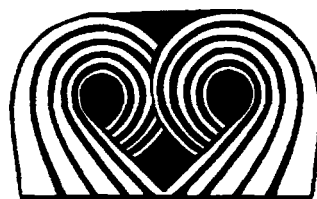# Research reports

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Facilitating collaborative knowledge construction in computer-mediated learning with structuring tools

February 2003

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Abstract

Collaborative knowledge construction in computer-mediated learning environments puts forward difficulties regarding what tasks learners work on and how learners interact with each other. For instance, learners who collaboratively construct knowledge in computer-mediated learning environments sometimes do not participate actively or engage in off-task talk. Computer-mediated learning environments can be endorsed with socio-cognitive structuring tools that structure the contents to be learned and suggest specific interactions for collaborative learners. In this article, two studies will be reported that applied content- and interaction-oriented structuring tools in computer-mediated learning environments based on electronic bulletin boards and videoconferencing technologies. In each study the factors "content-oriented structuring tool" and "interaction-oriented structuring tool" have been independently varied in a 2X2-factorial design. Results show that interaction-oriented structuring tools substantially foster the processes of collaborative knowledge construction as well as learning outcomes. The content-oriented structuring tools facilitate the processes of collaborative knowledge construction, but have no or negative effects on learning outcome. The findings will be discussed against the background of recent literature.

Keywords: Collaborative learning, structuring tools, scripted cooperation, computer-mediated communication, electronic bulletin boards, video-conferencing

Zusammenfassung

Gemeinsame Wissenskonstruktion in computervermittelten Lernumgebungen birgt Schwierigkeiten in Bezug darauf, welche Aufgaben Lernende bearbeiten und wie sie dabei miteinander interagieren. Lernende, die gemeinsam Wissen in computervermittelten Lernumgebungen konstruieren, nehmen z. B. manchmal nicht aktiv an der Bearbeitung von Lernaufgaben teil oder beschäftigen sich mit inhaltsfremden Themen. Computervermittelte Lernumgebungen können mit Hilfe sozio-kognitiver Strukturierungswerkzeuge unterstützt werden, die die Lerninhalte vorstrukturieren und den Lernenden spezifische Interaktionen nahe legen. In diesem Beitrag werden zwei Studien berichtet, die inhalts- und interaktionsbezogene Strukturierungswerkzeuge in computervermittelten Lernumgebungen, die auf web-basierten Diskussionsforen und Videokonferenz-Technologien beruhen, zum Einsatz gebracht und analysiert haben. In jeder der Studien wurden die Faktoren "inhaltsbezogenes Strukturierungswerkzeug" und "interaktionsbezogenes Strukturierungswerkzeug" unabhängig voneinander in einem 2X2-Design variiert. Die Ergebnisse zeigen, dass interaktionsbezogene Strukturierungswerkzeuge die Prozesse sowie die Ergebnisse gemeinsamer Wissenskonstruktion substanziell fördern können. Die inhaltsbezogenen Strukturierungswerkzeuge unterstützen die Prozesse gemeinsamer Wissenskonstruktion, zeitigen aber keine oder negative Effekte auf die Lernergebnisse. Die Befunde werden vor dem Hintergrund aktueller theoretischer Ansätze diskutiert.

Schlüsselwörter: Kooperatives Lernen, Strukturierungswerkzeuge, Kooperationsskripts, computervermittelte Kommunikation, web-basierte Diskussionsforen, Videokonferenzen

FACILITATING COLLABORATIVE KNOWLEDGE CONSTRUCTION IN COMPUTER-MEDIATED LEARNING WITH STRUCTURING TOOLS

Current approaches of learning and instruction emphasize the relevance of collaborative learning environments (cf. Gerstenmaier & Mandl, 1999; Greeno, Collins, & Resnick, 1996; Resnick, 1987). In these approaches collaborative learning is both, method and aim of instruction. Firstly, collaborative learning can facilitate knowledge building processes by requesting students to engage in beneficial learning activities when cooperatively solving a problem task or discussing and elaborating text material (cf. Slavin, 1995; Webb, 1989). Furthermore, working in small groups should prepare learners for life-long learning activities, which are largely embedded in social contexts. There is a broad understanding regarding these benefits of collaborative learning. Unfortunately, numerous studies show, that collaborative learning not always leads to the desired outcomes. Without assistance, learners often fail to engage in effective learning activities when collaboratively working in small groups. Dillenbourg (2002) distinguishes two different ways to facilitate collaborative learning. On one hand, teachers can indirectly influence the effectiveness of collaboration by arranging basic conditions like the group size, the group task or the communication media. On the other hand, direct approaches aim at directly influencing the interactions of group members by giving appropriate instructions. A possibility to directly affect collaborative learning activities is to give learners instructions by providing them with structuring tools (Roschelle & Pea, 1999). Structuring tools aim at facilitating processes of collaborative knowledge construction by guiding interaction with constraints and affordances of the learning environment, by suggesting a structure to learners' collaboration or by providing support regarding the learning contents. This kind of support has been studied extensively in face-to-face contexts. Yet, recently structuring tools have gained more and more importance for the design of computer-mediated learning environments. This contribution highlights central assumptions and empirical findings of this field of research in educational psychology. Moreover, we will describe two studies we recently conducted in order to analyze the effects of socio-cognitive structuring tools in different computer-mediated learning environments.

Fostering Collaborative Knowledge Construction by Socio-Cognitive Structuring Tools

The socio-cognitive perspective probably is the most influential theoretical framework in order to explain the benefits of collaborative learning environments (see Slavin, 1996; Webb, 1989). According to this framework, when working in small groups, learners construct knowledge by active participation in discussing and sharing knowledge with their learning partners. Cooperative learning aims at fostering processes of what we call collaborative knowledge construction (Fischer, Bruhn, Gräsel, & Mandl, 2002). Students actively engage in learning processes when jointly working on a learning task by mutually explaining the learning contents, giving feedback to contributions of their teammates asking and answering questions etc. However, particularly less experienced groups encounter difficulties when engaging in activities of collaborative knowledge construction. Numerous studies indicate that the desired effects often fail to emerge. For instance, not all group members participate in group discussions (Salomon & Globerson, 1989) or group discussion remains at a superficial level (Coleman, 1995; Linn & Burbules, 1993). Reasons for these deficits can result from individual prerequisites of the single learner but also from the unique character and formation of a group.

Interaction-oriented structuring tools

In order to overcome such deficits, socio-cognitive structuring tools can help learners to structure discourse according to successful patterns of knowledge construction. Successful interaction patterns usually involve meta-cognitive processes such as regulation and reflection on the subject matter. These structuring tools can be referred to as *interaction-oriented structuring tools*, which sequence and specify individual interactions. When using the term 'interaction-oriented structuring tools' we refer to different approaches that have been developed and investigated in educational-psychological research over the last twenty years. The most discussed models in this field presumably are reciprocal teaching (Brown & Palincsar, 1989; Palincsar & Brown, 1984), guided reciprocal peer teaching (King, 1999) and scripted cooperation (O'Donnell & Dansereau, 1992). These approaches provide a set of instruction, which aim to structure the interactions in groups in order to enhance the quality of learning. The instructions include the assignments of roles, which are associated with special learning tasks. In addition, the instructions prescribe a sequence of phases in which different learning activities should be applied by the learners (Kollar, Fischer, & Hesse, subm.).

The design of an interaction-oriented structuring tool profoundly depends on the underlying theoretical assumptions regarding the process of collaborative knowledge construction. For example, reciprocal teaching takes up text comprehension research, which stresses the relevance of cognitive and meta-cognitive processes for effectively learning from texts. Starting from this framework Palincsar and Brown (1984) provided learners with a structure for comprehending text material in small groups. The teacher models several activities in a specific sequence. The first step requires all students to read the beginning section of a text. Subsequently one learner takes the role of the teacher. The learner's task is to ask questions on the text that should be answered by another learner. Then, the student in the teacher role tries to summarize the main ideas of the text. If necessary the learning partner completes missing matters. Thereafter the 'teacher' identifies difficult passages of the text and tries to clear them up in collaboration with the learning partner. Finally, all learners try to predict the contents of the following text passages. The adopted strategies of questioning, summarizing, clarifying and predicting, tend to enhance learning by facilitating the learners to engage in effective processes of knowledge construction. Similar to reciprocal teaching, scripted cooperation aims at fostering learning of students who collaborate in dyads (O'Donnell & Dansereau, 1992). This cooperation script contains the activities of reiterating, providing feedback and elaborating. By collaboratively engaging in the tasks suggested by the script, learners should construct knowledge better than 'unscripted' groups when learning from texts or working on other learning tasks.

Content-oriented structuring tools

Other models of socio-cognitive tools provide structures not by referring to interaction of learners but by structuring the content to be learned. These *content-oriented structuring tools* also aim at facilitating processes of collaborative knowledge construction by assisting the learners to focus on the main topics and ideas when collaboratively discussing and constructing knowledge. A variety of content-oriented approaches can be distinguished, such as guided reciprocal peer teaching (King, 1999) or content schemes (Brooks & Dansereau, 1983). In guided reciprocal peer teaching, one of the learners is supposed to supervise the collaboration with the help of prompt cards. This learner possesses several prompt cards with clauses like "What inferences can be drawn from ...?" which the learners should complete in their discourse. In this way, reciprocal peer teaching is supposed to be guided by meaningful questions about the content. Content-oriented structuring tools often provide some kind of visualization, such as a diagram or a table that contain central, yet

abstract characteristics of the content discussed during their collaboration. Suthers and Hundhausen (2001) use the concept of *representational guidance*, in order to explain the effectiveness of content schemes. They assume that content-specific structuring methods facilitate collaborative knowledge construction by giving hints to learners concerning the material to be learned. Content schemes can support the group in structuring the contents to be discussed and can provide 'anchors' for each learner to integrate the new knowledge.

Fischer and colleagues (2002) present empirical findings indicating that content-oriented structuring tools can foster processes and outcomes of collaborative knowledge construction. Dyads which worked with a pre-structured visualization tool not only externalized and elicited more task-related knowledge, but also benefited with respect to the quality of a collaborative problem solution when compared with dyads of a control group that received a non-structured visualization tool. Suthers and Hundhausen (2001) compare different types of representations (textual, graphical, and matrix) learners had to work on during collaboration in order to facilitate their learning processes and outcomes. The results of their study indicate, that the type of representational tools can significantly affect the learners' collaborative knowledge construction.

Summing up, structuring tools constitute instructional approaches that aim at facilitating knowledge communication in collaborative learning environments. Despite this common goal, these structural aids can be designed in very different ways. As shown above, one group of structuring tools in particular tries to facilitate collaborative knowledge construction by giving instructions that aim at the interaction of learners. These interaction-oriented structuring tools can be based on various approaches, for instance scripted cooperation (O'Donnell & Dansereau, 1992). The interaction-oriented structuring tools investigated here, are based on scripted cooperation. Therefore, the interaction-oriented structuring tools will be referred to as *interaction-oriented cooperation scripts*. Another group of structuring tools tends to affect collaborative knowledge construction by pre-structuring the tasks of the learning content. This second kind of tools will be referred to as *content-oriented cooperation script* in the first study. The content-oriented structuring tool of the second study are based on content schemes (Brooks & Dansereau, 1983). Thus, we will refer to this variant of a content-oriented structuring tool as *content scheme* in the second study.

Socio-cognitive structuring tools have been developed for different learning tasks. Besides assisting students to collaboratively comprehend textual information, structuring tools can also facilitate problem-based learning, when students jointly work on learning cases. Concerning the mode of face-to-face collaboration there is a large body of empirical data that gives evidence for the

effectiveness of the use of structuring tools (e.g., Rosenshine & Meister, 1994). In contrast, research in the context of computer-mediated environments has not only had a short tradition, but also has faced theoretical shortcomings. The latter are associated with the variety of applications of communication technologies for the design of computer-mediated learning environments. In the context of computer-mediated learning, structuring tools can have quite different characteristics, e.g., depending on the communication mode (synchronous vs. asynchronous) they consider and the time periods (from one hour to a semester) they cover (Dillenbourg, 2002). When considering structuring tools in the context of computer-mediated learning, questions need to be raised more specifically: How are the instructions of the structuring tool presented and to what degree are the learners coerced to follow a structure given by the tool? Dillenbourg (2002) points out, that structuring tools may have a higher level of coercion compared to traditional instructions. For example, instructed cooperation scripts provide students oral or written instructions that they have to follow. This kind of cooperation script makes explicit the teacher's expectation regarding the desired interactions, but gives the students a high degree of freedom concerning the application of the induced strategies. Structuring tools, however, constrain and/or afford specific activities in order to facilitate knowledge construction in a more defined manner. Scripted cooperation in computer-mediated learning environments, for instance, may be realized with prompts displayed on the communication interface. Learners are supposed to respond to these prompts and thereby, engage in the intended activities (cf. King, 1999). In the following section we will describe structuring tools of this type in the context of text-based computer-mediated learning environments.

Empirical Studies on the Use of Structuring Tools in Computer-Mediated Learning Environments

Based on the outlined framework, we arranged and investigated different computer-based learning environments, which made use of interaction- and content-oriented structuring tools as described above. In these learning environments we applied two different communication technologies: (1) a text-based medium with the use of electronic bulletin boards and (2) videoconferencing which allowed synchronous communication. In both of the studies we focused on the question, to what extent content- and interaction-oriented structuring tools affect collaborative knowledge construction.

Study 1: The Use of Cooperation Scripts in Text-Based Communication

Text-based computer-mediated communication enables new collaborative knowledge construction scenarios. Locally distant learners may participate in asynchronous collaborative knowledge construction. The main idea of collaborative knowledge construction in text-based computer-mediated communication is, that learners engage in more active, reflective, and socially supported knowledge construction (Clark, Weinberger, Jucks, Spitulnik, & Wallace, in press; Scardamalia & Bereiter, 1994, 1996). There are indications, however, that collaborative knowledge construction in text-based scenarios may need additional support. The medium does not appear to be an efficient tool for complex learning tasks (Kiesler, 1992; Straus & McGrath, 1994). Text-based computer-mediated communication poses additional efforts for learners (e.g., navigating in an online environment, typing, spelling, waiting for an answer), which in turn reduce the learners' capacity for actual knowledge construction activities (see Fischer & Waibel, 2002; Hesse, Garsoffky, & Hron, 1997). First, these disadvantages of the medium could compromise the quality of collaborative knowledge construction with respect to *how theoretical concepts are being applied*. Learners may disregard important aspects of the learning material and try to make sense on grounds of their prior knowledge only, instead of applying theoretical concepts to the problem task (Hogan, Nastasi, & Pressley, 2000). Based on Vygotsky's (1978) model of collaborative knowledge construction as an internalization of social processes, the *application of theoretical concepts to the problem task* during the processes may have effects on how knowledge is acquired collaboratively. Second, these disadvantages may impair *how peers interact with each other*. For example, learners may try to quickly come to a possibly false consensus rather than engage in cognitive conflict, which has been regarded as a crucial indicator for the quality of collaborative knowledge construction (Doise, 1990). *Conflict orientation* can facilitate the development of new knowledge structures by suggesting alternative perspectives, focussing learners on the task, and receiving new information (Doise & Mugny, 1984). The main goals of the structuring tools in the text-based scenario used in this study are therefore, to facilitate the quality of collaborative knowledge construction with respect to the application of theoretical concepts and with respect to conflict-orientation of collaborative learners. Based on *scripted cooperation*, structuring tools can be implemented in text-based communication in order to directly affect the discourse of learners (Baker & Lund, 1997; Hesse et al., 1997; Scardamalia & Bereiter, 1996). In the first study, an *interaction-oriented* and a *content-oriented cooperation script* have been implemented in a text-based computer-mediated learning environment with the help of prompts that pre-structured the discourse of small

groups of three learners (Weinberger, Fischer, & Mandl, 2002; Weinberger, Fischer, & Mandl, in press). The research questions of study 1 are:

1. What are the effects of a content-oriented cooperation script, an interaction-oriented cooperation script, and their combination on the processes of collaborative knowledge construction regarding the application of theoretical concepts to problem cases and conflict orientation in a text-based communication scenario?

With respect to this first question of the study, the hypothetical assumption can be made, that the content-oriented cooperation script fosters the application of theoretical concepts to problem cases whereas the interaction-oriented cooperation script facilitates conflict orientation.

2. What are the effects of a content-oriented cooperation script, an interaction-oriented cooperation script, and their combination on the learning outcome of collaborative knowledge construction in a text-based communication scenario?

On the grounds of the theoretical framework on collaborative knowledge construction outlined above, both cooperation scripts should enhance learning outcome.

Sample and Design of Study 1

96 students in their first semester of Pedagogy from the University of Munich participated in this study. The students participated in an online learning session about Attribution Theory (Weiner, 1985), a standard part of the curriculum. Participation was required for receiving a course credit at the end of the semester, even though learning outcomes of the experimental session were not accounted for in students' overall performance. Students were invited individually – each student to one of three different laboratory rooms. Each group was randomly assigned to one of the four experimental conditions in a 2X2-factorial design. Learning partners did not know each other before the experimental session. We varied the factors "interaction-oriented cooperation script" (with vs. without) and "content-oriented cooperation script" (with vs. without).

Learning Environment of Study 1

Students in all conditions had to work together in applying theoretical concepts to three case problems that were presented online as a text, and jointly prepare an analysis for each case by communicating via web-based electronic bulletin boards (figure 1).
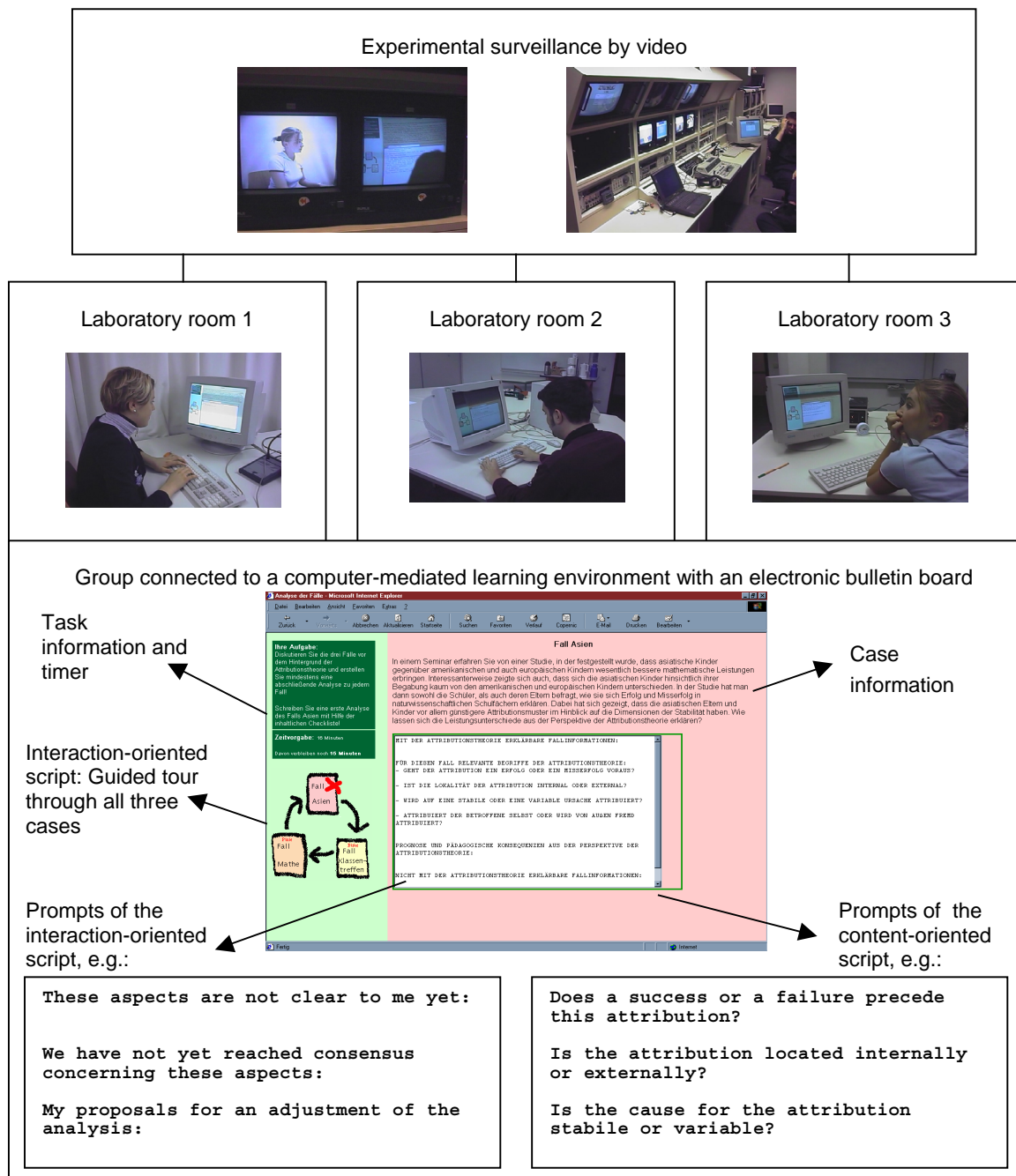
Figure 1: The experimental setup with video control center and a learning group of three participants in separate rooms (upper section of the figure) and the computer-mediated learning environment with an electronic bulletin board (lower section of the figure).

They were asked to discuss the three cases using the Attribution Theory and to jointly compose at least one final analysis for each case, i.e. they typically drafted initial analyses, discussed them, and wrote a final analysis. The cases portrayed typical attribution problems of university students, e.g., a student interpreting his failure in an important test:

"I have never liked text analysis – not even at school! And now? Because of this stupid course I failed a test for the first time ever! My girlfriend simply told me 'Never mind, after all it was 50 percent of the students who didn't pass.' But I just don't like text analysis. I am simply not talented for it at all. Well, I don't need to become a translator of literature. Interpreter or teacher of Spanish wouldn't be bad either, now would it? I really enjoy oral practice in contrast to text analysis, you know? I am really gifted at speaking Spanish – it was a piece of cake to learn that language."

All groups collaborated in three electronic bulletin boards – one for each case. The electronic bulletin boards provided a main page with an overview of all message headers. In this overview, answers to original messages appeared in outline form. The learners could read the full text of all messages, reply to the messages, or compose and post new messages. In the replies, the original messages were quoted out with ">" as in standard newsreaders and e-mail programs.

Interaction-Oriented Cooperation Script

The interaction-oriented cooperation script aimed to foster conflict-oriented interactions in order to avoid quick and false consensus. For this reason, each student in the interaction-oriented cooperation script condition was assigned two roles: (a) analyst for one of the cases and (b) constructive critic for the other two cases. Role (a) included taking over the responsibility for the preliminary and concluding analysis of one case and responding to criticism by the learning partners. In their role (b) as a constructive critic, the learners had to criticize the analyses of the two other cases presented by the learning partners. These activities were supported by the prompts of the interaction-oriented cooperation script (see figure 1), which were automatically inserted into the critics' messages and into the analyst's replies in order to help learners successfully take over their roles. Students were given a time limit for each of the required activities. All together, these activities lasted 80 minutes as in the groups without the cooperation script. The students were guided through all three cases and were asked to alternately play the role of the analyst and of the critic.

Content-Oriented Cooperation Script

The content-oriented cooperation script aimed at facilitating how the learners worked through the learning task. With the help of prompts, learners were suggested to apply theoretical concepts to problem cases. When composing a new message that represents the initial contribution to a discussion thread, content-specific prompts pre-structured the input window (see figure 1), i.e., the learner's message already contained prompts. These prompts were questions about the case and are aimed at supporting the learners with identifying the

relevant case information, applying the concepts of Weiner's Attribution Theory (1985) to case information, and making predictions and proposals for pedagogical interventions regarding the case. Thus, the students' task was basically to respond and jointly elaborate on the given prompts.

Procedure of Study 1

After a pre-test, the students were asked to individually study a three page description of the attribution theory. Then, the learners were briefly introduced to the respective prompts and/or the handling of the learning environment. After this individual phase, the learners worked together on three cases. The collaboration was followed by an individual post-test which paralleled the individual pre-test. Time-on-task was about 3 hours in all four conditions.

Dependent Variables, Instruments, and Data Sources of Study 1

In order to investigate the activities of the learners in the collaborative phase, the written discourse of the learners and their individual analyses have been analyzed with a multi-level category system (Weinberger, Fischer, & Mandl, 2001). With the help of this category system, the learners' discourse and their analyses have been segmented (87% interrater-agreement) and classified (κ = .90). The analysis aimed at how well the learners collaboratively applied theoretical concepts to problem cases, to what extent they engaged in conflict-oriented interactions, and learning outcome.

Application of theoretical concepts to problem cases. The task of the learner was to analyze and discuss problem cases. With respect to the application of theoretical concepts to problem cases, relations between theoretical concepts and case information have been analyzed. On the ground of expert solutions, correct and central relations between theoretical concepts and case information have been identified within the discourse of the learners. For instance in the above case example, the case information of a student who failed a test and said "I am simply not talented for it at all" needed to be explained by the subjects with the theoretical concepts of a stable and internal attribution according to Weiner's Attribution Theory (1985). A subject who analyzed the case information "No talent" as a stable, internal attribution applied theoretical concepts to the problem case.

Conflict orientation. Any response of the learners which declined or modified statements of the learning partners explicitly has been rated as conflict orientation. Thus, individual conflict-oriented segments are indicated by explicit rejections ("I think you are wrong in that"), replacements (A:" The attribution of the teacher is de-motivating."; B: "The attribution of the teacher is beneficial!"), modification (A: "The attribution of the parents is positive, because it liberates Michael of his feelings of guilt"; B: "It is positive in the sense, that the parents do

not put pressure on Michael, but basically accept him"), or endorsement (A: "The teacher motivates Michael by ascribing his bad performance to laziness"; B: "The teacher motivates Michael also by evaluating the attributions of his parents").

Learning outcome. Data regarding the learning outcome has been collected in a post-test, in which learners had to analyze cases individually. Similar to the application of theoretical concepts to problem cases as a process variable, the relations between theoretical concepts and case information in the learners' case analyses have been coded with respect to an expert solution. The sum of all correct relations between theoretical concepts and problem case, the learners had to construct in the individual post-test, is taken as indicator of the learning outcome (Cronbach's α = .55).

All measures will be reported with z-scores calculated over the whole sample for better comparability.

Results of Study 1

Application of theoretical concepts to problem cases. The discourse analysis shows, that the content-oriented cooperation script has produced a substantial effect with respect to the application of theoretical concepts to problem cases ($F(1,28) = 6.44$; $p < .05$). Neither a main effect of the interaction-oriented cooperation script ($F(1,28) = 0.63$; *n.s.*) nor an interaction effect of both cooperation scripts ($F(1,28) = 0.63$; *n.s.*) could be found.
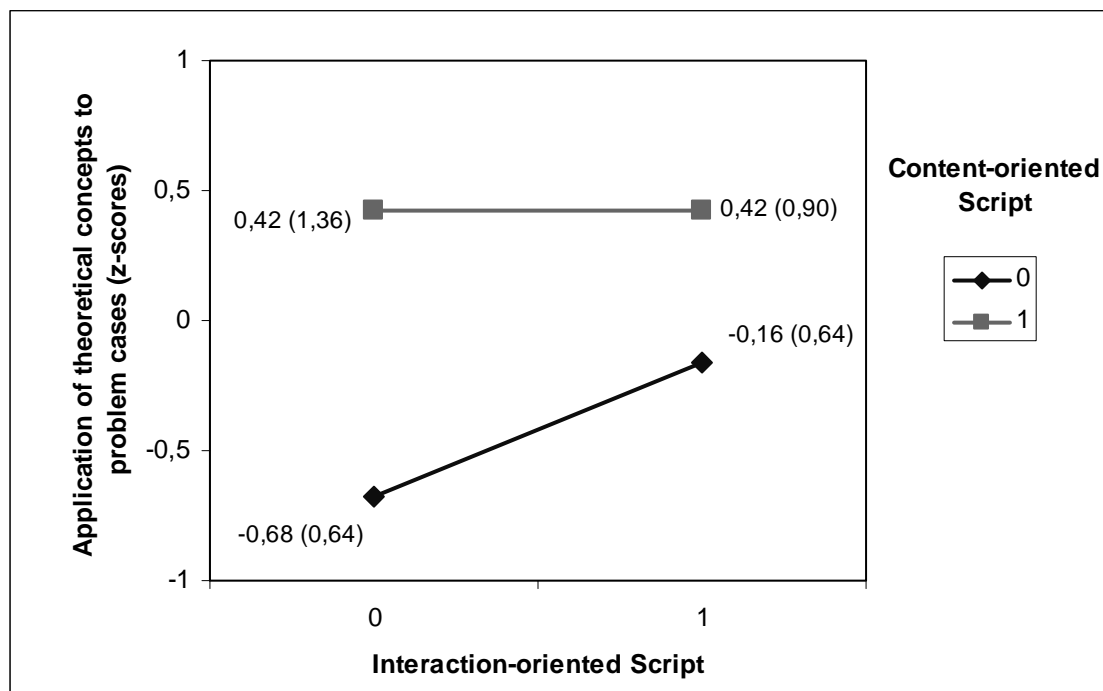

Figure 2: Application of theoretical concepts to problem cases in z-scores in study 1 (standard deviation in brackets).

As figure 2 shows, the content-oriented cooperation script could actually foster the processes of collaborative knowledge construction with respect to how learners applied theoretical concepts to problem cases.

Conflict orientation. Figure 3 shows a main effect of the interaction-oriented cooperation script ($F(1,28) = 4.10$; $p < .05$), but neither an effect of the content-oriented cooperation script ($F(1,28) = 0.15$; *n.s.*) nor an interaction effect of both cooperation scripts ($F(1,28) = 0.09$; *n.s.*).
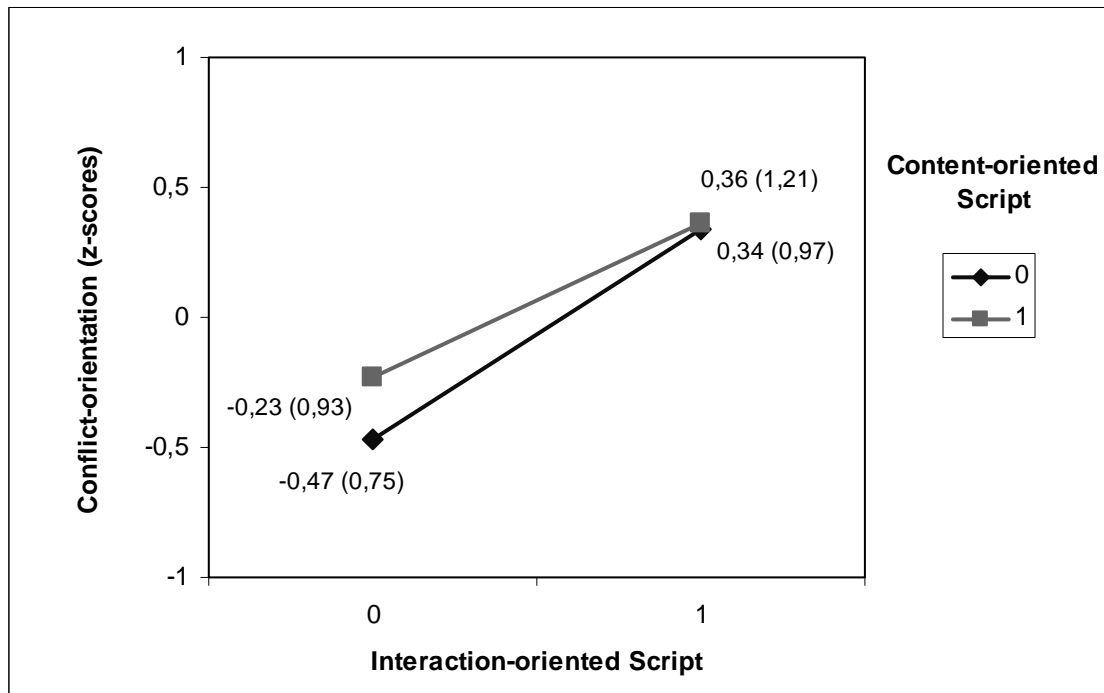

Figure 3: Conflict-orientation in z-scores in study 1 (standard deviations in brackets).

These results indicate, that the suggested interactions of the interaction-oriented cooperation script to critically resume the contributions of the learning partners took effect as intended.

Learning outcome. With respect to learning outcome two main effects of both cooperation scripts could be found (see figure 4): A negative effect of the content-oriented ($F(1,28) = 6.89$; $p < .05$) and a positive effect of the interaction-oriented cooperation script ($F(1,28) = 3.56$; $p < .05$). But no interaction effect ($F(1,28) = 1.32$; *n.s.*) could be found.

These results indicate, that learning outcome could be facilitated with the interaction-oriented cooperation script, whereas the content-oriented cooperation script impeded the learning outcome.
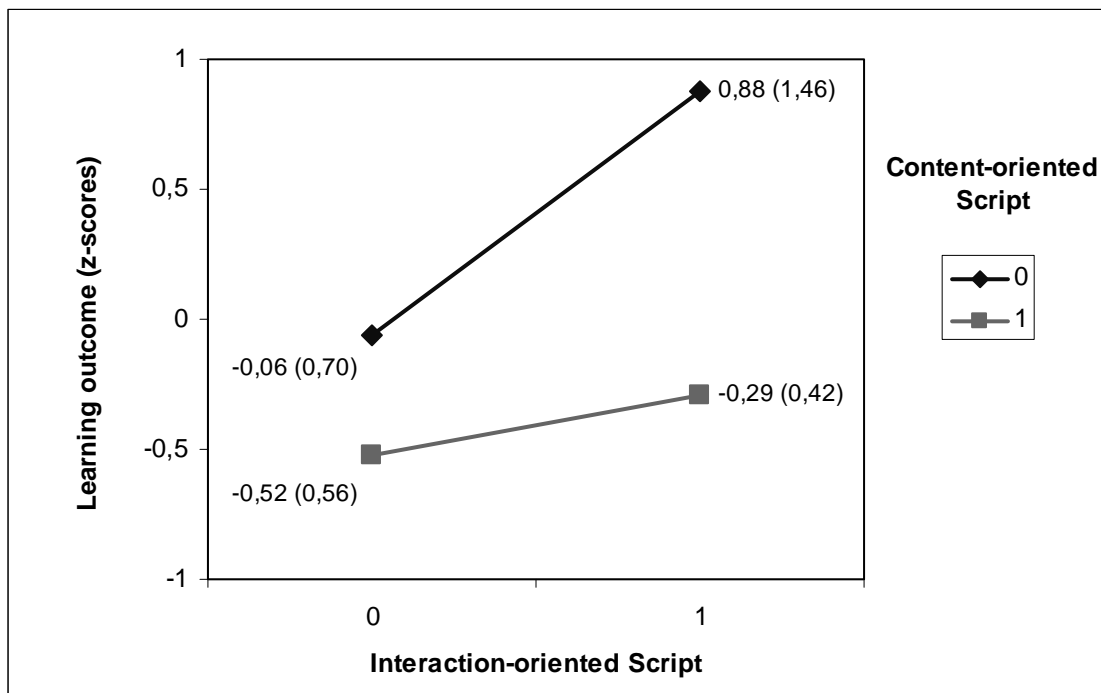
Figure 4: Learning outcome in z-scores in study 1 (standard deviations in brackets).

Discussion of Study 1

The findings show that important processes and outcomes of collaborative knowledge construction can be influenced not only by the preliminary training and moderation of collaborative learning, as studies to date have shown (O'Donnell, 1999; Scardamalia & Bereiter, 1996), but can also be influenced by structuring tools that implement scripted cooperation into a computer-mediated learning environment with the aid of prompts that structure the learning discourse itself.

The prompted interaction-oriented cooperation script proved to support the conflict-orientation of learners substantially. The learners appeared to be encouraged to confront their ideas with their partners' perspectives, reflect on the differences of perspectives, and sometimes modify their initial point of view. Moreover, the results show, that interaction-oriented cooperation scripts can facilitate learning outcome.

A prompted content-oriented cooperation script could support the application of theoretical concepts during the collaborative knowledge construction phase as expected, but was significantly detrimental to the learning outcome. This can be ascribed to several reasons: While the content-oriented cooperation script may have supported the participants in solving cases during the collaborative phase, it might not have fostered the *internalization* of concepts since important processes of learning failed to take place. The content-oriented cooperation

script may have limited processes of reflective thinking about the cases. Like a checklist, it may have facilitated the identification of sub-problems and application of theoretical concepts as long as the cooperation script was available to the learners, but did not support the subjects in developing their own conceptual understanding. An integral part of content-oriented cooperation scripts must then be the fading of this support as outlined by Collins, Brown, and Newmann (1989).

Study 2: Cooperation Scripts and Content Schemes in a Videoconferencing Environment

Videoconferencing enables synchronous forms of collaborative distance learning when frequent and complex interactions between learners are required. Despite these conveniences, videoconferencing so far does not play a prominent role for the design of computer-mediated learning environments. One reason therefore, of course, are the technical demands users have to face when using systems which need high transfer rates. Yet another reason can be seen in the lack of concepts for distance learning which are responsive to the advantages of videoconferencing. Therefore, in our first step we worked out a conceptual design for a learning environment based on videoconferencing. Results from earlier studies (Geyken, Mandl & Reiter, 1998) indicate, that videoconferencing in particular is suited for (peer-)tutoring respectively peer-teaching settings. These settings are characterized by situations in which a (peer-)tutor respectively peer-teacher directly interacts with the tutee or student when the latter face a learning problem and therefore need assistance. The tutors or teachers tasks are to give explanations, or feedback, when needed, but also to ask questions in order to help the partner to finish the learning task. Taking up these considerations, in study 2 we investigated a peer-teaching setting in which the learning partners collaborated via a videoconferencing system. We studied the effects of two treatments, which should facilitate peer-teaching activities: (1) a cooperation script in order to directly affect the learners' interactions and (2) a content structure which should assist learners to engage in relevant aspects of the learning contents. The second intervention will be called *content scheme*. The research questions of study 2 were:

1. How do a content scheme and a cooperation script influence processes of collaborative knowledge construction in a video-conferencing peer-teaching setting?

2. How do a content scheme and a cooperation script influence outcomes of collaborative knowledge construction in a video-conferencing peer-teaching setting?

Participants and Design of Study 2

86 students in their first semester of Pedagogy at the Ludwig-Maximilians-University of Munich took part in this experiment. Participation was required for receiving a course credit at the end of the semester, even though learning outcomes of the experimental session were not accounted for in the students' overall performance. Dyads were set up and randomly assigned to one of four conditions in a 2X2-factorial design. Learning partners did not know each other before the experimental session. The partners were seated in two different rooms where they stayed during the experiment. We varied the factors "cooperation script" (with vs. without) and "content scheme" (with vs. without).

Learning Environment and Procedure of Study 2

A desktop video-conferencing system including audio- and video-connection and a shared application to support the dyads' knowledge construction allowed synchronous verbal communication and joint creation of text material. The shared application was realized with Microsoft Netmeeting 3.01. As text editor we applied MS-Word 2000, an application that we expected to be well known among our participants and therefore easy to handle. This technical solution enabled the learners to alternately type or edit notes in the text-editor. Since we de-activated most of the advanced Word features, the participants were only able to create text material. The creation of tables or diagrams was not possible. The reason for this restriction was to focus the participants' activities on learning-relevant processes.

The experiment was conducted in one session that consisted of two main phases. During the individual text acquisition phase one learner of each dyad read a text which contained a description of the theory of genotype-environment-effects. In the following cooperative learning phase this person took the role of the tutor. Correspondingly the other learner took the role of the tutee during collaboration. The individual text acquisition lasted 25 minutes. An additional 10 minutes were given in order to provide the tutor an opportunity to prepare for the following cooperation. During the cooperation the tutor's task was to teach the individually learned contents to the learning partner. The cooperative phase lasted about 40 minutes.

The shared text editor was used to realize the different experimental conditions. In the condition with *content scheme*, the text document was structured in a way that it included several content-related guiding questions which were supposed to direct the dyads' discussion throughout this phase towards the contents. In the *cooperation script* condition, the text document included instructions about the explainer- and learner-role in order to effectively direct the learners' interaction. Dyads in the condition with both treatments (scheme + script)

worked with a text document that included the guiding questions as well as the instructions of the cooperation script. Participants in the control condition, worked with a text document that contained no further aids.

Content Scheme

The content scheme was implemented by a pre-structured shared text document that contained eight guiding questions. Table 1 shows the questions of the content scheme. The structure of the scheme was adopted from Brooks and Dansereau (1983) and adapted in accordance with the purposes of our study. As can be seen in Table 1, the content scheme was divided into four sections consisting each of two questions. The different sections stressed important aspects including concepts and main ideas of the theory, empirical findings, consequences and individual judgements regarding the theory. Participants were asked to generate answers to all questions and write them down in the text document. Both theory texts did not provide any information concerning the questions regarding the consequences and the individual judgement. By answering these questions, the participants were expected to draw conclusions that go beyond the scope of the texts.

Table 1: Questions included in the content scheme.

Theory	Empirical Findings
- What are the most important concepts of the theory? - What are the main ideas of the theory?	- How was the theory examined? - What were the results of the empirical studies?
Consequences	**Individual Judgement**
- Which pedagogical interventions can be concluded from the theory? - Which limits of pedagogical interventions can be concluded from the theory?	- What do I like/dislike about the theory? - Which of my own experiences support/do not support the theory?

Cooperation Script

Learners in these conditions also received a pre-structured text document. This text document included a short description of the explainer- and learner-role and directed the learners' interactions during the collaborative learning phase by defining four steps of interaction: (1) explaining the text material (explainer) and asking comprehension questions (learner), (2) typing the information received (learner) and supporting the learner (explainer), (3) generating own ideas concerning the theory (explainer and learner individually), and (4) discussing (explainer and learner) and writing down the results of the discussion (learner only, see Table 2). An observer, who stayed in one of the two rooms, supervised the correct application of the specified roles and controlled the time in which the different tasks were to be completed. After the discussion of the first theory had finished, the partners changed roles and repeated the same procedure, now discussing the second theory. Time-on-task for each theory was 40 minutes.

Dyads in the unscripted groups received no instructions regarding their interaction. According to the given time in the scripted groups, time-on-task for both theories was 80 minutes. The partners in the unscripted groups were able to decide how much time within this time period they wanted to spend discussing each theory. For example, if they took 50 minutes discussing the first theory they only had 30 minutes left for the second theory.

Table 2: Steps and learning activities included in the cooperation script.

	Explainer	**Learner**
Step 1 (approx. 10 min.)	Explaining the text material	Asking comprehension questions
Step 2 (approx. 15 min.)	Supporting the learner's activities	Explaining and typing the information received in the shared text document
Step 3 (approx. 5 min.)	Elaborating on text information individually	
Step 4 (approx. 10 min.)	Discussing generated ideas with the partner	Discussing generated ideas with the partner and writing the results in the shared text document

Dependent Variables, Instruments, and Data Sources of Study 2

Learning process. In order to get insights in the processes of the collaborative situation, we analyzed the written contributions the learners typed in the shared text editor during the collaborative learning phase. For this analysis we first segmented the shared text documents in propositions, each consisting of a meaningful statement related to the learning contents. In a second step each identified unit was assigned to one of the three following categories, which followed the design of the content scheme: (1) theory (units referring to the theory of genotype-environment-effects), (2) empirical findings (units referring to empirical evidence of the discussed theory and (3) elaborations (units regarding consequences and individual judgement).

Learning outcome. We measured the individual outcome of collaborative knowledge construction on the basis of a cued recall test which covered the main contents of the read theory text.

Results of Study 2

Figure 5 illustrates the results concerning the collaborative production of the shared text document. Our findings show a significant main effect of the cooperation script regarding the production of theory related propositions ($F(1,38) = 4.63$; $p < .05$), that is learners, supported with the cooperation script, constructed more propositions that were based on theory. In addition, a main effect of the content scheme indicated a lower quantity of propositions referring to theoretical concepts ($F(1,38) = 8.89$; $p < .01$). The differences concerning the category empirical findings were not significant. In contrast, results regarding elaborations showed clear effects in the expected direction. This means that dyads who worked with help of the content scheme produced significantly more written elaborations than the learners in the other conditions ($F(1,38) = 59.98$; $p < .01$).
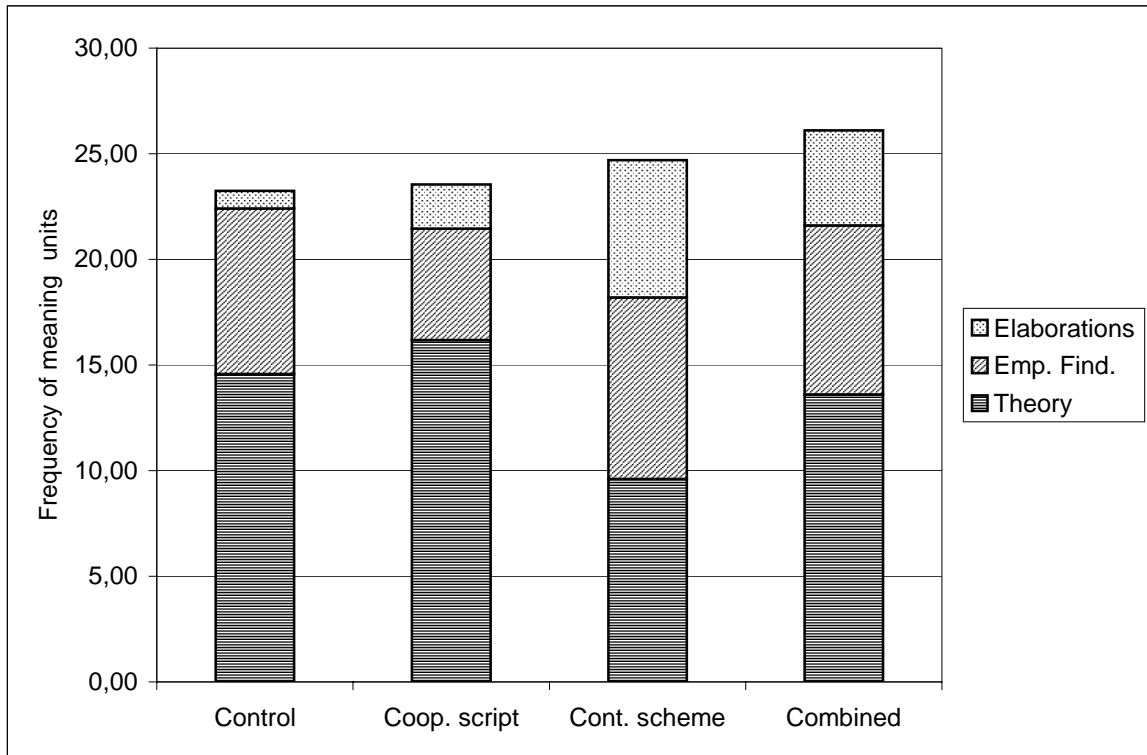
Figure 5: Distribution of propositions of external representation in the four experimental conditions in study 2.

Figure 6 shows the results concerning individual learning outcomes for all experimental conditions. Learners who collaborated in the scripted conditions tended to gain higher individual learning outcomes ($F(1,39) = 3.54$; $p < .10$).
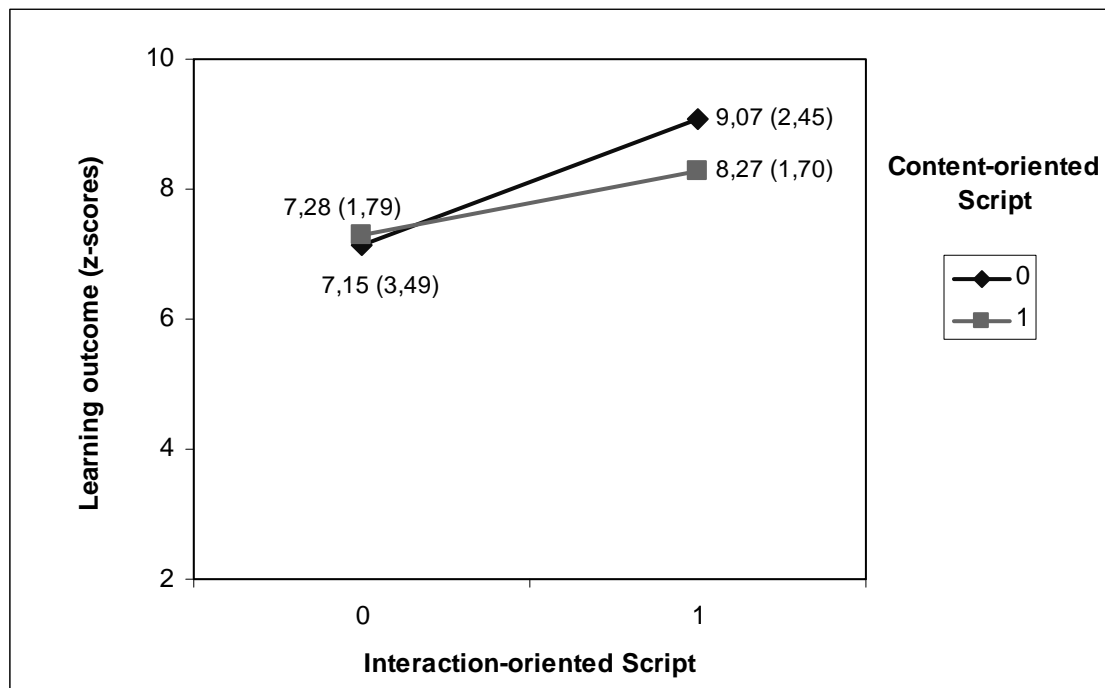

Figure 6: Individual learning outcomes in study 2 (standard deviations in brackets).

Discussion of Study 2

The results show clear effects of both treatments with regard to processes and outcomes of collaborative knowledge construction. As data sources for the process measures we analyzed the written texts the learners typed in the shared text document during collaboration. These learners generated external representations showing clear differences dependent on the experimental condition: Learners who worked with the cooperation scripts obviously focused more on theoretical concepts whereas dyads who worked with the help of the content scheme also took into consideration the other content fields as they were expatiated by the content scheme.

Hence, the effects of the content scheme correspond with the concept of "representational guidance" as described in section 2: the guiding questions of the scheme assisted the learners to consider not only theoretical concepts but also empirical findings and own judgements regarding the discussed theory. In correspondence to these findings the cooperation script also fostered the externalization of theoretical concepts.

Concerning the learning outcomes of collaborative knowledge construction the cooperation script showed the expected effects. Learners in the scripted conditions on the average gained higher test scores. These findings indicate the benefit of the developed script for fostering collaborative knowledge construction in videoconferencing. In contrast no outcome effects occurred concerning the factor content scheme.

One important question concerns the discrepancy of process and outcome effects of the content scheme. The answer might be the inadequate fit of the questions implemented in the scheme, on the one hand and the demands required to answer the knowledge test (i.e. the outcome measure) on the other. So, the content scheme was able to guide the learners to more frequently discuss empirical findings and to produce elaborations on the text material. However, to answer the knowledge test, the learners in particular were required to understand theoretical concepts. That means, the knowledge test did not require learners to apply knowledge that was acquired collaboratively with the help of the content scheme.

Final Discussion

The two studies reported in this article have conceived various structuring tools to facilitate collaborative knowledge construction in a computer-mediated setting. Rather than arranging the basic conditions (e.g., group size), these structuring tools aimed to support the processes of collaborative knowledge construction directly (cf. Dillenbourg, 2002). The advantages of structuring tools over condition-oriented approaches are plain to see. First of all, condition-oriented approaches may be more difficult to design. Condition-oriented approaches aim to facilitate the processes of collaborative knowledge construction indirectly. The rationale of this approach is, that when the basic conditions are set, the relevant processes of collaborative knowledge construction will emerge. However, the number of basic conditions relevant to collaborative knowledge construction may be high, and mutual dependencies between these conditions are complex (cf. Bruhn, 2000). For instance, the effects of incentive structures on collaborative knowledge construction depend on the complexity of the learning task, with the complexity of the learning task influencing what kind of processes are beneficial to knowledge construction and so on (cf. Cohen, 1994). Therefore, the arrangement of conditions that foster specific collaborative knowledge construction scenarios may be difficult. Second, condition-oriented approaches may be more costly. For instance, the prior knowledge and experience in collaboration has been identified as a central basic condition of collaborative knowledge construction and thus, has been subject to cooperation training (Rummel & Spada, this volume). Some of these training programs, however, take more time than the actual collaboration of learners (e.g., Hytecker, Dansereau, & Rocklin, 1988). These costs may make the application of condition-oriented approaches less likely and less practical in real world settings. Furthermore, some basic conditions of collaborative knowledge construction may not be arranged at all. Mandl, Gruber and Renkl (1996) note, that examination regulations typically disregard knowledge and competencies fostered by collaborative knowledge construction in particular. Typically, students rather need to memorize theoretical concepts in order to pass exams rather than to reflect and defend multiple perspectives on a complex subject matter. Therefore, to bring students together in a small group to work on a more or less complex learning task may not be sufficient to facilitate collaborative knowledge construction activities. Against this background, structuring tools may be more feasible, because they apply *during* the collaborative processes and because they can aim to facilitate *specific* activities and interactions of learners. Still little is known with respect to how socio-cognitive structuring tools may facilitate collaborative knowledge construction in computer-mediated learning environments. What kinds of

activities and interactions of learners should be fostered by structuring tools? What effects on processes and on outcomes do computer-based structuring tools have? How may structuring tools apply with different communication media? What learning tasks may be facilitated in what ways with structuring tools? In this contribution, we provided some answers to these questions by the development and investigation of different structuring tools. In two studies we investigated the effects of different structuring tools in computer-mediated learning environments. The researched learning environments differed not only concerning the communication media (e-mail vs. videoconference), but also in reference of the learning task (problem solving vs. text comprehension). Despite these differences the two studies had in common that they investigated similar treatments, which were adapted to the characteristics of the respective learning task: (1) an interaction-oriented structuring tool that aimed to facilitate *how* learners interacted with each other and a content-oriented tool that structured *what* learners discussed to handle the group task. Our results led to similar conclusions despite the mentioned differences of the two studies. The results of the two studies indicate, that structuring tools may facilitate processes and outcomes of collaborative knowledge construction. The findings indicate further, that in both scenarios the interaction-oriented structuring was able to enhance the processes and the outcomes of collaborative knowledge construction as was intended. The interactions of learners in computer-mediated learning environments can and have been improved. Furthermore, the support of specific interactions also improves learning outcome. Thus, interaction-oriented structuring tools may enable learners to actually exploit the aforementioned advantages of collaborative knowledge construction. In contrast, the content-oriented structuring tools of both studies did not show any positive outcome effect. In study 1 the content-oriented structuring tool actually hampered the learning outcome. Positive effects of the latter treatment only appeared on the level of collaborative processes. How can you explain this discrepancy of process and outcome effects of the content-oriented structuring tools? The answer might be the inadequate fit of the prompts respectively questions implemented in the content structure, on the one and the demands required to answer the knowledge test (i.e. the outcome measure) on the other hand. This interpretation in particular may be the case in the videoconferencing study. Another (related) interpretation is that the content-oriented structuring tools were not designed in an optimal manner in order to guide learners to the expected outcomes. Possibly, the individual prompts or schemes have disregarded the needs of novices, but were rather designed for more advanced learners. The content-oriented structuring tools provided an approved, correct structure of categories, which implied a specific model of the theoretical concepts, in which individual theoretical concepts could be collated. The

learners were able to use theoretical concepts adequately with the help of the structuring tools. However, the content-oriented structuring tools might have hampered the construction of a coherent *cognitive representation* of the theoretical concepts. In this way, the process-outcome-discrepancies might have occurred due to the lack of internalization of the models suggested by the content-oriented structuring tools. This explanation would clarify, why the learners could make use of the content-oriented structuring tools as long as these tools were available to the learners, but did not acquire knowledge individually. In this case, a fading of the structuring tool sensu Collins and colleagues (1989) could improve internalization processes. Based on these findings, computer-mediated learning environments for virtual seminars can be designed, where learners collaboratively construct knowledge over longer periods of time in which fading of the structuring tools would become particularly relevant. Content-oriented facilitation may be further improved. Instead of being provided with an approved, correct task strategy, learners could be prompted to construct a coherent model of the content themselves. In this line of thought, structuring tools sometimes may need to make learning more difficult (see Reiser, 2002). This appears to be particularly relevant in computer-based learning environments. Learners may apply cognitive resources in order to handle the computer-mediated environment instead of focussing on the learning task and constructing knowledge together. Computer-based structuring tools therefore need not to reduce the cognitive demands, but facilitate the actual participation in the collaborative construction of knowledge by keeping the learning task challenging.

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