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Computer support for collaborative learning environments

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Absatz

This paper deals with computer support for collaborative learning environments. Our analysis is based on a moderate constructivist view on learning, which emphasizes the need to support learners instructionally in their collaborative knowledge construction. We will first illustrate the extent to which the computer can provide tools for supporting collaborative knowledge construction. Secondly, we will focus on instruction itself and show the kinds of advanced instructional methods that computer tools may provide for the learners. Furthermore, we will discuss the learners' prerequisites and how they must be considered when constructing learning environments.

Keywords: computer supported learning, collaborative learning, problem-based learning, construction, instruction, script, external representation, content scheme, learning environment, tools for learning

Zusammenfassung

Dieser Bericht behandelt die Unterstützung kooperativer Lernumgebungen durch den Einsatz von Computern. Der theoretische Hintergrund greift auf einen moderaten Konstruktivismus zurück, der die Notwendigkeit einer instruktionalen Unterstützung für die gemeinsame Wissenskonstruktion betont. Darauf aufbauend beschreibt der Bericht in einem ersten Schritt, wie der Computer Werkzeuge zur gemeinsamen Wissenskonstruktion bereitstellen kann. Im zweiten Teil steht die Instruktion für das kooperative Lernen im Vordergrund. Dabei werden Methoden instruktionaler Unterstützung vorgestellt, die computerbasierte Werkzeuge für die gemeinsame Wissenskonstruktion bereitstellen, insbesondere Skripts und inhaltliche Strukturvorgaben. Darüber hinaus beschreibt der Bericht, inwieweit individuelle Lernereigenschaften, wie z.B. das Vorwissen, einen Einfluss auf die Realisierung von Lernumgebungen haben.

Schlüsselwörter: Computerunterstütztes Lernen, kooperatives Lernen, problembasiertes Lernen, Konstruktion, Instruktion, Skripts, externale Repräsentationen, Wissensschema, Lernumgebung, Wegzeuge zum Lernen

COMPUTER SUPPORT FOR COLLABORATIVE LEARNING ENVIRONMENTS

During the last decade, computers have become a fundamental tool for learning. Today, through connection to the Internet, they provide access to worldwide communication and information. Alongside these new possibilities, computers have become a pedagogical tool, e.g. used for students' scientific inquiry or for their collaborative knowledge construction. This is reflected in the widespread utilization of computers in education. Computers can be found in elementary school classrooms, in universities and in many other kinds of adult education. Computers are not only used in a general sense for learning, but may also provide specific tools for supporting collaborative learning environments.

The very use of the term learning environment implies that learning is dependent on various environmental factors. According to Mandl and Reinmann-Rothmeier (2001), a learning environment is made up of a specific composition of teaching strategies and methods, learning material and media. Learning environments target more than just knowledge acquisition. According to De Corte (2003), *powerful* learning environments also target the *transfer* of knowledge. Transfer means that the knowledge acquired does not remain inert (see Renkl, Mandl & Gruber, 1996). Furthermore, transfer implies the productive use of the knowledge and skills acquired. Therefore, powerful learning environments usually involve situated learning scenarios (see Lave & Wenger, 1991), which rely on a moderate constructivist approach to learning. Such learning scenarios focus on learner's active knowledge construction. They start with authentic problems and consider the social context of learning. In situated learning scenarios, learners usually work in small groups, which enables them to view the learning material from multiple perspectives. In these scenarios, the learning partners engage collaboratively in knowledge construction and negotiate with one another to reach a shared understanding about a particular topic. However, simply providing the forum for active knowledge construction may be ineffective as a stand-alone measure, because this often results in excessive demands being placed on the learners. For this reason, Mandl and Reinmann-Rothmeier (2001) stress the need for instructional support, particularly through providing the learners with guidance during their knowledge construction. This is reflected in the approach of problem-based learning environments (see Dochy, Segers, van den Bosche & Gijbels, 2003). Problem-based learning environments provide both problems to solve and instructional resources for the learners (Reinmann-Rothmeier & Mandl, 2001;

also Ertl, Winkler & Mandl, 2006). In these environments, the problems are the driver for the learner's active knowledge construction, while the instructional resources provide guidance during the learners' process of knowledge construction.

In the context of learning environments, the computer can provide tools for learner's collaborative knowledge construction as well as tools for learners' instructional guidance during this process. With respect to the learner's collaborative knowledge construction, the computer mainly provides tools that facilitate communication between the learners. We will illustrate this point in the first part of this paper. With respect to instructional guidance for the learners, the computer offers a foundation for introducing advanced instructional methods to the collaborative learning environment. These methods would hardly be possible without the use of a computer.

Computer support for collaborative knowledge construction

In collaborative learning environments, particularly when learners are separated by distance, the computer can facilitate communication between the learners. In recent years, numerous tools for enabling communication between learners have emerged. These tools allow for either an asynchronous or a synchronous mode of communication. The modes affect the selection of the learning scenario. Synchronous communication requires learners to be online at exactly the same time, whereas asynchronous communication allows learners to be online any time they choose. Besides simply providing tools for communication, the computer often provides learners with the opportunity to *share* the interface of the learning environment—even when in different locations. This means that learners work in the same learning context and have a shared screen in the learning environment. Different levels can be distinguished within the shared screen. The basic level simply provides learners with the same interface structure and contents when accessing the learning environment; however, learners do not necessarily see the same picture at the same time (see Weinberger, 2003). The enhanced level supports learners by having them to share one application simultaneously *(application sharing).* This allows learners to work collaboratively and simultaneously using the same application. They can view the actions of their learning partners and often coordinate their activities using another communication channel (e.g. chat, audio; see Dillenbourg & Traum, 1999; Ertl, Fischer & Mandl, in press; Pata, 2005). The level of screen sharing used often depends on the mode of communication. In asynchronous communication, learners mostly share the structure of the learning environment, whereas when communicating synchronously, they often use application sharing.

In the following, we will describe two learning environments that offer different modes of communication. In the first scenario, learners communicate asynchronously through discussion boards. In the second scenario, learners communicate synchronously through videoconferencing. After describing both examples, we will highlight the similarities and differences found in each.

A learning environment using asynchronous communication

When the computer provides asynchronous communication, learners often communicate through discussion boards in the learning environment. Such learning environments are quite commonly used for virtual seminars in higher education (see Koschman, Suthers & Chan, 2005; Schnurer, 2005; Weinberger, 2003). Using the discussion board, learners express themselves by typing statements into the computer interface. Learners can post messages to the system and also have the opportunity to read and reply to the messages of their learning partners. The communication is asynchronous, which means that there is no immediate reply to each learner's contribution. However, this method also provides enough time for learners to compose thoughtful replies to other learners' contributions (see Schnurer, 2005; Weinberger, 2003). The written messages are permanent and usually allow for later access (see Pächter, 1996). Furthermore, many systems allow learners to edit and improve their contributions (see Clark & Brennan, 1991; Dennis & Valachic, 1999). The advantage of discussion boards and other asynchronous learning scenarios is that each learner can proceed with the learning process at his/her own pace. This means that learners have time to think when writing contributions because there is no immediate need for response (Ellis, 2001; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). On the other hand, learners are often dependent on each other's contributions, e.g. when working on a team assignment collaboratively. It is often necessary for learners who depend on one another to have a "similar pace" for their collaborative work (see Fischer & Waibel, 2002). This means that learners should contribute to the discussion in a timely manner so that the other learners have the chance to pick up statements and reply to them.

The first sample learning environment was comprised of a collaborative learning scenario for three learners working to gain a more in-depth understanding of the attribution theory (see Weinberger, 2003). They worked on three authentic learning cases and used the attribution theory to identify the causes for some pupils' problems in school. In this scenario, learners worked independently on an initial case solution and then worked as a group to further develop the best solution. In collaboration with their co-learners and by referring to individual resources, learners discussed their analyses and other ideas to develop the most suitable solution for each case. Thus, students invested much effort in exploring the learning material on an individual basis and also shared their own perspectives during collaboration. Using the discussion board, learners composed an initial analysis and posted it to the learning environment. The learning environment provided three discussion boards for the discussion of the learners' analyses, one for each case. The learners composed messages about case diagnoses and commented on each other's contributions. Following these analyses, one learner prepared a final solution for each case. In this scenario, the asynchronous learning platform enabled learners to communicate and reply to each other's comments with a temporal delay. Yet, because the learners were highly dependent on one another for composing the collaborative case solution, they worked within a fixed timeframe for their collaborative negotiation.

A learning environment using synchronous communication

The computer can provide synchronous communication in the form of a chat or videoconferencing tool. In this learning scenario, learners are permanently connected with one another throughout the learning process. They communicate either by typing statements or sentences when using computer chat or by speaking into a microphone during videoconferencing. The communication partners receive these communication acts instantly. In this way, synchronous communication enables highly frequent learner interaction. In our example, we analyze a learning environment that uses videoconferencing. Videoconferencing enables learners to communicate in spoken words through an audio and a video channel (see Ertl et al., in press). The audio channel transmits spoken discourse and the video channel generally provides an image of the head and the chest of the learning partners. In such collaboration scenarios, learners often find a shared application on their screen. This shared application functions as a tool for making the contents of the spoken communication permanent, which is an important aspect when dealing with demanding learning tasks.

In the second example, two learners were engaged in collaborative problem solving (see Fischer, Bruhn, Gräsel & Mandl, 2000). The learners used videoconferencing to work collaboratively on a problem-solving task about motivational theories. They found themselves in the role of teachers, who were tasked with developing a lesson plan. In this scenario, they had to deal with different styles of cooperative assignments for the pupils and were to provide incentives for the pupils to cooperate. When developing the lesson plan, they were asked to consider which assignment could best motivate learners for a certain purpose. Using the videoconference, learners collaborated intensely to create the most suitable lesson plan. The mode of communication (videoconferencing) enabled the learners to communicate in spoken words, as they would on the telephone. Additionally, the learners had a slightly delayed image, which showed the head and the chest of their learning partner, and a shared application (whiteboard) for taking notes collaboratively. During their joint effort, they had to consider how different group assignments would affect the pupils' motivation and discuss the pros and cons of each of the different assignments. Furthermore, they had to decide collaboratively on the design of the lesson plan and document this lesson plan in the shared application. Learners utilized the shared application both to note the pros and cons of each of the different assignments and to document the final lesson plan.

Similarities and differences of each of the learning environments

We have chosen examples of both asynchronous and of synchronous communication to show the extent to which the computer may provide different tools for quite similar learning scenarios. The particular features of each tool offered learners different communicational aspects for their task-specific negotiation. In the first example, the tool offered a *discussion of* contributions, whereas the second one provided fast responses and highly frequent interactions for the learners to *collaborate together* on a solution and to make decisions about how to document their solutions in the shared application. Considering the different features of each tool, the question revolves around the degree to which the learners were able to reach their learning goal using each of the respective tools. When considering this issue, Weinberger (2003) as well as Fischer et al. (2000) report that learners were able to reach their learning goal using each of the respective learning environments. More specifically, they found beneficial effects with respect to both the collaborative work on the task and individual learning outcomes. Learners improved their knowledge about the particular learning material during their activity in both learning environments (see Fischer et al., 2000; Weinberger, 2003). In addition, Weinberger (2003) emphasizes that learners acquired beneficial collaboration strategies and Fischer et al. (2000) refer to the better use of theoretical concepts.

These results indicate that learners may achieve different goals by using different tools for communication. Focusing on the discussion of individual solutions resulted in the use of an asynchronous communication tool, in particular a discussion board. Focusing on the collaborative strategy led to the use of a synchronous communication tool, in this case videoconferencing. This difference in synchronicity evokes quite different learner interactions. In synchronous scenarios, the communication is quite intense. Learners talk or “chat” with each other while learning collaboratively and can react instantly to their partners’ statements. In contrast, during asynchronous communication, partners have to wait until a statement has arrived. Therefore the communication flow is not as intense (see Weinberger, Ertl, Fischer & Mandl, 2005). This means that synchronous communication features highly frequent interaction and coordination, whereas asynchronous communication evokes more thoughtful and comprehensive replies (see e.g. McGrath & Hollingshead, 1994). Consequently, when designing a learning environment, consideration should be given to the relationship between the learning scenario and the mode of communication. Learning scenarios that require highly frequent interaction—for example, collaborative problem solving—may be better served with a tool for synchronous communication. Thoughtful case analyses, on the other hand, may be better served by a tool for asynchronous communication (see also McGrath & Hollingshead, 1994; Pächter, 2003).

Such interrelations have recently become hot topics in communication research. Researchers have worked to compare users’ performance on the same task using different communication tools (see e.g. Anderson et al., 1997; Bernard et al., 2004; O’Connaill, Whittaker & Wilbur, 1993; Pächter, 2003; Piontkowski, Böing-Messing, Hartmann, Keil & Laus, 2003). This research resulted in several theories and taxonomies about media choice (see e.g. Daft & Lengel, 1984; Dennis & Valacich, 1999; McGrath & Hollingshead 1994). However, these research results and the theories are rather descriptive and quite specific. Moreover, the rapid development in communication technologies and problem-based learning environments are not yet reflected in current meta-reviews in this area (e.g. Bernard et al., 2004). Thus, research has only just begun to answer questions about learning scenarios and beneficial tools for communication. However, to obtain a satisfying answer, it is important to ask the right questions. To do this, one should follow Clark’s (1994) argumentation, which states that the type of instruction influences the learning much more than the medium, i.e. the communication tool. Considering that each tool has its own associated affordances and constraints, the question is not about which tool is best for communication, but rather how to design a learning environment in which the learners perform optimally, using a specific communication tool.

As seen in each of our examples, communication occurs differently when using asynchronous or synchronous communication. However, the instruction provided may even out these differences (see Clark, 1994) by introducing important tasks and strategies for collaboration. Specific instruction may facilitate the learners’ ability to reach the particular learning goals.

In the example of asynchronous communication, instruction may focus on problems that occur when the schedule is too flexible. In such cases, some learners take too much time for making their contributions. Due to the late arrival of these contributions, the other learning partners may miss the chance to take these contributions into account. To counteract this problem, the instruction could provide a timeframe for the learners' activities. This timeframe could, to a certain extent, synchronize the learners' pace in the learning environment. This kind of synchronization may help learners finish their collaborative task in a timely manner while giving consideration to the contributions of all collaborating partners (see e.g. Fischer & Waibel, 2002; Schnurer, 2005; Weinberger, 2003).

In the videoconferencing example, one could introduce individual phases to provide learners with an opportunity for individual reflection during the synchronous communication (see Ertl, Reiserer & Mandl, 2005; Rummel & Spada, 2005). This could even out problems, which may arise during highly frequent interaction and could also support thoughtful individual reflections. Another possibility would be to introduce a shared application during which the learners would have the opportunity to record any important contents of their collaboration: The swift contents of synchronous discourse become permanent when they are fixed in the shared application and therefore provide a lasting foundation for collaborative reflection (see Ertl, Reiserer & Mandl, 2005; Pächter, 1996). This shared screen may thereby offer both a resource and a space for communication between the collaborating partners to support their collaborative activities and their knowledge construction (see Bell, 2002; Schnurer, 2005; Weinberger, 2003). Furthermore, the contents displayed on the shared screen may focus the learners' discourse and may therefore receive increased attention from the learners (see Ertl et al., in press; Suthers & Hundhausen, 2003).

In summary, the instruction and the learning scenario indicate which communication tool is best for promoting learners' knowledge construction. Furthermore, instruction may stem from several support methods, which can further improve learners' performance within each specific learning environment.

Instructional guidance for computer-supported learning environments

When the computer supports the instructional guidance of a learning environment, it mainly offers a tool for implementing advanced instructional methods. In this context, the main feature of the computer is the shared screen. We have already mentioned that this shared screen can serve as a permanent knowledge base, thus facilitating the learners' collaborative knowledge construction. In addition, it can also introduce advanced instructional methods to collaboration, which would not be realizable without the use of the computer.

These advanced instructional methods have their roots in methods for supporting traditional learning scenarios. They are tailored to the specifics of collaborative learning environments and therefore often take on a particular significance (see Bromme Hesse & Spada, 2005; Fischer, Mandl, Haake & Kollar, in press). Methods for improving learning environments focus on the *learner* and the learner's performance within the environment. The focus is on potential problems that learners may encounter during the learning process. To address problems that occur during collaborative work on the task, the methods focus both on difficulties with *working to solve the collaborative task* and on difficulties with *structuring its content*. In the following, we will show approaches for improving computer-supported collaborative learning environments that relate to both aspects. However, because these methods focus on the learners' performance within the learning environment, they also may depend on their individual prerequisites. This aspect will be discussed at the end of this section.

Facilitating the work on the collaborative task solution

Methods that aim to improve the work on the collaborative task solution are often based on approaches such as *scripted cooperation* (see O'Donnell & King, 1999). These scripts sequence learners' work on the task. Furthermore, they may provide roles for the learners and encourage them to apply beneficial strategies for solving the task. From this perspective, scripts have two main purposes: they structure the *collaborative negotiation* as well as the work to determine a *solution for* the task. Applying scripts in face-to-face scenarios mainly aims to evoke beneficial cognitive and meta-cognitive strategies from the learners. One example is the method of scripted cooperation by O'Donnell and Dansereau (1992). This script sequenced the learner's collaboration process in four phases for individual text reading, recall from memory, peer-feedback and elaboration. However, although this script structures the work on the task, the main motor for the comprehension processes lies in the strategies applied during each of the different phases (see also Rosenshine & Meister, 1994).

Furthermore, learners take on different roles that correspond to the application of particular strategies within each phase. For example, one learner takes on the role of recaller, while the other functions as questioner. This example also shows how scripts depend rather marginally on the content of the text: the scripted cooperation method can be applied to texts within different content areas. However, the script is specific to the learning task.

Recently, scripts have gained in importance in the field of computer-supported collaborative learning (see Fischer et al., in press). In contrast to scripts used in face-to-face scenarios, the scripts used in computer-supported learning contexts do not necessarily structure both the collaboration process *and* the actual work on the task. For example, Baker and Lund (1997), describe a script that directed only the collaboration process. Using speech act buttons in the shared application, the collaborating learners had to agree on any modifications made by other learners in the shared application before they were allowed to continue. Weinberger et al. (2005) described a different script that guided learners through various discussion boards without specifying how to collaborate. However, most scripts use a mixture of both aspects and sequence specific strategies for handling a task.

Ertl, Reiserer and Mandl (2005, see tab 1) described one example for scripting in videoconferencing. In this learning environment, two learners were given task of teaching theories of educational science to one another. To do this, they first worked independently and expanded their knowledge about a particular theory. The learners then entered the videoconferencing session for collaborative teaching. During this videoconferencing session, the learners also had a shared application for making notes about important aspects. Furthermore, half of the collaborating dyads received instructional support in the form of a script. The aim of this script was to improve learning during the task of collaborative teaching. The script structured the collaborative work on the task, the roles of the learners, and the application of beneficial strategies for collaborative negotiation. Results of the study show that the script was able to facilitate learners' negotiation with theoretical concepts during the collaboration process. For individual learning outcomes, the script specifically helped learners in the learner role acquire new theoretical knowledge (see Ertl, Reiserer and Mandl, 2005). Other studies also report the beneficial effects that scripts have on learning processes (see Baker & Lund, 1997; Weinberger, 2003) and on individual outcomes in computer supported learning environments (see Rummel & Spada, 2005). Baker and Lund (1997) were able to show that applying a script could foster the learner's collaboration processes. Weinberger (2003) reported that scripts used to facilitate learning resulted in more homogeneous work on the task as well as a higher individual learning outcome, measured by a higher score in an individual post-test case. Furthermore, Rummel and Spada (2005) reported that the script was able to support learners' acquisition of beneficial collaboration strategies.

Table 1: Script for collaborative teaching in videoconferencing (taken from Ertl, Reiserer & Mandl, 2005).

	Teacher role	**Learner role**
Phase 1: Communicate	Explaining the text material	Asking comprehension questions
Phase 2: Expanding their understanding	Supporting the learner	Rehearsing and typing the information received into the shared application
Phase 3: Reflection	Individual reflection and elaboration, based on the shared application	
Phase 4: Discussion	Discussing on the basis of reflection with the partner	Discussing on the basis of reflection with the partner and capturing the results of the discussion in the shared application

Facilitation relating to the structure of the content

In contrast to the approach of scripts, which mainly concentrate on the work involved in solving the task and collaboration-specific strategies, content-specific facilitation is directed at a conceptual level. It aims to facilitate learners' understanding of a particular problem. For this purpose, content-specific facilitation highlights central characteristics of the learning material by representing important content structures. According to Zhang and Norman (1994), this representation of content influences the learners' ability to deal with the content. When provided with a beneficial representation, learners may perceive the problem in a different manner. This may then enable them to deal with its content more swiftly (see Zhang & Norman, 1994). In computer-supported learning environments, the shared screen provides an ideal forum for realizing content-specific support (see Ertl et al., in press). Pre-structuring the shared screen can make important task characteristics *salient* and can thereby function as a representational guide for content-specific negotiations (see the concept of *representational guidance*, e.g. in Suthers & Hundhausen, 2003). The broad variety of structures for conceptual representation (see Löhner & van Joolingen, 2001) has led to a wide variety of facilitation methods. These methods mainly differ in the degrees of freedom that learners have and in the degree of support the learners receive when working with them. For this reason, one can differentiate between different classes of support: *templates* and *conceptualization tools*.

Templates pre-structure the content domain (see Brooks & Dansereau, 1983; Ertl et al., in press; Suthers & Hundhausen, 2003). They provide categories, mainly in the form of tables, which are particularly important for content-specific negotiation. Learners fill in the empty spaces in the template and thereby focus on important categories. However, learners cannot change the structure of the template or model new relationships. Templates therefore basically aim to facilitate the understanding of important aspects or categories within a subject area.

Conceptualization tools allow learners to model relations. When these tools are used, they provide objects of different style and different relations important for the content area. Learners are able to create their own representation of the structure of a particular content (see Fischer, Bruhn, Gräsel & Mandl, 2002; Suthers & Hundhausen, 2003). Consequently, conceptualization tools aim at facilitating the deeper understanding of structures within a particular subject area.

Ertl et al. (in press) present one example for improving content-specific aspects of the learning environment using a template (see Figure 1). In this scenario, three learners collaborated through videoconferencing. The subject was attribution theory and it was the learners' task to solve a case, which used the attribution theory to describe a pupil's problems with math. Learners were asked to search within the case material for possible causes for the problem. They adopted different perspectives and tried to analyze the case with respect to attribution theory. To do this, they had to deal with information about consensus and consistency and formulate attributions (see Ertl et al., in press). To develop a good solution to this case, learners had to integrate their different perspectives and substantiate their claims according to attribution theory (cf. Kopp, 2005). All groups used a shared text editor for documenting their solution to the case. Furthermore, half of the groups received a supporting template, which was included in the shared application. The template aimed to support learners by providing them with a framework for performing attributions. To this end, the learning environment contained a template, which aimed to focus learners on aspects important for formulating attributions, particularly the information about consensus and consistency and attribution patterns. It is important to note that such a template can change the learners' perception of the task. In contrast to the naïve strategy of simply focusing on causes, learners using the template may use the strategy of justifying their attributions based on case information. Such a strategy change may be permanent and may prove effective in a later situation—e.g. a post-test—without facilitation (see Ertl et al., in press).

Cause	**Information**		**Attribution according to**	
	Consensus	Consistency	Kelley	Heider

Figure 1: Content-specific facilitation in template style (taken from Ertl et al., in press).

The results of the study show that the template was able to focus learners on the important aspects of their attribution. When compared to a control group, they determined the attribution pattern for each cause and justified each attribution through case information regarding consensus and consistency. This resulted in a higher score for learners' collaborative and individual learning outcomes (see Kopp, Ertl & Mandl, 2004). The effect of the support on the individual outcomes is of a particular importance since learners completed the individual post-tests without support.

Many other studies have also described the beneficial effects of content-specific facilitation in computer-supported learning environments (see Ertl, Reiserer & Mandl, 2005; Fischer et al., 2002; Suthers & Hundhausen, 2003): Ertl, Reiserer and Mandl (2005) were able to show that a template focused learners' collaborative knowledge construction on contents that they neglected without the template. Suthers and Hundhausen (2003) reported that a template helped learners to describe the relationships between theoretical concepts and evidence. Furthermore, Fischer et al. (2000) found that learners who used conceptualization tools also converged regarding the knowledge acquired. This means that the post-test scores of learners who had been provided with support were much more similar than the scores of the other learners.

Facilitation and learners' prerequisites

In several studies, collaboration-specific and content-specific support measures have proven themselves beneficial for learning. However, the decision to employ a support measure should be driven by the specific characteristics of the learning scenario. Solid theoretical considerations and aspects of usability, rather than technical feasibility, should be the driving force for the design of facilitation. Not all of the opportunities that facilitation methods offer may have the desired effects (see Weinberger et al., 2005). The key for this issue often lies in the learners' individual prerequisites, e.g. prior knowledge (Dochy, 1992, Ertl, Kopp & Mandl, 2005; Shapiro 2004), cognitive abilities (Sweller, van Merrienboer & Paas, 1998) or motivational aspects (Deci & Ryan, 1992). These prerequisites mean that scripts and content-specific support may have a varied impact.

With respect to scripts, there is the risk that excessive rigidity may have a negative impact on learners' motivation (see Deci & Ryan, 1992). This could also have a detrimental impact on learning processes and outcomes (see Weinberger, 2003). Dillenbourg (2002) introduced the term of "over-scripting" a learning environment, which means that too much structure in the learning process may hinder the exchange of information and reduce the beneficial effects of scripts on the learning processes (see also Cohen, 1994).

With respect to content-specific facilitation, methods that provide learners with too much freedom might prove too complex for beneficial activities (see Dobson, 1999). When applying complex conceptual facilitation, such methods may exceed learners' cognitive abilities and lead to cognitive overload (see Sweller et al., 1998), which may negate the facilitation effect. This means that complex methods, which allow a high degree of freedom, may be best suited for highly experienced learners, while rather restricted, highly structured methods provide most benefits for inexperienced beginners. Therefore, it becomes clear that the learners' skills and their prior knowledge must be taken into consideration (see Ertl, Kopp & Mandl, 2005; Reiserer, 2003; Shapiro, 2004).

On the other hand, if facilitation methods over-simplify the task, this could lead to decreased mental activity in the learners and therefore to lower learning outcomes (see also Salomon, 1984). Because the learners' cognitive activities are the key to their understanding, facilitation methods might paradoxically make the task more difficult. The greater level of difficulty then works to evoke increased mental activity and may improve learning outcomes (see Reiser, 2002). Therefore, combining different facilitation methods may benefit the learning environment (see Ertl et al, in press).

Conclusions

In this paper, we have focused on the computer as a tool for supporting collaborative knowledge construction and for introducing advanced instructional methods to collaborative learning environments. In doing so, we have discussed the constraints and affordances relating to both aspects. Regarding collaborative knowledge construction, we showed the extent to which the learning scenario and the mode of communication relate to one another. However, we also showed the degree to which instruction could influence this relationship. With respect to instruction, we illustrated how the support method depends on the learner’s individual prerequisites. Yet, there is one additional aspect to consider, which lies between the learning environment and learners’ progress in this environment.

In learning environments that exist over a longer time period, e.g. a whole course term, learners repeatedly work within the same learning scenario. One could expect that, over time, through repeatedly working in the same learning environment that learners internalize the structure and the particular facilitation methods applied. In terms of the interaction processes between the learners’ prerequisites and support measures, this additional experience raises their individual prerequisites and may thereby reduce the need for support after several learning sessions. Consequently, computer-supported learning environments should also provide a fading mechanism based on the cognitive apprenticeship approach (see Collins, Brown & Newman, 1989; Puntambekar & Hübscher, 2005). This fading mechanism should reduce the amount of support learners receive to the amount they actually need. This would reduce the structure of the learning environment and enable more self-directed learning over time. Using such a procedure could increase the learners’ awareness of the self-regulation strategies that are needed and counteract loss of motivation as well as course dropout, which occur when learners work in a computer-supported learning environments for longer periods (see Deci & Ryan, 1992). Future research should focus on the question of how to apply facilitation methods in a flexible manner. This includes facilitation strategies adapted to the learners’ requirements. As learners gain experience, the facilitation should be faded.

The success of computer-supported collaborative learning scenarios has its origins in two sources: in learners’ collaborative knowledge construction and in the specific instructional support provided to the learners. To achieve this success, the computer can be a powerful tool by providing communication, advanced instructional methods, and also an array of valuable and authentic resources for the collaborative learning environment. Thus, learning environments should not only use the new technology, they should also benefit from the new instructional methods that are enabled by this technology. The goal for using computer-based learning should be to create powerful learning environments that facilitate both beneficial learning activities and fruitful social interactions between learning partners (see De Corte, Verschaffel, Entwistle & Van Merrienboër, 2003).

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Literature

Anderson, A. H., O' Malley, C., Doherty Sneddon, G., Langton, S., Newlands, A., Mullin, J., Fleming, A. M. & Van der Velden, J. (1997). The impact of VMC on collaborative problem solving: An analysis of task performance, communicative process, and user satisfaction. In K. E. Finn, A. J. Sellen & S. Wilbur (Eds.), *Video mediated communication* (pp. 133-155). Mahwah, NJ: Lawrence Erlbaum Associates.

Baker, M. & Lund, K. (1997). Promoting reflective interactions in a CSCL environment. *Journal of Computer Assisted Learning, 13,* 175-193.

Bell, P. (2002). Using argument map representations to make thinking visible for individuals and groups. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL 2. Carrying forward the conversation* (pp. 449-485). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Bernard, R. M., Abrami, P. C., Lou, Y., Borokhovski, E., Wade, A., Wozney, -. L., Wallet, P.-A., Fiset, M. & Huang, B. (2004). How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research, 74,* 379-439.

Bromme, R., Hesse, F.-W. & Spada, H. (2005). *Barriers and biases in computer-mediated knowledge communication - and how they may be overcome* (Vol. 5). Dordrecht: Springer.

Brooks, L. W. & Dansereau, D. F. (1983). Effects of structural schema training and text organization on expository prose processing. *Journal of Educational Psychology, 75,* 811-820.

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development, 42,* 21-29.

Clark, H. H. & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick (Ed.), *Perspectives on socially shared cognition* (pp. 127-149). Washington, DC: American Psychological Association.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64,* 1-35.

Collins, A., Brown, J. S. & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Laurence Erlbaum Associates.

Daft, R. L. & Lengel, R. H. (1984). Information richness: A new approach to managerial behavior and organizational design. *Research in Organizational Behaviour, 6,* 191-233.

Deci, E. L. & Ryan, R. M. (1992). The initiation and regulation of intrinsically motivated learning and achievement. In A. K. Boggiano & T. S. Pittman

(Eds.), *Achievement and motivation: A social-developmental perspective* (pp. 9-36). Cambridge: Cambridge University Press.

De Corte, E. (2003). Designing learning environments that foster the productive use a acquired knowledge and skills. In E. De Corte, L. Verschaffel, N. Entwistle & J. J. G. v. Merrienboer (Eds.), *Powerful learning environments: Unravelling basic components and dimensions* (pp. 21-33). Amsterdam: Pergamon.

De Corte, E., Verschaffel, L., Entwistle, N. & Merrienboer, J. J. G. v. (Eds.). (2003). *Powerful learning environments: Unravelling basic components and dimensions.* Amsterdam: Pergamon.

Dennis, A. R. & Valacich, J. S. (1999). *Rethinking media richness: towards a theory of media synchronicity.* Paper presented at the 32nd Annual Hawaii International Conference on Systems Sciences.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL: Can we support CSCL?* (pp. 61-91). Heerlen: Open Universiteit Nederland.

Dillenbourg, P. & Traum, D. (1999, January). *Does a shared screen make a shared solution?* Paper presented at the Conference on Computer Support for Collaborative Learning (CSCL), Stanford.

Dobson, M. (1999). Information enforcement and learning with interactive graphical systems. *Learning and Instruction, 9,* 365-390.

Dochy, F. J. R. C. (1992). *Assessment of prior knowledge as a determinant for future learning. The use of prior knowledge state tests and knowledge profiles.* Utrecht: Uitgeverij Lemma B.V.

Dochy, F., Segers, M., Van den Bossche, P. & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction, 13,* 533-568.

Ellis, A. (2001, 9-12 December). *Student-centred collaborative learning via face-to-face and asynchronous online communication: What's the difference?* Paper presented at the 18th ASCILITE Conference, Melbourne.

Ertl, B., Fischer, F. & Mandl, H. (in press). Conceptual and socio-cognitive support for collaborative learning in videoconferencing environments. *Computers & Education.*

Ertl, B., Kopp, B. & Mandl, H. (2005). Effects of individual's prior knowledge on collaborative knowledge construction and individual learning outcomes in videoconferencing. In T. Koschmann, D. D. Suthers & T. Chan (Eds.), *Computer Supported Collaborative Learning 2005.* Mahwah: Lawrence Erlbaum Associates.

Ertl, B., Reiserer, M. & Mandl, H. (2005). Fostering collaborative learning in videoconferencing: The influence of content schemes and cooperation scripts on shared external representations and individual learning outcomes. *Education, Communication & Information, 5*(2), 147-165.

Ertl, B., Winkler, K. & Mandl, H. (2006). E-learning - Trends and future development. In F. M. M. Neto & F. V. Brasileiro (Eds.), *Advances in Computer-Supported Learning.* Hershey, PA: Idea.

Fischer, F., Bruhn, J., Gräsel, C. & Mandl, H. (2000). Kooperatives Lernen mit Videokonferenzen: Gemeinsame Wissenskonstruktion und individueller Lernerfolg [Cooperative learning in videoconferencing. Collaborative knowledge construction and individual learning outcomes]. *Kognitionswissenschaft, 9,* 5-16.

Fischer, F., Bruhn, J., Gräsel, C. & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction, 12,* 213-232.

Fischer, F., Mandl, H., Haake, J. M. & Kollar, I. (Eds.). (in press). *Scripting computer-supported communication of knowledge - Cognitive, computational, and educational perspectives.* Berlin: Springer.

Fischer, F. & Waibel, M. C. (2002). Wenn virtuelle Lerngruppen nicht so funktionieren, wie sie eigentlich sollen [If virtual learning groups don't work as they should]. In U. Rinn & J. Wedekind (Eds.), *Referenzmodelle netzbasierten Lehrens und Lernens – virtuelle Komponenten der Präsenz-lehre* (pp. 35-50). Münster: Waxmann.

Kopp, B. (2005). *Effekte schematheoretischer Unterstützung auf Argumentation und Lernerfolg beim kooperativen Lernen in Videokonferenzen [Effects of schemata on argumentation and learning outcomes in videoconferencing].* Berlin: Logos.

Kopp, B., Ertl, B. & Mandl, H. (2004). Fostering cooperative case-based learning in videoconferencing: Effects of content schemes and cooperation scripts. In P. Gerjets, P. Kirschner, J. Elen & R. Joiner (Eds.), *Instructional design for effective and enjoyable computer- supported learning. Proceedings of the first joint meeting of the EARLI SIGs Instructional Design and Learning and Instruction with Computers [CD-ROM]* (pp. 29-36). Tuebingen: Knowledge Media Research Center.

Koschmann, T., Suthers, D. & Chan, C. (Eds.). (2005). *Computer Supported Collaborative Learning 2005: The next 10 years!* Mahwah, NJ: Lawrence Earlbaum Associates.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* New York: Cambridge University Press.

Lipponen, L., Rahikainen, M., Lallimo, J. & Hakkarainen, K. (2003). Patterns of participation and discourse in elementary students' computer-supported collaborative learning. *Learning and Instruction, 13,* 487-509.

Löhner, S. & Joolingen, W. v. (2001). Representations for model construction in collaborative inquiry environments. In P. Dillenbourg, A. Eurelings & K. Hakkarainen (Eds.), *Proceedings of the First European Conference on Computer-Supported Collaborative Learning (euroCSCL)* (pp. 577-584). Maastricht: McLuhan Institute.

Mandl, H. & Reinmann-Rothmeier, G. (2001). Environments for learning. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Bahavioral Sciences* (Vol. 7, pp. 4697-4701). Oxford: Elsevier Science.

McGrath, J. E. & Hollingshead, A. B. (1994). *Groups interacting with technology: ideas, evidence, issues, and an agenda.* Thousand Oaks, CA: Sage.

O'Connaill, B., Whittaker, S. & Wilbur, S. (1993). Conversations over video conferences: An evaluation of the spoken aspects of video-mediated communication. *Human Computer Interaction, 8,* 389-428.

O'Donnell, A. M. & Dansereau, D. F. (1992). Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interactions in cooperative groups. The theoretical anatomy of group learning* (pp. 120-141). New York, NY: Cambridge University Press.

O'Donnell, A. M. & King, A. (Eds.). (1999). *Cognitive perspectives on peer learning*. Mahwah, NJ: Laurence Erlbaum Associates.

Pächter, M. (1996). *Auditive und visuelle Texte in Lernsoftware [Auditive and visual texts applied in software for learning].* Münster: Waxmann.

Pächter, M. (2003). *Wissenskommunikation, Kooperation und Lernen in virtuellen Gruppen [Knowledge communication, cooperation and learning in virtual groups].* Lengerich: Pabst.

Pata, K. (2005). *Scaffolding of collaborative decision-making on environmental dilemmas.* Turku: Painosalama Oy.

Piontkowski, U., Böing-Messing, E., Hartmann, J., Keil, W. & Laus, F. (2003). Transaktives Gedächtnis, Informationsintegration und Entscheidungsfindung im Medienvergleich [Transactive memory, integration of information and decision making with respect to different media]. *Zeitschrift für Medienpsychologie, 15,* 60-68.

Puntambekar, S. & Hübscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed. *Educational Psychologist, 40,* 1-12.

Reinmann-Rothmeier, G. & Mandl, H. (2001). Unterrichten und Lernumgebungen gestalten [Teaching and the design of learning environments]. In A. Krapp & B. Weidenmann (Eds.), *Pädagogische Psychologie (*pp. 601-646). Weinheim: Beltz.

Reiser, B. J. (2002). Why scaffolding should sometimes make tasks more difficult for learners. In G. Stahl (Ed.), *Computer Support for Collaborative Learning: Foundations For A CSCL Community* (pp. 255-264). Boulder, CO: Laurence Erlbaum Associates.

Reiserer, M. (2003). *Peer-Teaching in Videokonferenzen. Effekte niedrig- und hochstrukturierter Kooperationsskripte auf Lernprozess und Lernerfolg [Peer-teaching in videoconferencing. Effects of low- and high structured cooperation scripts on learning process and learning outcomes].* Berlin: Logos.

Renkl, A., Mandl, H. & Gruber, H. (1996). Inert knowledge: Analyses and remedies. *Educational Psychologist, 31,* 115-121.

Rosenshine, B. & Meister, C. (1994). Reciprocal teaching: A review of the research. *Review of Educational Research, 64,* 479-530.

Rummel, N. & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem-solving in computer-mediated settings. *Journal of the Learning Sciences, 14,* 201-241.

Salomon, G. (1984). Television Is "Easy" and Print Is "Tough": The Differential Investment of Mental Effort in Learning as a Function of Perceptions and Attributions. *Journal of Educational Psychology, 76,* 647-658.

Schnurer, K. (2005). *Kooperatives Lernen in virtuell-asynchronen Hochschulseminaren. Eine Prozess-Produkt-Analyse des virtuellen Seminars "Einführung in das Wissensmanagement" auf der Basis von Felddaten [Cooperative learning in virtual-asynchronous university courses. A process-product analysis of the virtual course "introduction to knowledge management" based on empirical data].* Berlin: Logos.

Shapiro, A. M. (2004). How including prior knowledge as a subject variable may change outcomes of learning research. *American Educational Research Journal, 41,* 159-189.

Suthers, D. D. & Hundhausen, C., D. (2003). An experimental study of the effects of representational guidance on collaborative learning processes. *The Journal of the Learning Sciences, 12,* 183-218.

Sweller, J., Van Merrienboër, J. J. G. & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10,* 251-296.

Weinberger, A. (2003). *Scripts for computer-supported collaborative learning. [Dissertation, Ludwig-Maximilian-University Munich].* Available:

http://edoc.ub.uni-muenchen.de/archive/00001120/01/Weinberger_Armin.pdf [October 27, 2005].

Weinberger, A., Ertl, B., Fischer, F. & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science, 33,* 1-30.

Zhang, J. & Norman, D. A. (1994). Representations in distributed cognitive tasks. *Cognitive Science, 18,* 87-122.