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Ludwig-Maximilians-University Munich, Germany
Institute for Empirical Pedagogy and Pedagogical Psychology
Chair Prof. Dr. Heinz Mandl
Leopoldstraße 13, 80802 Munich
Telephone: ++49-89-2180-5146 – Fax: ++49-89-2180-5002
e-mail: mandl@edupsy.uni-muenchen.de, weinberg@edupsy.uni-muenchen.de
http://lsmandl.emp.paed.uni-muenchen.de/

Editor: PD Dr. Michael Henninger

e-mail: henninge@edupsy.uni-muenchen.de

Computer-mediated knowledge communication

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Abstract

New communication technologies enable an array of new working and learning scenarios in which knowledge is being communicated. This article deals with the question to what extent these technologies can impede or facilitate knowledge communication. First, the various computer-based communication technologies will be classified. Second, effects of the medium on knowledge communication will be discussed based on results of studies of the current special priority program "Net-based Knowledge Communication in Groups". Third and last, computer-based possibilities to facilitate computer-mediated knowledge communication will be reviewed.

Keywords: Computer-mediated communication, knowledge communication, facilitation, media choice, interface design, channel reduction

Zusammenfassung

Neue Kommunikationstechnologien ermöglichen eine Reihe neuer Arbeits- und Lernszenarien in denen Wissen kommuniziert wird. Dieser Beitrag beschäftigt sich damit, inwiefern diese Technologien Wissenskommunikation einschränken oder fördern können. Dazu werden in einem ersten Schritt die verschiedenen computerbasierten Kommunikationstechnologien untergliedert. In einem zweiten Schritt werden Wirkungen des Mediums auf die Wissenskommunikation diskutiert. Dazu werden u. a. die Ergebnisse von Studien des aktuellen Forschungsschwerpunkts "Netzbasierte Wissenskommunikation in Gruppen" berichtet. In einem dritten und letzten Schritt werden computerbasierte Möglichkeiten zusammengefasst, computervermittelte Wissenskommunikation zu fördern.

Schlüsselwörter: Computervermittelte Kommunikation, Wissenskommunikation, Förderung, Medienwahl, Interface-Design, Kanalreduktion

COMPUTER-MEDIATED KNOWLEDGE COMMUNICATION

The dissemination of computer-based information and communication technologies has produced a new array of working and learning scenarios. New communication technologies grant access to expert opinions and bridge time and space to influence communities of practice and learning. The medium of the computer may have beneficial or detrimental effects on how knowledge is communicated in these scenarios. Thus, it can be argued, computer-mediated knowledge communication may need to be facilitated in order to foster its potential and reduce its possible disadvantages. In the following chapters, various computer-based communication media will be portrayed. Next, their potentials and barriers for typical knowledge communication practice will be discussed on the basis of recent pedagogical and social psychological findings. Finally, a summary will be presented on the ways to facilitate computer-mediated knowledge communication suggested by the presented studies.

Classification of computer-based media for communication

In what way is computer-mediated communication (CMC) different from face-to-face communication (FTF)? A range of techniques has been developed on how communication may be mediated via the computer (e.g., e-mail, chat, video conferencing). Therefore, there are not one, but many forms of computer-based media with distinct qualities. In this paragraph, some characteristics and types of computer-based media will be presented which refer to the various forms.

CMC started out in the late 60ies as a *decentralized form of electronic communication*, which may continue even when individual relay stations (= servers) were not functioning. The transmitted information was split up into several packages and transported in a nonlinear, non-predetermined fashion over a network of servers. If one server was out of order, the individual packages could still reach their destination on alternative routes through the network. This sort of *routing* reflects the difference between CMC and other forms of telecommunication (e.g., radio, telephone, etc.).

The network of servers called the internet has an exponentially growing, but still limited capacity. An important aspect of CMC is therefore its *bandwidth*. The bandwidth measures how much data can be transmitted in ”bps” (bits per second). Bandwidth can be costly and some connections may be able to utilize only little bandwidth, e.g. the ”last mile” to the user. Thus, one social CMC rule is to ”save bandwidth”, i.e. to not send unnecessary data. Regarding bandwidth, messages differ extensively with respect to their *code*. Information may be coded as a text, as a picture or graphic, as sound or video. Text-based messages require less bandwidth than messages that are based on pictorial codes, for instance. Therefore, computer-based media can be categorized roughly by their bandwidth and their code. Some computer-based media can be categorized as low-bandwidth and text-based (e.g., email), while others are high-bandwidth, audio-visual media (e.g., video conferencing).

In addition to this general schema of low-bandwidth, text-based media vs. high-bandwidth, audio-visual media, some other characteristics of computer-based media can be further delineated. These are less definite regarding the media, but rather describe how the individual medium is typically used (cf. Dillenbourg, 1999). The ascription of these social parameters to specific media has emerged, because of a specific cultural practice with the distinct media. Therefore, the extent to which these parameters apply highly depends on the social context of CMC.

In contrast to nonelectronic mail, CMC is transmitted with a much smaller technical delay. This enables a discourse, which has been described as *synchronous*. In synchronous communication, the discussants are supposed to participate in discourse at the same time. In contrast to FTF communication however, any message can be recorded and stored by the author or the recipient for later retrieval. This potential permanence of CMC enables so called *asynchronous* forms of communication. The discussants are not expected to interact at the same time, but any nontechnical delay between the individual discourse activities may take place. This means, that discussants can record the message and respond to it at any later, convenient time. Another characteristic of CMC is that discussants may remain *anonymous* or may assume different identities. This means, for example, that communicants may use nicknames or fake addresses. However, online discussants may also reveal some information unwillingly (e.g., their server address) or on purpose (e.g., by maintaining a homepage).

Low-bandwidth, text-based CMC

Email

The most disseminated and most often used form of computer-mediated communication is email. Email is mostly used in an *asynchronous* way, that is, email communication is expected to be delayed due to nontechnical reasons. Emails usually provide some information about the sender like his or her email address and could be regarded as *less anonymous*, even though these addresses may not correspond to a real person. Emails can be sent to one or more addresses at once (one-to-many communication). In text-based CMC, emails may also be addressed to *mailing lists*, which forward the message to anyone who is subscribed to the list. Mailing lists may be public and dedicated to one specific subject. Therefore, anyone who addresses the mailing list may send messages to a large number of people.

Electronic bulletin board

Similar to email, electronic bulletin boards are *asynchronous*, but are recorded on a central database and not addressed to one specific person. Discussants may use their real names or any nickname and thus, may be more or less *anonymous* according to the users choosing. The text-based messages may be represented in various ways. Some electronic bulletin boards simply list the messages according to their entry date with the full text. In the archetypal electronic bulletin board (e.g., newsgroups), the messages are represented in *discussion threads*. These threads start with one particular message that is indicated in a message overview by its title, the author and the date of entry. Any response to a message is graphically connected to an initial message by a line or ”thread” and indented. Thus, a cascading discussion thread is built in which the discussants are supposed to continue the specific subject which was initialized with the very first message. New subjects are meant to be set off with a new message.

Chat

Chats are text-based forms of communication in which very short messages are sent in a chat channel or chat room. The chat participants are meant to communicate *synchronously* and delays are ascribed to technical problems (lags) and typing speed rather than discussants not focussing on the chat. The messages are listed chronologically one after the other together with the name of the author. Usually, the authors use nicknames and thus, chat is mostly *anonymous*. Due to the delays caused by typing, several discussions may evolve that are intermingled in one chat window. For instance, an answer to a specific question will appear only after somebody else has sent another message in-between. In addition to discourse, users may also indicate specific actions textually by specific commands (e.g., ”hug” or ”slap” others). These textually represented activities are particularly important in *MUDs* (Multi User Dungeons). In MUDs users interact with each other as in chats and also with a virtual environment, which consists of various objects and spaces. More recent MUDs support graphical interfaces and thus, are similar to *online games* in which users usually control a representational computer generated figure (avatar).

High-bandwidth, audio-visual CMC

Video conferencing

Video conferences require additional computer equipment, namely video cameras and microphones. Video conferences resemble spoken, *synchronous* FTF discussions to a certain degree depending on the quality of sound and image transmitted through the net. Usually the cameras portray face and upper part of the body (talking heads video). Thus, video conferences provide prosodic, para- and nonverbal, visual information about the discussants depending on bandwidth and display detail. Thus, video conferencing is *less anonymous* because of the additional information about the discussants, and because video conferencing is mostly conducted in known groups such as virtual seminars or spatially distant teams. Video conferences utilize much more bandwidth than text-based forms of CMC. In order to save some bandwidth, *audio conferences* may be held that work on the same principle as video conferences, without the visual connection.

Shared applications

Shared applications enable spatially distant users to operate textual or graphical interfaces or programs together. This may include applications based on different code, e.g., text windows which can be filled in successively, interfaces in which graphical symbols can be arranged, or 3D spaces that can be manipulated together. The term ”shared applications” refers to a wide variety of distinct communicative scenarios, which do not imply secluded messages, but rather a virtual space in which two or more communicants may collaborate. Shared applications are mainly employed in organizational contexts, in which *nonanonymous*, existent spatially distant working and learning teams need to *synchronously* operate on one problem together and are usually combined with other communication media, e.g., video conferencing.

Potentials and barriers of computer-mediated knowledge communication

Email, electronic bulletin boards, video conferencing, etc. are new communication media. How do these various computer-based media influence knowledge communication? In the mid 90ies it was been debated if technology would at all influence how knowledge is constructed and communicated. One position was that there is no influence of any media on knowledge communication (cf. Clark, 1994). It has been argued, that the medium is a mere vehicle that does not turn information into knowledge. Although media shows some excellent features to guide attention, to illustrate realistically, to repeat learning steps, etc., these are not exclusively features of (new) media. In contrast to this position, many studies have shown, that CMC differs from FTF communication. Participants may communicate differently, because they may be more anonymous, because they may have more time to formulate their contributions, because they have to type what they want to communicate, etc. Using the medium of the computer provides a scenario or a context in which knowledge can be communicated. Therefore, the medium needs to be put into perspective to analyze and to facilitate knowledge communication (Jonassen, Campbell, & Davidson, 1994).

In this chapter, some effects of low- and high-bandwidth CMC on communication will be introduced. Subsequently, results of a current priority program of the DFG (Deutsche Forschungsgemeinschaft = German Science Foundation) called ”Net-based Knowledge Communication in Groups” will be presented. This experimental research tends to focus on the various media (email, electronic bulletin boards, chats, video conferencing, and shared applications) in different settings of knowledge communication, namely knowledge communication within communities of practice, within learning communities, and knowledge communication between experts and laypersons.

Impact of low-bandwidth, text-based computer-based media on communication

Low-bandwidth, text-based CMC differs from FTF communication in a number of ways. Discussants type their messages, send them off and receive texts from their partners on screen. This scenario differs from FTF communication in some respects. The main difference between text-based CMC and FTF communication is that some social context cues (e.g., the visual appearance of a discussant) are filtered out in text-based CMC. In text-based CMC, discussants do not see or hear each other. Therefore, neither elegant clothes nor commanding voice may provide any background information about the social status of the speaker. This *channel reduction* of text-based CMC can lead to a range of effects on communication. CMC discussants are less likely to recognize each other’s social status. Therefore, CMC may reduce inhibitions caused by status differences to avoid conflicts (Kiesler, Siegel, & McGuire, 1984). Furthermore, the social context cues that are filtered out in the reduced CMC channel usually support the coordination of FTF discussants (e.g., turn taking). Due to the resulting coordination difficulties, text-based CMC is often characterized by less frequent turn taking and longer individual messages (Quinn, Mehan, Levin, & Black, 1983). Therefore, text-based CMC groups take more time to come to conclusions and have been considered as less productive than FTF groups (Straus & McGrath, 1994). Only in idea generating tasks have text-based CMC groups performed equally as well as FTF groups (Dubrovsky, Kiesler, & Sethna, 1991). This effect has been ascribed to the possibility to give input simultane ously in text-based CMC, whereas members of FTF groups may mutually block the production of ideas as each discussant is expected to wait for his or her turn. Channel reduction has also been associated with some potentially beneficial effects of text-based CMC. In comparison to FTF communication, CMC has also been characterized by being more task related, more equal with respect to participation, and more diversified with respect to the positions held and the perspectives that are considered in online talk (Kiesler & Sproull, 1992; Riel, 1996; Woodruff, 1995). Therefore, text-based CMC has been considered as a more ”democratic” medium, that may foster an ideal, ethical discourse in which arguments may be exchanged equally oriented towards mutual understanding and based on evidence (Marttunen, 1997; Miller, 1991).

These findings on channel reduction of CMC have been put into perspective by research that considered time as an important constraint in text-based CMC. In this respect, text-based CMC groups may perform equally well as FTF groups, but require more time due to the typing lag (Walther, 1996). Groups that communicate in a computer-mediated way for longer periods of time have often developed a discourse comparable to FTF groups (Spears, Lea, & Lee, 1990; Walther, 1992). These results indicate, that any former channel reduction research is particularly valid for any anonymous ad-hoc groups that interact for short periods of time only. Studies on groups in real world settings have shown that users may compensate the channel reduction effects of text-based CMC. This means, that social context cues may not be filtered out completely, but the user may evaluate diction, provide personal background information (e.g., homepages), and simulate social context cues in a text-based manner (Döring, 1999). For instance, discussants may enrich text-based CMC by emoticons or smileys (e.g., :-)), comic language (e.g., *grin*), web-specific abbreviations (e.g., ROTFL = Roll on the floor laughing), or TYPING IN CAPITAL LETTERS, which is considered to be screaming.

Impact of high-bandwidth, audio-visual CMC on communication

As indicated above, new forms of high-bandwidth, audio-visual CMC like virtual 3D-spaces emerge, but have not been subject to extensive research. Therefore, the focus of this section is the video conferencing that is typically used in combination with shared applications. These video conferencing scenarios have been compared with low-bandwidth, text-based CMC against the background of the channel reduction approach (Bruhn, 2000). In high-bandwidth, audio-visual CMC, the channel is less reduced and more social context cues are transmitted. In this respect, high-bandwidth CMC may be more similar to FTF communication in some aspects. But even providing that the transmission quality of sound and video is adequate, the examined video conferencing scenarios showed some subtle differences that affected communication. First of all, in video conferencing only ”talking heads” are transmitted. These talking heads provide no spatial or proximal cues and discussants may not refer to a shared physical space by deictic gestures. Furthermore, video conferees cannot establish eye contact, because the camera and the video image of the conversational partner are not located at the same place. The camera is typically mounted on top of the monitor and the video image appears on the screen. Therefore, video conferees may have difficulties in referring to specific objects and conversational partners. For instance, due to lack of eye contact and deictic gestures, video conferees may misjudge where the focus of the conversational partner lies. As a consequence, video conferencing shows some differences to FTF communication even under optimal technical conditions (Gräsel, Fischer, Bruhn, & Mandl, 2001; O'Connaill & Whittaker, 1997). Some studies show, that video conference participants achieve a comparable quality of group work, but again have some time disadvantage against FTF groups (Anderson et al., 1997; Olson, Olson, & Meader, 1997). These results suggest that successful computer-mediated interaction is also correlated to a certain accustoming and learning effect with the new media (Bruhn, 2000). Similar to text-based CMC users, video conference participants may need to learn how to compensate for these specific disadvantages of audio-visual CMC. Some speakers gesticulated more intensely when they noticed that their addressees did not respond to their gestures (Heath & Luff, 1993). In this study, however, addressees showed no reaction to intensified gestures in video conferences, either. Similarly, video conference participants are expected to coordinate social interaction and the technical environment more explicitly (e.g., ”It's my turn, isn't it.” or ”Now, I am clicking on the button in the upper left corner.”).

However, the results on knowledge communication via video conferencing are highly inconsistent in this area. This has been ascribed to different context variables (e.g., different video / shared application environments) and the explorative character of some of the studies (cf. Bruhn, 2000).

In sum, high-bandwidth, audio-visual CMC may suffer from channel reduction, but several studies show that the influence of this medium on communication is more subtle and video conferencing more comparable to FTF communication than to low-bandwidth, text-based CMC. Although the impact of this medium on communication may be smaller, users also appear to be less familiar with compensating channel reduction effects in video conferences.

Knowledge communication in various computer-mediated scenarios

Computer-mediated knowledge communication may have a range of backgrounds and goals. In the following paragraphs three typical scenarios will be discussed on the basis of recent findings on computer-mediated knowledge communication.

- *Communities of practice*. Knowledge communication is practiced in communities in which knowledge and experience are being shared equally to apply or to create new knowledge (Wenger, 1999).
- *Learning communities*. Knowledge communication is also practiced in learning communities in which groups of learners co-construct knowledge (Bielaczyc & Collins, 1999; Scardamalia & Bereiter, 1996; Winkler & Mandl, 2002).
- *Expert-layperson communication*. Another particular area of knowledge communication is characterized by discussants of varying domains or degrees of expertise (Jucks, 2001; Jucks, Bromme, & Runde, in press).

These fields of knowledge communication practice have been examined in various computer-mediated scenarios.

Communities of practice build on the concept that knowledge is shared equally amongst the members of the community. CMC may facilitate this equal exchange of knowledge. However, discussants of high status may verbally dominate computer-mediated even more than FTF knowledge communication in certain circumstances. It has been found, that video conferencing may actually exaggerate status constraints when the status hierarchy within the community is known (France, Anderson, & Gardner, 2001). This finding may indicate that the formerly reported higher equality of CMC may be restricted to anonymous ad hoc groups and text-based media like email or chat. But even in some anonymous computer-mediated knowledge communication contexts, further barriers to the equalizing effects of text-based CMC have been identified. Communicants are often reluctant to share knowledge equally because they may profit more by ”lurking” in anonymous computer-mediated communities of practice rather than sharing knowledge. This social loafing or free riding effect may become more prevalent in some more anonymous, text-based communication situations, e.g., in knowledge databases (Creß, Barquero, Buder, Schwan, & Hesse, in press; Hesse, Cress, Barquero, & Schwan, in press). Due to the low and heterogeneous participation in knowledge databases, organizations typically reward input of employees. The studies of Hesse and colleagues show, however, that rewards may have no overall effect on knowledge communication. A psychological solution to low and heterogeneous participation may be, that communicants receive a feedback about the received usefulness of their individual contributions. Use-related rewards can be calculated, for instance, by how often a contribution has been received and how it has been rated by the recipient. Rewards that depend on the usefulness of the individual input have shown to foster the selection of qualitatively better, more useful input (Creß et al., in press). Consequently, these studies indicate that equalizing effects of CMC may be restricted to anonymous ad hoc groups in abstract contexts, rather than apply to real communities of practice. Interestingly, computer-mediated knowledge communication may not be fostered by rewards alone. Productive and equal participation in communities of practice may rather depend on the awareness of the group members about the others, about the social context, and about the usefulness of their individual contributions. This awareness can be facilitated by feedback, which is calculated and automatically communicated by the computer interface. This approach aims to support the group to regulate itself (cf. Dillenbourg, 2002). An example for this sort of feedback for group awareness which is reified within a CMC interface is the group awareness widget (GAW) – a software tool which may implement different kinds of group awareness by utilizing the permanence of CMC (Kreijns, Kirschner, & Jochems, 2002). GAWs provide a representation of the recorded and thus permanent group processes. This may include, for instance, that GAWs graphically indicate in what phase of knowledge communication process discussants are and how much each of them has contributed. The rationale of this approach is that the individual discussants identify deficient behavior with the help of the representation of the group processes and regulate it accordingly. This would include, for instance, that community members realize that they have communicated little with reference to the average participation of the group and then try to converge towards the group norm. However, a feedback on the participation of community members may also affect those who participate more. These discussants may equally lower their efforts to comply with the group norm.

Learning communities differ from communities of practice in the intention to acquire knowledge by collaboration and communication. The goal of learning communities is to share knowledge within the community and thus, also foster individual knowledge acquisition (Bielaczyc & Collins, 1999). In the learning community scenario, communicants are supposed to analyze and discuss complex problems together. Through this collaborative inquiry and reflection, learners may master the increasingly complex problems of a domain (Brown & Campione, 1994, 1996). In Knowledge Forum, formerly called CSILE (= Computer Supported Instructional Learning Environment), these principles of a knowledge building community are utilized and supported by a text-based, computer-mediated learning environment (Scardamalia & Bereiter, 1996). In Knowledge Forum the learners contribute new ideas and comments in an electronic bulletin board that preserves discussions over generations of learners. The goal of Knowledge Forum is to utilize the permanence of electronic bulletin boards to advance the inquiry of learning communities. Furthermore, the learners are meant to take over the responsibility of their collaborative inquiry and to make use of text-based, asynchronous communication to verbalize more reflective contributions than in FTF seminars. There are some indications, however, that computer-supported collaborative learners do not systematically exploit the potential of text-based communication for more task-oriented, multi-perspective, and reflective discourse, but rather try to come to a consensus quickly and hardly explain or justify their claims (Fischer & Waibel, 2002; Hesse, Garsoffky, & Hron, 1997). In order to facilitate the discourse of learning communities directly, collaborative scripts have been designed and reified using various learning environments based on electronic bulletin boards, chats, or video conferencing with a shared text editor (Pfister & Mühlpfordt, 2002; Reiserer, Ertl, & Mandl, 2002; Weinberger, Fischer, & Mandl, in press). Scripts suggest and sequence specific activities, e.g., applying critique, asking questions, formulate justifications, etc. One central question is whether scripts should suggest content-oriented activities, e.g., analyzing a problem with respect to specific theoretical concepts, or rather structure interaction, e.g., prescribe an ordered sequence of contributions, assign specific social roles, etc. Therefore, both content- and interaction-oriented forms of scripts have been designed and applied to text-based and audiovisual computer-mediated communication scenarios. In the video conferencing setting in which scripts were reified by a shared text editor, a content-oriented script fostered learning processes, but had no substantial impact on learning outcome. An interaction-oriented script benefited both learning processes and outcomes (Reiserer et al., 2002). Similarly, in the text-based setting of an electronic bulletin board, an interaction-oriented script substantially supported learners on processes and outcomes of learning, but a content-oriented script only fostered learning processes and had detrimental effects on knowledge acquisition (Weinberger et al., in press). It has been argued, that content-oriented scripts may substitute the construction of mental models to a certain extent, whereas interaction-oriented scripts motivate both social and reflective cognitive processes. In this respect, interaction-oriented scripts may render as problematic some interactions that aid learning (Reiser, 2002). These studies indicate that scripts should challenge learners to approach problems more reflectively. Content-oriented scripts may ease important subtasks of collaborative learning so that learning communities are able to apply knowledge successfully as long as they are supported by the script, but fail to help participants interact reflectively and to actually acquire knowledge.

Expert-layperson communication in computer-mediated settings may not only include counseling scenarios, but also knowledge communication between experts of different domains. One basic problem of expert-layperson communication is, that experts have inadequate models about what laypersons know. This means that experts often overestimate the prior knowledge of laypersons. Computer-mediated expert-layperson communication may aggravate the difficulty of experts to adjust to prior knowledge of laypersons due to filtered out social context cues. Typically, additional codes are provided to improve mutual understanding, which means that additional textual or graphical representations of the subject matter are added to the communication interface to facilitate mutual understanding and referential identity (Jucks et al., in press). The rationale of this application of shared representations is based on *physical co-presence heuristics* (Clark & Marshall, 1981). For instance, a graphic about the subject matter that the communicants view online, may be available to both the expert and the layperson. This shared representation may be a common reference point for the communicants and therefore, reduce the knowledge gap between expert and layperson and complement the expert explanations. However, shared representations may also affect how detailed and elaborate the explanations of experts are, because experts may misjudge the explanatory power of the representation. The shared representation may create the *illusion of evidence*, i.e. the expert overestimates the understanding, which results from the shared representation alone. Thus, experts may tend to elaborate less when they share a representation with the layperson and may disregard the knowledge gap of laypersons when they formulate their explanations. For instance, physicians may often overestimate how much their patients recognize in radiographs and thus, do not explain or explain with more technical terms the important aspects of the radiograph. In asynchronous CMC this illusion of evidence may aggravate, because the laypersons cannot immediately give feedback of incomprehension. The lack of nonverbal signals may add to this problem in CMC scenarios (Bromme & Jucks, 2001). Results of a study on the effect of graphical and text-based, shared representations in expert-layperson communication in contrast to expert-expert communication show that shared representations can reduce the orientation of an expert towards the layperson. Experts address the layperson less often and use more technical terms when a representation is shared. These results indicate, that shared representations may strongly guide the explanations of experts, i.e. that a representation may suggest experts to discuss the individual components of a subject matter successively (Jucks et al., in press). Conclusively, typical forms of support – additional, shared representations in this case – may actually hamper knowledge communication. Consequently, the research group of Bromme and colleagues plan to encourage experts to anticipate and consider the degree of the actual layperson's prior knowledge (Bromme, Rambow, & Nückles, 2001).

Facilitating computer-mediated knowledge communication

How can computer-mediated knowledge communication be facilitated so that possible advantages of CMC for knowledge communication may be fostered and possible disadvantages reduced? Apart from traditional approaches to facilitate knowledge communication (e.g., training the communicants or moderating knowledge communication processes), some new facilitation methods aim to foster the processes of knowledge communication directly and may be achieved with computer-based media. One important characteristic of CMC is that it comes in a range of guises and that computer-based communication interfaces may be modifiable. That is, CMC may not only pose a different setting for communication, but also offer new ways to influence knowledge communication. In this chapter, two complementary, media-based approaches to facilitate knowledge communication will be summarized: Computer-mediated knowledge communication may be facilitated by choosing the most adequate medium for the individual scenario and by adapting the media interfaces to the specific knowledge communication purpose.

Facilitating computer-mediated knowledge communication by media choice

The adequate *media choice* may appear to be a simple and obvious approach to facilitate knowledge communication, because any media may come with potentials and disadvantages related to different scenarios of knowledge communication. This *task-media-fit-approach* involves the notion that low-bandwidth, text-based CMC may be more appropriate for some tasks than high-bandwidth, audio-visual CMC and FTF communication. The individual capacity to transmit more or less information through these media is matched with a number of tasks that require different degrees of information (McGrath & Hollingshead, 1993, 1994). An idea-generating task, for instance, does not require as much interaction between the discussants as the negotiation of conflicts. Therefore, generating tasks are appropriate for low-bandwidth, text-based CMC whereas other tasks require more bandwidth as in video conferencing or FTF communication. The task-media-fit-approach therefore suggests that media choice should be *rational* to facilitate knowledge communication. A rational media choice means, that specific characteristics ascribed to the individual media make the media more or less appropriate for specific communicative scenarios. For instance, email has been judged as appropriate for informing, but in order that participants get to know each other, FTF communication is usually considered more appropriate (Rice, 1993). This includes the notion that the preferred medium is not necessarily the most costly medium. Anderson and colleagues describe, for instance, that video conferencing may be considered less useful in knowledge communication compared with noninteractive video resources

(Anderson et al., 2000). Actual media choice in real world settings can be explained by several approaches, however, and may not always be based on an ideal fit between medium and knowledge communication scenario (cf. Döring, 1997). Media may be chosen *normatively* based on what users know and appreciate best. It has been shown, for instance, that the appreciation of email in organizational contexts is related to the experience of the individual in handling email and also to the estimation of email by colleagues and superiors (Schmitz & Fulk, 1991). Media choice may also be *interactive* and depend on how many and to what extent possible communicants use a specific medium. In this respect, a critical mass of communicants enhances the use of a specific medium (Markus, 1987). Some studies show that communities can be supported best by using modest, common, and easily accessible equipment rather than high-technology, highly specialized communication tools (Carletta, Anderson, & McEwan, 2000). Therefore, computer-based approaches to facilitate knowledge communication should consider the actual context of the individual user.

Facilitating computer-mediated knowledge communication by interface design

Interface design is another method of confronting the problems of computer-mediated knowledge communication. This approach argues that no medium was genuinely designed for knowledge communication and thus, the design of the medium interface could be improved for specific knowledge communication scenarios (Mandl & Fischer, in press; Roschelle & Pea, 1999). Therefore, media can be adapted to foster knowledge communication by technically implementing support into the CMC environment. The development and experimental research of these computer-based tools to support knowledge communication has many practical implications. The rationale of knowledge communication tools is that a specific interface design may substitute extensive training and feedback by co-present moderators and warrant a standardized quality of knowledge communication. The tool may afford and constrain specific activities of knowledge communication (Greeno, 1998). Several forms of how media may be designed to foster learning have been suggested (Mandl & Fischer, in press; Roschelle & Pea, 1999):

Shared active representation tools support knowledge communication by providing discussants with shared representations in different codes (text, graphic, etc.) of the subject matter. In CMC, shared applications typically utilize shared representation tools. With respect to knowledge communication, shared active representation tools can be distinguished by their interactivity. The least interactive form is a representation of the subject matter accessible by all discussants, but which the individual user cannot modify. These representations may guide knowledge communication by emphasizing specific aspects of a subject matter

(Suthers & Hundhausen, 2001). The salience of specific aspects in representations would increase the chance that these aspects would enter the discourse. Representations may also facilitate knowledge communication by providing a common ground of the discussants in accordance with the physical co-presence heuristics (Clark & Marshall, 1981). Shared representations may provide information that does not need to be interpreted, but can be used by the discussants immediately (Mandl & Fischer, in press). In this respect, shared representations could reduce ambiguous communication. For instance, graphical representations may define subjects in a more definite and more complete way than possible in pure discourse (Schnotz, Boeckheler, & Grzondziel, 1997). However, as Jucks et al. show, graphical representations could also increase the illusion of evidence in expert-layperson-communication. These inconsistency may be explained by the fact, that the beneficial effects of shared representations are highly dependent on the degree of prior knowledge of all communicants (Fischer, 1998). Shared active representation tools may also model group processes or the subject matter in a more interactive way. For instance, *mapping techniques* are based on the idea to represent individual concepts on single cards and to graphically link these concepts with specified relations in a map. Online mapping techniques have been successfully applied in computer-mediated cooperative learning scenarios (e.g., Fischer, 1998). The rationale of these more interactive forms of shared active representation tools is that users may record important processes and results of knowledge communication. This permanent record may in turn facilitate metacognition, e.g., monitoring what aspects of the subject matter have been discussed already. Therefore, discussants may less likely fall victim to an illusion of evidence when they need to construct a shared representation together.

Community building tools aim to support the social coherence of communities by providing defined virtual spaces as MUDs do, for instance (Fischer & Mandl, in press; Mandl & Fischer, in press). Community building tools, such as Knowledge Forum, are based on the principle that the individual members of the community contribute to a specific subject matter on which other members of the community may further build. In this way, community building tools should help to allocate knowledge resources, to build groups of interest and to continuously generate better answers to complex problems. One aspect of community building tools is therefore ”knowledge mining”. This means that community building tools may help users to discover the knowledge of the entire community on a particular subject matter and recommend specific resources and experts within the community (Roschelle & Pea, 1999). The separation of the CMC environment into specific, purpose-built virtual spaces, which may be accessible to community members only, aims to improve the knowledge search within a community (Weinberger & Lerche, 2001). For instance, ”online-cafés” are supposed to provide space for informal conversations, ”virtual information center” inform new community members how to use the environment, ”virtual libraries” represent the collected archive of the community, etc. The communication of knowledge within these computer-mediated knowledge communication environments is often supported by several types of media (e.g., electronic bulletin boards and chats). The community strongly builds on the commitment of its members. Therefore, reward systems (e.g., electric currencies) are often applied with varying success (cf. Creß et al., in press). Whereas more informal communities are motivationally self-sustained on the grounds of the shared interest of the community members (e.g., self-help groups), little is known about how commitment in more formal communities initiated by third persons such as superiors, teachers, or companies can be facilitated. There are indications that awareness about the usefulness of one's own contributions may improve the effects of traditional incentive structures (Creß et al., in press).

Socio-cognitive structuring tools aim to structure discourse according to successful patterns of knowledge communication. Successful interaction patterns usually involve metacognitive processes such as mutual regulation and reflection on the subject matter. These structuring tools have also been referred to as scripts, which sequence and specify individual interactions (O'Donnell, 1999). Scripts are usually taught prior to actual knowledge communication and moderated. In case of computer-mediated knowledge communication, there is the possibility to adapt the interface to utilize scripted cooperation (Baker & Lund, 1997; Scardamalia & Bereiter, 1996). The individual activities can be specified with prompts or note starters, e.g., ”My theory is ...” or ”I need to understand ...”, that discussants are supposed to complete when starting to write a message in text-based CMC (Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2002; Weinberger et al., in press). These prompts are implemented into the text window that discussants use to formulate messages in online debate. The studies show, that these scripts can improve knowledge communication and encourage discussants to disagree and explore alternative viewpoints in comparison to open discourse in text-based CMC. In this respect, text-based CMC may be appropriate for modifying discourse directly by sequencing and timing content or interaction or by assigning specific activities or roles to individual group members. However, scripts may also be detrimental to knowledge communication when the discussants are more experienced or when the script is too detailed (Baker & Lund, 1997; Cohen, 1994; Dillenbourg, 2002). Socio-cognitive structuring tools may disturb ”natural” interactions. Socio-cognitive structuring tools aim to achieve specific interactions, but an a priori structure of discourse cannot foresee any ambiguity or necessary ”side tracks” in knowledge communication. Especially advanced knowledge communicants may apply individual successful knowledge communication strategies that the structuring tool may not recognize. In particular a very detailed prescription of interactions may hamper knowledge communication on complex subjects. Complex subjects may afford a big number of various interactions and allow many solution paths. A detailed structure may reduce the required multiple perspectives on complex subjects. Therefore, socio-cognitive structuring tools may need to be designed for specific contexts and with sufficient degrees of freedom for the discussants. Computer-based media may pose an ideal test bed for adapting structuring tools to various contexts and enable rather than constrain interactions.

Conclusion and outlook

In sum, computer-based facilitation of knowledge communication may not have found the ”silver bullet” to miraculously turn the often deficient scenarios into ideal forms of knowledge communication, but may be a practical and thus, intriguing approach for real world settings. Of course, the efficiency of knowledge communication may be a question of several context variables: Ideally, the subject matter is complex and interesting, participation is voluntarily and equally, the participants are experienced in communicating knowledge, the communication tools meet the requirements etc. However, these contextual conditions are rarely met and knowledge communication rarely shows ideal characteristics: Ideally, knowledge communicants participate highly and equally in coherent and reflective discourse. The idea to foster these discourse processes directly has challenged research and fields of practice. Instead of training the discussants prior to knowledge communication – which is seldom done – computer-based tools may be selected and designed to facilitate interactions. Some studies have reported promising results on how to facilitate computer-mediated knowledge communication. Future studies may apply these methods in real world settings to optimize actual knowledge communication scenarios.

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