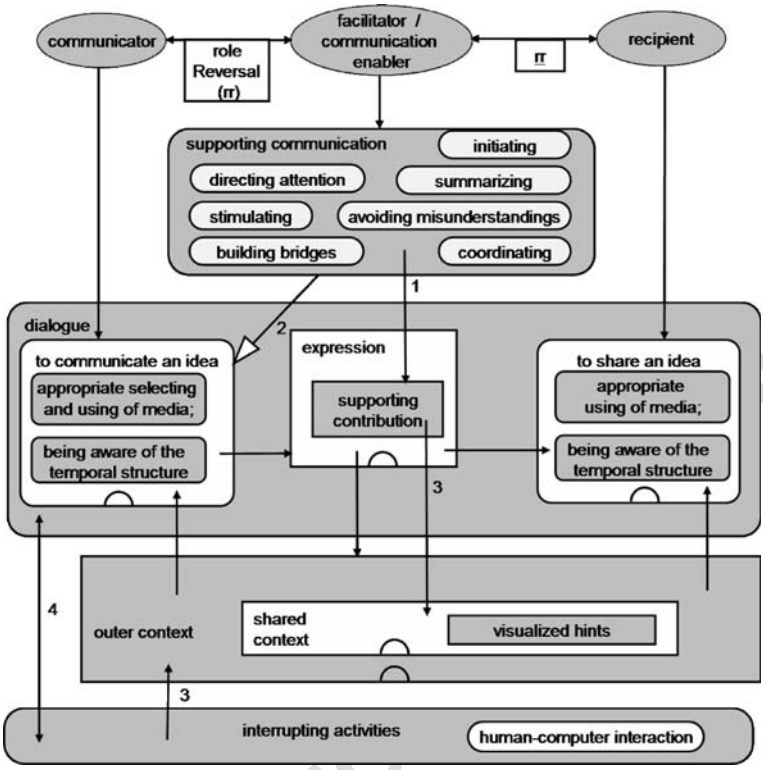

Fig. 9 Revised context-oriented model of communication

To promote contributions to an ongoing discussion two functionalities are offered:

- Emphasis can be placed on single contributions to a discussion by using a *highlighting functionality*; to label an element of a discussion thread, the facilitator can choose from a variety of background colours. Marking contributions in this way can be used, for example, to group similar contributions or to accentuate important arguments or to stress (intermediary) results of a discussion. There is no predefined meaning to the usage of different colours; it was intended that a user group develops the corresponding conventions without a predefined meaning. The discussion of the meaning assigned to the applied colours fosters the development of shared understanding of the applied functionalities.
- *System-internal links* can be established if contributions that are semantically related to each other have to be interconnected. Establishing a relation between elements in such a way is especially reasonable if they deal with similar aspects of a topic but are distributed over several discussion threads and not directly connected to each other.

Experiences regarding the facilitation were gathered in a study that mainly referred to three different facilitation strategies and to findings about the technical support of the

facilitator's tasks (more details about the study can be found in Kienle and Ritterskamp 2007):

Open questions without any instructions At the beginning of the study the facilitator asked open questions as is the case with traditional facilitation in face-to-face groups. Students described obscurities concerning the (subjective) cognition of the progress in a discussion thread, especially whether a discussion was finished or not. With respect to this open-endedness, the students' preference for explicit deadlines became apparent in their answers.

Instruction, deadline and finalizing conclusion (one step towards more responsibility for the facilitator) In step 2, the facilitator used more instructional contributions which included deadlines. This strategy led to higher participation levels in the discussion. The analysis reveals for the first time that students worked at a rhythm similar to that given by the facilitator: on deadline days more contributions were added. Although participation was high, the discussions were not terminated, for example, in the form of an artefact that includes the discussion results. Students felt termination or finalizing should be done by the facilitator.

Conclusions with decisions by the facilitator (full responsibility of the facilitator) In a third step, the facilitator intervened more than during previous steps. She not only formulated more instructions that included deadlines, but terminated discussions. If some topics did not come to an end by the deadline, the facilitator decided to stop, and proposed a solution. Students confirmed that the progress of the process was achieved by the facilitator's intervention. From these findings we conclude that the activity of summarizing discussions has an increased relevance in computer supported settings.

Results concerning the technical support of the facilitator's tasks Students affirmed that emphasizing a facilitator's statements by using bold fonts proved to be helpful in following the course of a discussion. Since the contributions of a facilitator often brought up a new topic and thus resulted in a new discussion thread, emphasizing them pointed out the structure of an extensive discussion more clearly. For instance, if two facilitator statements were displayed one below the other, topics thus far not discussed became rapidly apparent. Regarding the highlighting functionality, the facilitator emphasized that the highlighting of single words would be more appropriate than highlighting the whole item. In terms of the communication model and additional activities of a facilitator, this fine-grained highlighting supports the facilitator in directing attention to the topic of the contribution.

The facilitator proposed further functionalities for an improved support for activities typical to the facilitation of both face-to-face and computer supported discussions. Firstly, a facilitator should be able to "assign questions and work orders individually" by means of a collaboratively shared task list. Supporting the assignment and handling of tasks is closely related to functionalities which foster the participant's awareness of the current state of the collaborative process in which they are involved. Furthermore, the facilitator asked for a means to support synchronous voting in order to speed up the process by which participants reach a group decision.

Discussion of design and theory 817

The studies of KOLUMBUS revealed suggestions for the design of support of context-oriented communication. Topics for the guidelines are the following: 818 819

Integration of communicative contributions and learning material The studies support the requirements derived from the context-oriented model of communication; learning material serves as context and supports the communication. The tight integration of communicative contributions in the form of annotations and segmented learning material helps, in general, the communicator to select the appropriate pieces of context information and the recipient to better understand the utterance of the communicator. However, problems with the detection of new communicative contributions occur when the content structure is growing very fast—this lead to the necessity for concepts like the annotation window (see the "Integration of material and communicative contributions" section). This problem is also related to the question of an appropriate granularity; a fine granularity helps a communicator to relate his expression exact to the context but results in a fast-growing content tree. A coarse granularity on the other hand leads to a manageable content structure but does not offer the possibility of relating the annotation to exact context information. The granularity of paragraphs seems to be appropriate for the joint development of texts but has its limitations for the facilitator (see below). Further research seems to be necessary to get hints about the "appropriate" granularity for discursive learning scenarios. 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835

Usage of categories as context information Categories are context information that helps the recipient to estimate the aim of the communicative contribution. KOLUMBUS differentiates between content-related and organizational contributions as required in the first round of evaluation. The studies revealed many incorrect typed contributions with the default entry "content-related" though they included only organizational issues. This shows that the participants often did not reflect on the type of their contributions and the recipients had the major burden of reconstructing the real aim of the annotation. The existence of a default entry is misleading because the entry suggests information that is not given by the communicator. On the other hand, the findings showed that both types are relevant for collaborative learning. To keep all these arguments in mind we propose the usage of the two categories, content-related and organizational, without a default entry. This avoids the problem of a suggested context category that is not given in the entry. 836 837 838 839 840 841 842 843 844 845 846 847

Usage of keywords as context information and to draw attention Keywords are a summary of the communicative contribution. The communicator labels the contribution with words that are important for him and that help the recipient to estimate the content. The results of the studies revealed that keywords are more often used when the previous annotation was written a longer time before. In timely nearby contributions the communicator seems to suppose that the recipient can derive the context from the recent discussion thread. We conclude that keywords are a helpful kind of context information that has to be included in a CSDL system—especially in long-period asynchronous discussions. A reply-entry (like in email applications) could support a communicator in automatic filling in the keyword when contributing to an already existing discussion thread. 848 849 850 851 852 853 854 855 856 857

Annotation window as awareness feature In scenarios with the joint creation of material by the group of learners, the content structure is growing very fast and the detection of new annotations "somewhere" in this structure becomes difficult. For these scenarios an annotation window comparable to an email in- and outbox gives an overview of communicative contributions and serves as a helpful awareness feature.

Support of the facilitator Concerning the tasks of a facilitator, the results of the study suggest that a facilitator occasionally has to make decisions on his own and needs to present intermediate results in condensed form. Compared to face-to-face situations, the facilitator is to a greater extend involved in activities concerning decision making and leadership taking when moderating asynchronous computer supported discussions. Concerning the support for the tasks of the facilitator, the discussion of the granularity comes up again. Here it could be helpful to implement a highlighter mechanism that is applicable in a more fine-grained manner (e.g., selecting of single words) in order to allow a precise accentuation.

Concerning the technical functionalities, the results reveal that rating and negotiation functionalities should be integrated in order to improve the support of group decisions and convergence that lead to an end of the discursive learning process. In addition, shared task lists as well as context-sensitive mechanisms would be helpful to provide a facilitator with information on which suitable strategies for intervention can be based.

With respect to our theoretical approach we found that the applied model of communication proved useful, but also needs some adaptations. It was considered as an advantage by the students that the learning material was immediately integrated as content, which served as context for the communicative statements that are inserted and threaded as annotations. Context orientation of communication can be considered as a principal guideline for the design of CSDL systems. The possibilities of minimizing explicitness by employing context provides a design rationale for features such as highlighting, sketching graphical relations, usage of hyperlinks, etc. It has furthermore proved helpful for explaining the behaviour of students to differentiate between intentional contributions of communicative statements and extra-communicative interaction with the computer. Students have to understand whether or not their interaction with the computer is a communicative act—we assume that the categorization of contributions was not considered such an act. Additionally, the readers of annotations have to understand that they are challenged as interpreters in a communicative dialogue who should try to reconstruct the ideas which are intended to be shared. Therefore we argue that the communication model gives valuable backgrounds about how students should be prepared for taking part in CSDL.

On the other hand, our observation of the positive influence of facilitation revealed a crucial deficit of the common communication models; they are all based on a dyadic structure of a communicator (sender, speaker) vs. a recipient (receiver, listener). Because of the ubiquity of these models, this dyadic structure is familiar to us though our daily experience is inevitably shaped by situations where a third party influences our dialogues with other persons. We therefore propose a *context-oriented third-party model of communication* as shown in Fig. 9. It includes the role of a facilitator or communication enabler who contributes supportive expressions (1) which initiate, stimulate, build bridges, summarize, help to avoid misunderstandings, and coordinate. This supportive communication is a (2) similar activity to "communicating an idea"—it is an idea about how the communication can be supported. The supporting expressions can become part of the context (3), e.g., in the shape of visualizations, highlighting etc. The need for facilitation is increased under the conditions of asynchronous communication; the indirectness and the

possible interruptions of communication by other activities (4) require more awareness by the communicators of the specific characteristics of the media that is used. Furthermore, the temporal structure has to be taken into account when expressions are planned or interpreted within asynchronous communication. Since interrupting activities—in particular mere human-computer interaction—may distract the communicators, they have to plan ahead about how they will find their way back to the topic and context of their communication after a break. Likewise, the facilitator has to provide help for the overcoming of temporal breaks, and she/he has to be aware of the specific temporal conditions—for example the end of an asynchronous discourse has to be marked much clearer, as in the case of a face-to-face meeting which ends when people are going apart.

Conclusion and further research

In this paper we described an approach to designing communication support in CSCL systems. The theoretical part is a context-oriented model of communication. It explains the relevance of context for activities of the participants in human communication. From this model, requirements for the design of CSCL systems supporting discursive learning (CSDL systems) are derived. One important aspect is the tight integration of communicative contributions and the appropriate context information. The design of the CSDL system KOLUMBUS takes these requirements into account; it interweaves communicative contributions in the form of annotations and segmented learning material that serves as context. Furthermore, it addresses the requirements for the support of meta-data as context information as well as an overview of annotations and the facilitation of communication processes; these requirements were gathered in the empirical field. These requirements were implemented and again evaluated in different settings and learning scenarios that all aimed at discursive learning. From our experience with KOLUMBUS, whose design is theory driven and improved by empirical findings, we have derived conclusions which can be presented as guidelines for the design of CSCL systems that support asynchronous discourses:

- Support context orientation by integrating communication as annotations into segmented learning material as context. The granularity of paragraphs is appropriate for the scenario of the joint development of material.
- Support detailed information about the requested context information, like categories and keywords. They are especially helpful in long-period settings and overlapping discourses because these situations require more explicit context information. Keep in mind that users have to be aware that they participate in communication acts and explain the benefit of using this context information.
- Provide a special view that helps to overview the course of annotations. This is especially useful in scenarios of discourses that start with a divergent phase where annotations are connected to different items of material that are widely spread over the content.
- Employ a communication model which takes facilitators as a third party into account and promotes the design of features which support specific communication acts such as initiation, stimulation, etc.
- Prepare students to be able to act communicatively and to be aware of the specific temporal structure or problems of interruptions that are inherent in asynchronous communication. Provide functions which make this awareness more feasible.

Further research is faced with the challenge of integrating synchronous and asynchronous communication in a way that supports discursive learning without losing the advantages of both modes; synchronicity promotes more immediate, uninterrupted and focused interaction while asynchronicity supports more deliberate reflection and more intensive research within the available material. With respect to this integration, we have particularly to investigate the relevance of features such as support for rating, voting or negotiation, increased immediacy and visibility for and of facilitation activities, and smooth switching between different communication modes.

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