Collaboration Scripts – A Conceptual Analysis

Ingo Kollar · Frank Fischer · Friedrich W. Hesse

Abstract This article presents a conceptual analysis of collaboration scripts used in face-to-face and computer-mediated collaborative learning. Collaboration scripts are scaffolds that aim to improve collaboration through structuring the interactive processes between two or more learning partners. Collaboration scripts consist of at least five components: (a) learning objectives, (b) type of activities, (c) sequencing, (d) role distribution, and (e) type of representation. These components serve as a basis for comparing prototypical collaboration script approaches for face-to-face vs. computer-mediated learning. As our analysis reveals, collaboration scripts for face-to-face learning often focus on supporting collaborators in engaging in activities that are specifically related to individual knowledge acquisition. Scripts for computer-mediated collaboration are typically concerned with facilitating communicative-coordinative processes that occur among group members. The two lines of research can be consolidated to facilitate the design of collaboration scripts, which both support participation and coordination, as well as induce learning activities closely related to individual knowledge acquisition and metacognition. In addition, research on collaboration scripts needs to consider the learners' internal collaboration scripts as a further determinant of collaboration behavior. The article closes with the presentation of a conceptual framework on script-based learning that incorporates both external and internal collaboration scripts.

Research on collaborative learning has repeatedly demonstrated that learners often do not collaborate well spontaneously (Cohen, 1994). For example, they tend not to participate equally (Cohen & Lotan, 1995), often engage only in low-level argumentation (Bell, 2004), and rarely converge on a comparable level of knowledge acquisition (Fischer, Bruhn, Gräsel,

I. Kollar (✉) · F. Fischer · F. W. Hesse
Knowledge Media Research Center,
Konrad-Adenauer-Strasse 40, 72072 Tübingen, Germany
e-mail: i.kollar@iwm-kmrc.de

& Mandl, 2002). There is a need for instructional support that guarantees a higher quality of both collaborative learning processes and individual learning outcomes. Such instructional support has been described and analyzed more systematically as scaffolding (e.g., Pea, 2004; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, & Soloway, 2004; Reiser, 2004; Sherin, Reiser, & Edelson, 2004; Tabak, 2004). Derived from the Vygotskyan concept of the Zone of Proximal Development (Vygotsky, 1992), scaffolding is seen as a way to support learners as they accomplish tasks that they would not be able to accomplish on their own (Wood, Bruner, & Ross, 1976). Originally addressing parent-child interactions, the term scaffolding has also been used to describe artifact-based instructional support (e.g., Quintana, et al., 2004). With respect to collaborative learning, at least two classes of scaffolds can be distinguished: (a) scaffolds that provide support on a content-related or conceptual level and (b) scaffolds that provide support related to the interactive processes between the collaborators. Scaffolds that provide learners with conceptual support relevant to the contents of a task include, for example, questions or prompts that guide learners in discussing a specific aspect of a physics problem such as "What is the relationship between force and motion?" or "If ball A hits ball B with the speed of X, what is the resulting speed of ball B?" Scaffolds that structure the interactive processes of collaborative learning shape collaboration by specifying different roles and associated activities to be carried out by the collaborators. For example, learners are asked to explain the contents of a text and to critique contributions of their learning partners at specific points in the learning process. Especially in research on computer-supported collaborative learning (CSCL), such scaffolds have been called collaboration scripts (e.g., Dillenbourg, 2002; Rummel & Spada, 2005; Weinberger, Ertl, Fischer, & Mandl, 2005). They describe an instance of socio-cognitive structuring (Ertl, Fischer, & Mandl, in press).

Collaboration scripts have been used to structure both face-to-face (e.g., O'Donnell & Dansereau, 1992; Palincsar & Brown, 1984) and computer-mediated collaboration (e.g., Dillenbourg, 2002; Rummel & Spada, 2005; Weinberger et al., 2005) and each specific lines of research have evolved. However, given the variety of existing collaboration script approaches, the term lacks conceptual precision. In this article, we analyze systematically previous research on collaboration scripts. We first work towards a definition of collaboration scripts by identifying central conceptual components that are shared among different approaches. We then take these conceptual components to compare prototypical collaboration script approaches used for either face-to-face or computer-mediated learning to detect commonalities, differences, and shortcomings of the two lines of research. Based on the identified deficits, we develop a conceptual framework that describes how collaborators and collaboration scripts interact during collaboration tasks. We believe that this framework can be used to inform both the design of collaboration script approaches and future theory building as well as trigger subsequent empirical research on collaboration scripts.

In sum, the article focuses on the following questions:

1. What are the central conceptual components of collaboration scripts?
2. Based on these components, what are the commonalities, differences, and shortcomings of collaboration scripts developed for face-to-face and computer-mediated learning?
3. What can be derived from this comparison with respect to design, theory building, and empirical research on collaboration scripts?

Central Conceptual Components of Collaboration Scripts

As a heuristic to answer research question 1 concerning the central conceptual components of collaboration scripts, we first examine the original meaning of the term script in cognitive psychology. Schank and Abelson (1977) used the term to refer to culturally shared knowledge about the world that provides information about conditions, processes, and consequences of particular everyday situations. In this perspective, scripts consist of a number of variables (or slots) for persons or objects playing prominent roles in such situations. A script provides individuals with knowledge about how these variables function within the course of action represented in the particular script. Furthermore, the script provides individuals with information about appropriate actions within the particular situation and helps them better understand the everyday situations they are involved in. This results in enhanced information processing and in a reduced need for coordination between the actors. Schank and Abelson (1977) explain the meaning of scripts by offering the "restaurant script" as an example. This script specifies that the guest enters the restaurant, signals the waiter, asks for the menu, chooses one item from it, waits for the meal to be brought to his table, etc. Once this script is activated, one is able to understand short information sequences like "Martin went to a restaurant and ate a beef steak." By possessing an adequate, culturally shared script and knowing its implications, a recipient has the knowledge necessary to fill in any gaps in the information sequence. In the case of the restaurant script, the recipient is, therefore, able to conclude that Martin entered the restaurant, signaled the waiter to have a look at the menu, chose one menu item, namely the beef steak, ordered it, waited until it was prepared, etc.

Cognitive psychology typically views scripts as highly specific memory structures that remain relatively fixed in situations in which the script is activated. This is especially true for approaches, which aim at developing computational models of cognitive systems that work in accordance with a prespecified script. For such models to function properly, the individual steps and activities of the script must be well-defined and comprise detailed rules (see Schank, 1999). For example, in the restaurant script, first taking a seat and then choosing a meal from a menu are activities that are constitutive for the activity "going to a restaurant" and are only alterable under exceptional circumstances (e.g., when all tables are occupied and guests have to wait at the bar). In contrast, collaboration scripts can vary in the degrees of freedom they attribute to learners to structure their collaboration. In a rather open version, they can provide a frame of reference in the form of a scenario (e.g., giving the global instruction to critique each other's contribution) without giving further instruction on what form the process of critiquing should assume. Learners are then relatively free to choose and perform appropriate activities (for example, re-read a text, ask thought-provoking questions, provide counterevidence, etc.). In scenarios using more restrictive collaboration scripts, learners are severely constrained in the specific activities they can choose from and how to perform them (e.g., a computer interface that demands a specific on-screen action be performed by a participant before displaying the next screen).

Although the usage of the script term diverges between cognitive psychology and educational psychology, at least five similarities can be detected, which might help derive a preliminary definition of what collaboration scripts are. First, both scripts used in cognitive psychology (which are viewed as individual cognitive structures) and in educational psychology (which are known as collaboration scripts) pursue specific *objectives*. According to Schank and Abelson (1977), scripts enhance both understanding and recall (on an individual level; e.g., Nuthall, 2000) and promote the coordination of activities in a particular situation (on a group level). Similarly, collaboration scripts are goal-oriented in the sense that specific approaches help learners engage in smooth collaboration processes and reach specific (learning) objectives.

Second, both cognitive scripts and collaboration scripts engage individuals in specific *activities*. In the restaurant script, these activities include entering the restaurant, waiting to be seated, following the waiter to a table, etc. In collaboration script approaches, such activities might be summarizing, questioning or explaining. The specificity of the script instructions can range from merely naming the activities learners are supposed to perform (e.g., "give an argument") to the specification of individual substeps of the activity (e.g., "give evidence," "state a claim," "give a reason" as substeps of developing an argument; see Kollar, Fischer, & Slotta, 2005). Each of the imposed (sub-)activities can also be presented in a more or less structured way. Although some scripts provide learners with a lot of freedom as to how to perform a specific activity, others do not. Activities should, however, be in accordance with the pre-defined objective of the script, regardless of whether they are broken down into scripted substeps or whether there are constraints on how the activities can be performed.

Third, *sequencing* plays an analogous role in scripts from the perspectives of cognitive and educational psychology. In both cases, the sequence in the script not only specifies which activities learners should perform, but also when they should perform them. In the restaurant script, the script provides actors with sequential knowledge about first entering the restaurant, then waiting to be seated (in the U.S. – but not in Europe), following the waiter to a table, and so on. Collaboration scripts also specify or imply which activities collaborators should perform and in what order, for example, first reading a text and then summarizing it (see O'Donnell & Dansereau, 1992).

Fourth, cognitive scripts and collaboration scripts specify and *distribute roles* among the participating individuals. The restaurant script specifies that the waiter brings the menu and the guest chooses a meal from it. Similarly, collaboration scripts distribute roles among the collaborating partners, for example, an explainer and a commentator role. Distributing collaboration roles helps support the collaborating partners in approaching the task from multiple perspectives. This, in turn, helps learners consider problems from various viewpoints (Spiro, Feltovich, Jacobson, & Coulson, 1991) and reduces the danger of acquiring inert knowledge (Renkl, Mandl, & Gruber, 1996). In both cognitive and collaboration scripts, role distribution, however, is not always made explicit. Sometimes, the activities that one participant is supposed to conduct define his or her role without explicitly naming this role. For example, playing a commentator role is automatically implied by having learners critique other learners' contributions.

Fifth, scripts can vary in the *type of representation* through which specific instructions are presented to the learners. Cognitive scripts are internal (mental) representations about courses of action in particular situations. Collaboration scripts are at least at the beginning external representations that are presented textually (e.g., King, 1998), as graphical representations (Pfister, & Mühlpfordt, 2002), or orally (e.g., Palincsar & Brown, 1984). There is evidence that different representations have differential effects on learning, which may, in turn, interact with learner characteristics (e.g., Mayer, 2001; Plass, Chun, Mayer, & Leutner, 1998).

In summary, a comparison between cognitive scripts and collaboration scripts reveals several parallels that can help define what collaboration scripts are. We identified five components as being pivotal for answering the first research question: "What are central conceptual components of collaboration scripts?" These components are (1) learning objectives, (2) type of learning activities, (3) sequencing of activities, (4) role distribution mechanisms, and (5) type of representation (see Table 1). As a working definition, a collaboration script can now be described as an instructional means that provides collaborators with instructions for

Table 1 Central conceptual components of collaboration scripts

Central conceptual components of collaboration scripts
Learnig objectives
Type of activities
Sequencing features
Role distribution
Type of representation

task-related interactions, that can be represented in different ways, and that can be directed at specific learning objectives. These objectives can be reached by inducing different kinds and sequences of activities, which are implicitly or explicitly clustered to collaboration roles. Scripted activities can be broken down into individual acts that together form a larger activity, and scripts can vary with respect to how much structure they provide.

Having defined the term collaboration script, we next apply these five conceptual components to review existing collaboration script approaches for face-to-face vs. computer-mediated learning (research question 2). By comparing approaches from these two lines of research, we aim to identify areas of convergence and divergence and thus pinpoint areas in which both lines of research can fruitfully inform the other concerning the appropriate design of collaboration scripts and theory building. We further identify research deficits that can be found in both lines of research to possibly inform future empirical research in the field.

Collaboration Scripts for Face-to-face Learning

Over the last twenty years, research has documented numerous ways to improve collaborative learning both in face-to-face and computer-mediated settings. In the following section, we present four prototypical collaboration scripts that have been developed for face-to-face learning. All the approaches are empirically based or have triggered substantial research. They are germane to different group sizes – from dyads to whole classes. The approaches under consideration are Scripted Cooperation (e.g., O'Donnell & Dansereau, 1992), ASK to THINK – TEL WHY®© (e.g., King, 1997), Structured Academic Controversy (Johnson & Johnson, 1994), and Reciprocal Teaching (Palincsar & Brown, 1984). All approaches are at first described and then analyzed with respect to the five conceptual components that are represented in Table 1. After the description and analysis of the single approaches, common features in collaboration script design for face-to-face learning are discussed.

Scripted Cooperation

This approach was developed by Angela O'Donnell and Donald Dansereau and their colleagues and triggered a large research agenda (for an overview, see O'Donnell, 1999). Several variants of Scripted Cooperation were subsequently developed and empirically tested (e.g., Larson, Dansereau, O'Donnell, Hythecker, Lambiotte, & Rocklin, 1985; O'Donnell, Dansereau, Hall, & Rocklin, 1987; Rewey, Dansereau, Dees, Skaggs, & Pitre, 1992). The original MURDER script (the acronym stands for "mood," "understand," "recall," "detect," "elaborate," "review" and describes its sequence) involves the interaction between two partners learning from a text. First, the experimenter or the learners themselves split the text up into paragraphs. Then, each learner reads the first passage individually. After that, the partners put the text aside and engage in different roles: One plays the recaller, whose task is to recall the text information as completely as possible. The other partner plays the listener and tries to detect and correct misconceptions and identify omissions. After that, the partners elaborate jointly on ways to make the text content more memorable. They can accomplish this by connecting the information with their own prior knowledge, for example, by drawing comparisons or links to other topics. Once the dyad has worked through the first text passage in this manner, the next segment is read and roles are switched. The script instructions can be presented to the learners in different ways. Lambiotte et al. (1987) provided the instructions in textual format after each text paragraph. Larson et al. (1984) did not provide learners with textual instruction during collaboration, but instead trained learners on the correct application of the script instructions prior to the actual collaborative learning phase. Hythecker, Dansereau, and Rocklin (1988) state that the usual training time is about one hour.

When analyzing Scripted Cooperation on the basis of the five conceptual components represented in Table 1, we come to the following conclusions: The *objectives* of the MURDER script are twofold. First, learners are supposed to acquire knowledge about text content. Second, they are supposed to acquire text-learning strategies. These strategies include cognitive strategies, such as explaining, and metacognitive strategies, such as monitoring. In accordance with these objectives, Scripted Cooperation increases learners' engagement in cognitive and metacognitive *activities*. As an example of cognitive activities, learners are supposed to engage in explaining. As an example of metacognitive activities, the collaboration script requires learners to engage in monitoring. To ensure that learners perform these activities effectively, they are often supposed to practice them first during a training phase. *Sequencing* of the activities is regulated by the different phases introduced in the MURDER script. First, both partners have to read a text passage. Next, learner A summarizes the text and learner B tries to detect and correct misconceptions and identify omissions. Then, the learning partners elaborate on the text content to make it more memorable. Finally, they read the next paragraph. This sequence is fixed and cannot be changed by the learners. The script also specifies and distributes *collaboration roles*. After having read a text passage, one learner has to play the recaller, while the other plays the listener. These roles are switched several times during the learning process. The *type of representation* of the MURDER script varies between empirical studies. In some instances, the instructions are presented and internalized before the actual collaboration phase, so that the collaboration is guided by the learners' mental representations of the MURDER script. In other studies, the instructions are written on the same sheets of paper that contain the text the learners are reading.

ASK to THINK – TEL WHY®©

Alison King worked extensively on methods for scaffolding collaboration, with a focus on supporting peer questioning. She developed a peer-tutoring approach for classrooms to support knowledge construction in dyads or in larger groups of learners (King, 1997, 1998, 2002). The ASK to THINK - TEL WHY model distributes structured reciprocal tutoring roles (questioner vs. explainer) among the learners and attaches specific activities to these roles. These activities are initially introduced by the teacher, who models them in class before the learners apply them in their subsequent collaboration (the training time is about 160 min spread over four school lessons; King, 1997). There are three main groups of activities: (a) specific question types that the learner in the questioner role asks during collaboration (review questions, thinking questions, probing questions, hint questions, and self-monitoring questions); (b) elaborative explanations that the learner in the explainer role creates in reacting to those questions (including answering the "why" and "how" of the question, as well as establishing links to one's own prior knowledge – and to that of the partner – rather than merely describing objects); and (c) communicative skills, such as listening attentively, providing sufficient thinking time, giving evaluative feedback, etc. After reading a text or listening to a class presentation, learners individually create and write down two review questions and two thinking questions. After that, the learning partners determine who plays the questioner and who plays the explainer first. The questioner then asks one review question (e.g., "What does... mean?") to activate the explainer's knowledge about the topic at hand. If the explainer fails to answer the question, the questioner then asks probing questions (e.g., "Tell me more about...") or hint questions (e.g., "Have you thought about...?"). If the review question is answered correctly, the questioner proceeds by asking thinking questions (e.g., "What do you think would happen to... if... happened?"). When appropriate, the questioner asks self-monitoring questions (metacognitive questions) that help the explainer make his or her learning process explicit and monitor it effectively. Throughout this process, learners are supposed to follow the communication rules mentioned above (giving appropriate thinking time, etc.). Learners are equipped with prompt cards that remind them to follow the sequence of question types. These prompt cards contain question starters for each question type and descriptions of what elaborated explanations are and what communication rules to apply during collaboration. After one complete cycle, the questioner and explainer roles are switched.

Taking the five conceptual script components represented in Table 1, ASK to THINK – TEL WHY®© can be analyzed as follows: The *objectives* of the ASK to THINK – TEL WHY approach are to support learners in their acquisition and comprehension of information presented in texts or oral presentations, as well as in developing the skills necessary to process the content. This includes cognitive skills related to asking questions, metacognitive skills related to monitoring, and communication skills related to giving enough thinking time. Accordingly, the *activities* can be grouped into cognitive, metacognitive, and communicative activities. In addition, these activities are explicitly *sequenced*: The learner in the questioner role asks certain question types in a pre-specified order. The script further prescribes an explicit distribution of *collaboration roles*. It specifies that one of the collaborators plays the questioner while the other plays the explainer. A role switch is also included. With respect to the *type of representation*, the model relies on (a) the teacher orally modeling the instructions (i.e., auditive representation) and (b) the prompt cards containing written reminders of the activity type (i.e., written representation).

Structured Academic Controversy

This method, developed by Johnson and Johnson (1994), involves groups consisting of four learners. Within these groups, dyads are created and assigned to opposing positions on a specific topic. The learning material is distributed between the two pairs and the dyads are instructed to make any information in their own material available to the other dyad when it might support their position. Pairs then develop their position and present their arguments to the other dyad. During this presentation, learners exchange thoughts and information, possibly create counterarguments to the other dyad's arguments and discuss the rationale of their group's approach. In this step, the discussion can be led relatively freely. However, the teacher encourages learners to abide by certain rules of constructive controversy, which they are introduced to before collaboration. The listeners are instructed to listen to the arguments as carefully as possible because they will later have the task of supporting their counterdyad's position. In the next step, a role switch indicates that the two dyads must adopt and present the position they have just tried to rebut. After that, the positions are dropped and all four learners are instructed to seek a synthesis of their discussion by writing a joint position statement. This position is to be presented to the class later on. Johnson and Johnson (1994) emphasize that training on social and interpersonal skills should precede the controversy, including “confirming others’ competence while disagreeing with their positions and challenging their reasoning (being critical of ideas, not people)” or “first bringing out all the ideas and facts supporting both sides (differentiating the differences between positions) and then trying to put them together in a way that makes sense (integration of ideas)” (p. 80). The teacher presents these instructions prior to collaboration and the learners practice them. The instructions also appear on the learners’ instructional sheets that they have at their disposal during collaboration.

On the basis of the five conceptual script components from Table 1, this approach can be analyzed as follows: Structured Academic Controversy aims at two kinds of *objectives*, namely to support learners in the acquisition of knowledge about the topic at hand and about debating skills. Therefore, the script induces relevant cognitive and metacognitive learning *activities*. Cognitive activities include generating arguments, explaining arguments, and generating counterarguments. Metacognitive activities include taking the opposing perspective or paraphrasing what someone said if it is not clear. Structured Academic Controversy further prescribes *sequences* of the induced learning activities. Learners are informed about the different collaboration phases: the development and presentation of a position, discussing the presentation, reacting to counterarguments on that position, adopting the other dyad’s position, and finding a synthesis. Within the individual steps, learners are free in how they choose to carry out these activities because no further support is provided on how to create arguments or how to rebut a position. The approach further distributes *collaboration roles* among the learners and gives instructions on what to do when adopting these roles. The script has one dyad present its position while the other dyad listens. Similarly, roles are distributed in subsequent phases. The script also specifies a role switch. Apart from naming the induced activities associated with these roles, there is no further support specifying how to act in these roles. The script’s *type of representation* includes an auditive representation of the teacher’s oral presentation of the strategies prior to collaboration and textual reminders on the instructional materials that provide rough guidelines rather than specific steps and substeps.

Reciprocal Teaching

This approach, developed by Palincsar and Brown (1984), was designed to support reading comprehension in beginning readers and children with poor reading comprehension abilities. At the core of this approach are four reading strategies that the teacher introduces to the class. These strategies are questioning, clarifying, summarizing, and predicting. After the teacher has modeled the correct application of the strategies, learners are divided into small groups of variable size. They then work to apply the strategies when reading new text passages, thereby rotating the teacher role among them. The adult teacher then takes on a coaching role and, in the ideal case, eventually abandons the teaching role so that the learners can take it over. The four strategies form a broad frame in which discussion about the text takes place: At first, the student in the teacher role asks questions concerning the content of the text. Next, the group discusses these questions and formulates further questions before the student in the teacher role summarizes the most essential parts of the text passage. If someone does not agree with that summary, all learners reread the passage and discuss the emerging summaries until they have agreed upon one variant. After that, learners make predictions about the next text passage. The duration of the intervention can span several weeks.

Considering the five conceptual components in Table 1, Reciprocal Teaching exhibits two kinds of *objectives*: From a cognitive perspective, learners are supposed to be supported in comprehending text content. From a metacognitive perspective, they are supposed to acquire comprehension-monitoring skills. Consequently, the induced learning *activities* are part cognitive and part metacognitive. Cognitive learning activities include questioning and clarifying; metacognitive activities include summarizing and predicting. Learning the correct application of these activities is an iterative process guided by the adult teacher, who is supposed to assume a coaching function rather than give detailed instructions on how the activities should be conducted. The activities are further performed in a specific *sequence*: First, the student in the teacher role asks questions about the text, which are then clarified by the group. After that, learners generate a summary. At the end of a cycle, they make predictions about how the text continues. In addition, the task of leading the discussion rotates among the learners. *Collaboration roles* are also distributed. At any time during collaboration, one learner plays the role of the discussion leader, while his or her co-learners stay in their natural student role. A role switch prescribes that each learner is supposed to play the discussion leader at least once. With regard to the *type of representation*, it appears that the script instructions are not always externally represented during collaboration. Before collaboration, the teacher presents the learning activities and their sequence orally via modeling and can re-introduce them whenever appropriate during collaboration. However, as long as the learners apply the script appropriately, the teacher does not interfere and re-introduce the script instructions again.

Comparing Collaboration Scripts for Face-to-face Learning

Although the selected approaches cover a variety of tasks, learning settings, and group sizes, they do exhibit certain commonalities that are summarized in this section. The presented approaches typically target two classes of *objectives*: cognitive objectives and metacognitive objectives. With respect to cognitive learning objectives, all approaches support learners in gaining knowledge about the text or task, as well as in acquiring elaborative learning strategies, such as questioning or explaining. The presented approaches also focus on promoting the acquisition of metacognitive skills like monitoring, which can be considered a higher-learning strategy (Rosenshine & Meister, 1994). Empirical research indicates that these interventions have helped learners achieve their particular learning objectives (e.g., Johnson & Johnson, 1994; King, 1998; O'Donnell, 1999; Palincsar & Brown, 1984).

The presented approaches aim to promote different learning *activities*: For example, the MURDER script has learners engage in activities such as summarizing or monitoring, whereas Johnson and Johnson's (1994) approach is more directed towards arguing and debating. From a more abstract perspective, the learning activities can be labeled as cognitive and/or metacognitive activities. However, there are differences with respect to how specific the instructions concerning these activities are. For example, the ASK to THINK – TEL WHY®© approach structures the activities on a rather detailed level by requiring learners to complete question prompts. Reciprocal Teaching gives rather general directives on how to engage successfully in clarifying, questioning, summarizing, and predicting. The activities induced in Structured Academic Controversy are rather implied than explicitly stated. By focusing on promoting learners to engage in elaborative and metacognitive activities, collaboration scripts for face-to-face learning tend to adopt an individual learner perspective: They are primarily concerned with augmenting the learning outcomes of all individual learners through their participation in the collaborative learning experience. In other words, collaboration is primarily seen as a means to support individuals in their acquisition of knowledge. Group-building and group-supporting processes, such as communicating or coordinating, which also are of importance in collaborative learning, are not the primary focus of this perspective. However, such group processes are touched upon in ASK to THINK – TEL WHY®©, Structured Academic Controversy, and Reciprocal Teaching, for example, by demanding that learners provide each other with enough thinking time.

With respect to their *sequencing* procedures, the four approaches are highly specific. In Scripted Cooperation and ASK to THINK – TEL WHY®©, learners are provided with specific directives concerning when to engage in which learning activity. To a lesser extent, this is also true for Reciprocal Teaching and for Structured Academic Controversy. Reciprocal Teaching sequences the four learning strategies that the whole class is supposed to employ and Structured Academic Controversy puts four collaboration phases in a fixed order. However, the concrete activities that learners are allowed to demonstrate in these phases are less strictly prescribed than in Scripted Cooperation and ASK to THINK – TEL WHY®©.

In terms of *role distribution*, there are fewer observable differences between the four approaches. They all regulate explicitly what roles are distributed between the learning partners. Moreover, all approaches include an explicit role switch to have each learner experience the benefits of each collaboration role and the associated learning activities. Reciprocal Teaching is the approach which gives learners the most freedom of choice regarding which role they want to assume. The learners themselves decide whether they want to adopt the teacher's role. In the other approaches, there is less opportunity for the learners to control their involvement in one or another role because the scripts provide explicit regulations specifying that each learner must engage in each of the corresponding roles.

Regarding the *type of representation* of the presented collaboration scripts, it is common for the specific instructions to be presented orally by a teacher or an experimenter and practiced by the learners before collaboration. These trainings can take up to several hours, as is the case in Scripted Cooperation or Reciprocal Teaching. During the actual collaboration phase, collaboration scripts are either represented as written notes on a sheet of paper (e.g., prompt cards in ASK to THINK – TEL WHY®©), or are re-presented by the teacher repeating them occasionally (e.g., Reciprocal Teaching), or are not externally represented at all (once learners have adequately internalized them during preceding training sessions and during the course of collaboration).

Now as we have used the five conceptual components from Table 1 to analyze prototypical collaboration script approaches for face-to-face learning, we try to draw some more general conclusions on this line of research. As we have seen, collaboration scripts developed for face-to-face learning tend to focus on encouraging learners to engage in effective collaboration on an individual, cognitive-elaborative level. Learners are supposed to conduct higher-order activities, such as generating elaborated explanations and asking thoughtful questions, for which they often receive highly specific support. Studies by Webb (1989) have shown that generating such explanations can improve knowledge acquisition. The act of questioning leads to a check of the learner's current understanding and ensures better learning of the text (Graesser & Person, 1994). Because collaboration scripts for face-to-face learning aim to foster such high-level (cognitive and metacognitive) learning (King, 1997), the merit of this research tradition lies in its ability to provide insights into the instructional design of what might be termed the *learning enhancers* of collaborative learning: Features that increase the learning success of individual learners engaging in collaborative learning to levels they would not be able to reach without instructional support.

Further we have seen that collaboration scripts for face-to-face learning are often designed in a rather detailed manner. Larger activities are often broken down into smaller substeps, which themselves are also scripted. For example, asking questions in ASK to THINK – TEL WHY®© is broken down into asking review questions, probing questions, thinking questions, hint questions, and metacognitive questions. Furthermore, collaboration scripts used for face-to-face learning often (at least in the beginning before the script instructions are internalized by the learners) do not allow the learners much freedom to decide (a) which activities to carry out at a particular point in time and (b) how to conduct these activities. The goal of highly structuring collaborative learning processes is to engage learners in fruitful collaboration processes while setting constraints for their engagement in suboptimal ones. As Dillenbourg (2002) describes, such highly specific instructions do, however, bear the danger of over-scripting which can lead to a significant loss of freedom and, therefore, may contradict the very nature of collaborative learning as an open, non-coercive endeavor. There seems to be a trade-off between effective structuring (effective in that it supports high-level cognitive and metacognitive processes) and over-scripting, which needs to be considered by designers of collaboration script approaches. The optimum degree of structuredness of a collaboration script is a question that deserves future research.

Collaboration Scripts for Computer-mediated Learning

We now turn to an analysis of collaboration scripts developed for computer-mediated learning. Due to the dynamic development of networked computer technologies, a number of collaboration scripts for computer-mediated settings has been described over the last few years, starting with the pioneering work of Scardmalia and colleagues on developing the CSILE environment (Scardamalia & Bereiter, 1991, 1993/1994; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). Although the term collaboration script is high on the agenda of the research community on Computer-Supported Collaborative Learning (CSCL; e.g., Dillenbourg & Jermann, in press; Dönmez, Rosé, Stegmann, Weinberger, & Fischer, 2005; Ertl, Kopp, & Mandl, 2005; Kollar et al., 2005; Miao, Hoeksema, Hoppe, & Harrer, 2005; Schellens, van Keer, Valcke, & deWever, 2005; Weinberger et al., 2005), not all authors of the approaches presented in the following call their approaches collaboration scripts. The selected approaches we present do, however, meet the criterion of supporting collaborative learning through encouraging specific collaboration processes rather than providing content-related conceptual support. The selection of approaches reflects the variety of scripts that have been developed in this strand of research. The group size ranges from dyads of learners to a theoretically infinite number of learners. They also cover the most common synchronous and asynchronous communication media like chat tools and discussion boards. Further, all approaches are prominent in their field and underwent empirical research. As can be seen in Table 2, the approaches considered in this article are the ones by Baker and Lund (1997), Hron, Hesse, Reinhard, and Picard (1997), Pfister and Mühlpfordt (2002, "Learning Protocol" approach) and Guzdial and Turns (2000, "Collaborative and Multimedia Interactive Learning Environment").

The approach by Baker and Lund (1997)

This approach integrates a collaboration script into a distributed text-based learning environment in which two learners communicate by aid of a chat tool and a shared physics diagram.

Table 2 Collaboration script approaches for face-to-face vs. computer-learning included in the analysis

Learning setting	Approaches included in the analysis
Face-to-face	O'Donnell and Dansereau (1992)
	King (1997)
	Johnson and Johnson (1994)
	Palincsar and Brown (1984)
Computer-mediated	Baker and Lund (1997)
	Hron et al. (1997)
	Pfister and Mühlpfordt (2002)
	Guzdial and Turns (2000)

The learners' task is to create collaboratively an energy chain model. Learners are provided with a real physical apparatus and a text highlighting the main concepts of the problem. The communication interface includes a number of buttons containing short sentences or sentence starters to guide the learners' interaction. These buttons represent four groups of communicative acts. The first set of buttons deals with the construction of an energy chain in the shared diagram (e.g., "I think that…"), the second represents communicative acts with the aim of reaching an agreement (e.g., "OK"), the third is designed to manage the learners' interaction (e.g., "Where do we start?"), and the remaining buttons represent acts geared towards doing something else (e.g., "Read the handout!"). A mouse click on buttons with complete sentences (e.g., "Do you agree?") immediately makes the sentence visible on the partner's screen. A click on a button containing an incomplete sentence (e.g., "I think that…") causes the sentence fragment to be copied into the text window on the learner's own screen. Then, the learner is supposed to complete the sentence and send it to the shared chat window.

With respect to the five conceptual components introduced earlier, the collaboration script developed by Baker and Lund (1997) can be analyzed as follows: The approach has two main *objectives*. The first objective is to enable learners to understand the energy concept by modeling energy flow behavior. The second objective is to help learners overcome communication problems associated with the characteristics of chat communication, such as incoherent text, missing nonverbal cues, etc. (Fabos & Young, 1999; Schwan, 1997). The *activities* the learners engage in are also two-fold. First, learners are supposed to engage in elaborative activities, such as giving explanations (which is achieved through the provision of buttons like "I propose to…"). Second, the tool directs learners to perform explicit coordination activities ("Do you agree?"; "Where do we start?," etc.). Although the approach does not explicitly prescribe a detailed sequence for engaging in activities, the various button prompts provide an implicit method of *sequencing*. For example, beginning a sequence by clicking on the "Do you agree?" button would not make sense. In contrast, "Where do we start?" is clearly supposed to be used at the beginning of collaboration. With respect to the distribution of *collaboration roles*, it appears that the approach does not explicitly require that the learners take on roles. Rather, the learners' preferences determine if and how they distribute roles, choose which activities to conduct in adopting roles, and maintain or switch roles. With respect to the script's *type of representation*, the instructions are represented textually, namely in the form of inscriptions on the buttons.

The approach by Hron et al. (1997)

Hron et al. (1997) developed a collaboration script that structures a dyad's interaction within a text-based setting. Learners are provided with erroneous graphical diagrams from the field of biology and asked to correct them using a graphical manipulation tool. First, one of the two learning partners receives a system message requesting an initial proposal for correcting the diagram. This initial suggestion has to be formulated and typed into a text field and sent to the learning partner. By clicking on a button with the title "Do you agree?", the learner asks for agreement from the learning partner. This causes a window to appear on the learning partner's screen that displays a request for signaling agreement or disagreement. If the learner disagrees with the partner's suggestion, he or she formulates a statement including the reasons for disagreement. The other learning partner is then asked to read this statement again and to signal agreement or disagreement. This discourse loop is repeated until an agreement on the partner's suggestion is reached. After that, the diagram is released for further manipulation.

The approach of Hron et al. (1997) can be characterized as follows: The *objectives* of this collaboration script are, first, to help learners acquire domain-specific knowledge about a well-defined biology problem and, second, to facilitate text-based online communication. To reach these objectives, Hron et al. (1997) engage learners in higher-order *activities* such as explaining and commenting. Coordinative activities ("Do you agree?") also play a prominent role in this approach. With respect to explaining and commenting, the script instructions are not further detailed. They do not provide learners with specific requirements for creating a good explanation or a fruitful comment. In contrast, the coordinative activity of asking for an agreement is highly structured. The interface remains blocked until learners come to an agreement. *Sequencing* of the learning activities is achieved by the interface design: It specifies that learners first must suggest how to correct the structure of the diagram and then request their partner's agreement. Learners can hardly ignore this imposed sequence because the interface does not allow for a deviation from these activities. Similarly, there is a rather explicit distribution of *collaboration roles* between the two learning partners, although roles are not explicitly labeled: One learner takes on a composer role and one takes on a commentator role. Learners are required to switch roles after the discourse loop is finished. The script's *type of representation* can be characterized by its reliance on textually coded instructions. These instructions are partially located in the system messages that prompt learners to perform a specific activity and partially in the inscriptions of the prompt buttons. One distinctive characteristic of the script is that not all structuring features are visible and therefore externally represented. For example, turn taking is guided by the design of the communication interface so that only one learner can contribute to the discussion at any given time.

The Learning Protocol approach by Pfister and Mühlpfordt (2002)

Pfister and Mühlpfordt (2002) developed a collaboration script for a chat-based learning environment for groups ranging from three to five persons, including one tutor. The learners' task is to discuss topics from geology and philosophy. The communication interface provides three kinds of interaction-structuring methods: First, the interface requires learners to indicate explicitly which message they are referring to. This is achieved by asking them to draw an arrow to the particular message or to a specific part of that message. Second, learners are supposed to specify what kind of message they are about to send to the shared chat window. Thus, a menu appears with a list of three possible statement types to choose from: question, explanation, and comment. Once the learners have made these first two selections, they are able to write a message and send it to the shared chat window. Third, the communication interface regulates the sequence according to which learners are supposed to send messages to the shared chat window. To this end, the system provides written information in a separate window concerning whose turn it is at that point in time, while blocking the other learning partners' interfaces. Usually, learners are supposed to send their messages in turn. If a learner categorizes a contribution as a question, the system automatically blocks all learners' chat windows and authorizes only the tutor to respond.

With respect to the five conceptual collaboration script components, the Learning Protocol approach can be analyzed as follows: The *objectives* of the Learning Protocol approach are to (a) learn key concepts from geology and philosophy by discussing them on the basis of introductory texts and (b) improve coordination to achieve a more coherent discussion. Students engage in two basic types of *activities*: First, learners engage in higher-order activities, such as questioning, explaining, and commenting. Learners must categorize their messages as a question, explanation, or comment. However, they are not provided with information on how to compose a relevant question, explanation, or comment. Second, learners engage in coordinative activities such as drawing arrows from their message to the message they want to refer to. *Sequencing* is achieved by requiring learners to take turns except when the tutor is asked a question. Despite this sequencing, learners are still free to choose when to compose which of the three possible message types. Although *collaboration roles* are not explicitly defined, the range of possible roles is restricted to a questioner, an explainer, and a commentator. However, these roles are not explicitly labeled, and learners are not told when to engage in which role. The script's *type of representation* includes different codes: The script contains written information about who is supposed to compose a message at any given point in time. Also, the list of the three possible message types is represented textually. A graphical code (arrow) is used to make the reference to other messages explicit. The interface is designed to specify which group member has to send a message and when. This is achieved by simultaneously blocking the other group members' chat windows. However, this component is neither explicitly stated nor externally visible to users.

The CaMILE approach by Guzdial & Turns (2000)

Guzdial and Turns (2000) developed a collaboration script approach for discussion forums in which an infinite number of learners can participate. The system operates on three design principles. First, to achieve a high level of transparency, it contains specific discussion management features. For example, for each message, the system displays the type (e.g., "new idea," "rebuttal"), author, and date of origin. Second, CaMILE provides certain facilitation features. For example, before typing a note, learners must specify what type of message they want to create. They can choose between five alternatives: new idea, rebuttal, revision, comment, and question. They can also select whether they want to have one of several prompts pasted into their note for further support (e.g., "I propose to. . ."), Third, CaMILE contains a so-called anchoring feature. An anchor can be any page on the Web that is of interest to the learners when a particular note in CaMILE includes a link to that Web page. This link can be installed by the instructor or by a learner. That note then represents the beginning (or anchor) of a new thread. For example, a teacher may create a web page containing provocative theses on abortion. By adding a link to the discussion forum, this web page automatically becomes the anchor of a new thread. Every participant who clicks on that link is then directed to the discussion forum.

By using the five conceptual script components, CaMILE can be analyzed as follows: Concerning the outcomes of collaborative learning, the *objectives* of the CaMILE approach are not pre-specified. The teacher can lead the discussion in multiple directions, although the script's structure implies that teachers will mainly use the system to support the learners' acquisition of domain-specific knowledge. The main process-related objective is to achieve a more coherent discussion by including instructions that encourage learners to focus on a specific topic. The *activities* supported by CaMILE revolve around elaborative strategies such as explaining, rebutting, or questioning. A distinctive feature is that the learners can choose to paste prompts into their message to support its composition. When a learners decides to do so, the system's support becomes more structured with respect to the chosen activity. With respect to *sequencing*, CaMILE does not include any features prescribing when to compose what type of message – or even to compose a message at all. Because the script provides learners with a list of prescribed learning activities, it implicitly triggers an engagement in either a composer- or a commentator-like *collaboration role*. The same is true with respect to switching collaboration roles, which is not explicitly prescribed but left to the discretion of the learners. With respect to the script's *type of representation*, the script instructions are provided in a textual format. However, the teacher using the script can give further script instructions, possibly in a graphical or an oral format.

Comparing Collaboration Scripts for Computer-mediated Learning

As was the case for the face-to-face approaches analyzed before, a comparison of the presented collaboration scripts for computer-mediated learning on the basis of the five conceptual collaboration script components represented in Table 1 can lay open several commonalities. With regard to their *objectives*, the presented approaches focus on fostering the acquisition of domain-specific knowledge about the learning material. In the approach by Baker and Lund (1997), for example, learners are expected to acquire knowledge about the energy concept, whereas Hron et al. (1997) focus on helping learners acquire knowledge about the biology problem at hand. All the approaches also emphasize achieving smooth communication and coordination among the learners. In the Learning Protocol approach, for example, this is achieved by designing the communication interface in a way that it controls turn taking. In CaMILE, communication and coordination are supported by requiring learners to label each contribution as a new comment, question, or rebuttal.

Each of the presented approaches aims at supporting slightly different types of *activities*. In general, two categories of learning activities can be identified: (a) cognitive-elaborative activities (e.g., explaining, commenting) and (b) communicative-coordinative activities (e.g., requesting agreement). However, in all the presented approaches for computer-mediated learning, the script instructions focus more heavily on communication and are specific with respect to each learner's involvement. Hron et al. (1997) require that the learners request their partner's agreement to their own activities. Baker and Lund (1997) provide support for effective communication activities to keep the workflow going. Pfister and Mühlpfordt (2002) are more concerned with promoting higher-order learning activities like explaining and commenting (as compared to the other three approaches), but they also focus on helping learners overcome the limitations associated with chat-based communication. Due to their focus on supporting communication and coordination, the approaches predominately support group processes that occur on a social rather than on an individual level. Individual learning processes are therefore implicitly treated as a consequence of smooth communication and coordination. As an exception, the CaMILE approach focuses more heavily on engaging the individual learner in cognitive-elaborative activities by offering support for activities like explaining or commenting. Yet, learners decide whether to paste prompts into their messages and can circumvent this support. In the Learning Protocol approach, learners are supposed to provide explanations but are not told what a good explanation is. The script does not provide learners with guidance on how to carry out the activities in a way that would relate more closely to individual knowledge construction. Learners may indeed engage more in giving explanations but presumably only learners with high-level explanation abilities will benefit, whereas learners with lower-level abilities may fail to create good explanations. Thus, collaboration scripts for computer-mediated learning are not as specific for higher-order, cognitive-elaborative learning activities as for communicative-coordinative activities.

The *sequencing* of particular learning activities is achieved differently in each of the approaches. The script developed by Baker and Lund (1997) provides a large degree of flexibility concerning when to carry out specific learning activities. The learners basically decide for themselves when to engage in one of the activities. Similarly, the scripts developed by Pfister and Mühlpfordt (2002) and Guzdial and Turns (2000) do not provide learners with clear guidance on when to engage in a particular activity because the learners have the opportunity to choose when they want to generate a specific type of message. The cues presented in the different script approaches do however sometimes trigger certain action sequences. It can be assumed that providing learners with less restrictive collaboration scripts will trigger internal action sequences that have been acquired before and guide further collaboration among the learning partners. In contrast, Hron et al. (1997) provide learners with rather explicit guidance concerning the sequence of activities they have to perform. The design of the communication interface stipulates that learners always take turns in giving suggestions or providing feedback to their partner's utterances.

With respect to *role distribution*, the analysis shows that some scripts for computer-mediated learning provide clearer specification than others. For example, in the Learning Protocol approach, collaboration roles and the related learning activities are rather explicit (at least in their labels), even though learners are free to choose one of the three induced collaboration roles. However, the communication interface hardly allows for any activities different from the ones that are presented as possible message types. In a similar way, this is also true for the script provided by Hron et al. (1997). In contrast, Baker and Lund's (1997) approach does not assign learners to specific collaboration roles. They can choose and design their roles without being bound to them for a whole learning phase. Similarly, CaMILE allows learners to choose whether they want to engage in a composer role to create a new idea, or whether they want to act as a commentator and provide a comment on a learning partner's idea. In the approach by Baker and Lund (1997) and in CaMILE, learners decide for themselves whether to adopt and perform a collaboration role.

The *type of representation* of collaboration scripts for computer-mediated learning is different in each of the presented approaches but may also vary within one particular approach. For example, the Learning Protocol approach uses different formats. The design of the communication interface requires learners to label their contributions as explanation, comment, or question. Learners are required to select the appropriate type from a written list represented in an applet window. In contrast, the learners' task of indicating which message they wish to refer to is represented in a graphical format (in the form of arrows). The third script component, sequencing, is represented textually in a separate window with a list of the participants. The other three approaches rely mostly on textual representations of the script instructions. In the Hron et al. (1997) approach, the interface specifies textually which learning partner is supposed to engage in a particular activity at what point in time. CaMILE and the approach presented by Baker and Lund (1997) also rely on textual representations for each of their specific collaboration script components. Some of the presented approaches are characterized by script components that are not visible or otherwise directly perceivable for the learners because they are part of the interface design. For example, in the approach by Hron et al. (1997), sequencing is not externally represented by a list specifying which learner's turn it is. Instead, the system simply blocks the chat window of the learner who is not supposed to write a contribution in the shared chat window.

When reviewing the arguments made about trends in script design for computer-mediated learning, their most apparent commonality is that all of them support and coordinate communication between individuals and only in secondarily focus on individual cognitive processes. Research on collaboration scripts for computer-mediated learning, therefore, provides insights into the instructional design of what might be termed the *interactional essentials* of collaborative learning: Features of the learning environment that guarantee that the basic interactional requirements for effective collaborative learning processes are met. Some collaboration scripts for computer-mediated learning hardly consider detailed instructions for higher-order learning processes as a major determinant of successful collaboration. Quite often, these approaches provide learners with unspecified script instructions and a great deal of freedom concerning how to engage in higher-order activities like explaining or commenting. Providing rather open collaboration scripts might be adequate for learners who already know how to engage effectively in collaborative learning situations. Problems may arise when learners lack or hold only inadequate knowledge about how to formulate a good explanation, for example. A lack of collaboration abilities might result in a deficient repertoire of effective collaboration strategies, causing learners to make inefficient use of the freedom provided by the collaboration script. These learners are then likely to fail to reach the desired learning objectives. Against this background, we submit that collaboration scripts for computer-mediated learning should also provide learners with more detailed support for how to engage in higher-order learning activities (Rosenshine & Meister, 1994) that are more closely related to individual knowledge acquisition. Initial steps in this direction have however been taken in the selected approaches. For example, the activities in CaMILE (such as analyzing and commenting) are activities that can be viewed as leading to higher-order learning, such as an acquition of elaborative and metacognitive skills. However, Guzdial and Turns (2000) concede that the provision of the specific cues in CaMILE "does not, in itself, mean that learning is going on" (p. 441). This indicates that further, more specific instructional support might be helpful for real learning (in terms of individual cognitive change) to take place. Similarly, the other three approaches remain unclear concerning the question of how the imposed learning activities, their sequence, the type of representation, and further features of the presented collaboration scripts relate to higher-order learning gains.

Finally when it comes to the type of representation, it appears that collaboration scripts for computer-mediated settings are often designed rather intuitively. Although all of the approaches presented have been designed innovatively and creatively, there is often a lack of a preceding theoretically and empirically guided analysis on how the respective script features should be represented during the learning process. Yet, there is research on how learners process different forms of external representations and how these affect learning (e.g., Mayer, 2001; Schnotz, 2002; Suthers & Hundhausen, 2003; Vekiri, 2002). This research should be considered by developers of collaboration scripts for computer-mediated learning to avoid any learning problems stemming from bad interface design. One real advantage of research on collaboration scripts for computer-mediated learning, however, is that scripts can be imposed without even making them explicit to the learners. In a face-to-face setting, this would hardly be possible. By reducing the amount of instruction, it is likely that learners will experience less cognitive load and have more cognitive resources available to elaborate upon content information (Sweller, Van Merrienboer, & Paas, 1998). This is likely to yield more desirable learning outcomes than when learners have to struggle to understand externally represented instructions.

What Can Researchers Who Investigate Collaboration Scripts for Face-to-face and for Computer-mediated Settings Learn from Each Other?

Our comparison of collaboration script approaches for face-to-face and computer-mediated learning with regard to the five conceptual components introduced at the beginning of this article reveals commonalities and differences – as well as strengths and weaknesses – of the two lines of research. Both lines of research can inform researchers investigating collaboration scripts from either perspective about how to design powerful collaboration scripts for various group sizes, tasks, communication media, and learning settings. However, not all problems in one research line can be compensated by strengths in the other. Instead, there are also shared deficits. In this section, we delineate commonalities and differences between the two lines of research, as well as deficits that are shared by both of them. Again, we use the five script components as a heuristic to illustrate these deficits.

With respect to their *objectives,* collaboration scripts designed for both settings have a strong cognitive focus (e.g., text learning or problem solving). In all face-to-face learning approaches under examination, there was an additional focus on metacognitive objectives, such as acquiring monitoring strategies. Collaboration scripts for computer-mediated learning, in contrast, often try to achieve smooth communication and coordination between the collaborators as a secondary objective. Yet, collaboration scripts might also be helpful in reaching further objectives. To date, neither of the two lines of research has dealt extensively with developing approaches to foster motivational or emotional variables. This is unfortunate because there is preliminary empirical evidence indicating that motivation can suffer when learners are provided with overly detailed collaboration scripts (e.g., Kollar, 2001).

Both collaboration scripts for face-to-face and computer-mediated learning aim to facilitate cognitive and metacognitive *activities*, such as explaining, questioning, or commenting. Yet, the ways in which these activities are typically introduced differ between the two lines of research. In approaches for computer-mediated learning, activities are often only labelled so that learners perform them without further instructions. In approaches for face-to-face learning, collaboration scripts often provide additional guidance (either through training or textual support) for how to engage in these activities. Collaboration scripts for computer-mediated learning also exhibit a focus on communicative and coordinative activities. This focus is rooted in the different communication characteristics between face-to-face and particular computer-mediated forms of communication. Computer-mediated collaboration often requires more explicit coordination efforts because nonverbal cues or other opportunities for coordination are limited (e.g., Dillon & Gabbard, 1998; O'Connaill & Whittaker, 1997). Consequently, script instructions concerning communicative-coordinative acts are often highly specific in collaboration scripts for computer-mediated learning.

The *sequencing* of activities in collaboration script approaches for face-to-face learning is often explicit. Learners receive clear instructions concerning when to engage in an activity. These instructions are introduced by training and often reinforced during collaboration by the teacher or by external artifacts such as prompt cards. In approaches for computer-mediated learning, sequencing is often left up to the learners. However, the communication interface often suggests an implicit sequence for the activities to be performed. For example, learners are given prompts that only make sense when they are used at a particular point in time. Another design strategy used in computer-mediated learning is implicit sequencing through a communication interface that, for example, blocks all chat windows except the window of the learning partner who is supposed to make a contribution. This design feature frees up learner resources for on-topic discussion and learning.

In many collaboration scripts for face-to-face learning, *role distribution* is often explicit because the scripts provide detailed instructions concerning which learner has to act in which role at what specific point in time. In contrast, approaches for computer-mediated learning often distribute collaboration roles in a rather implicit manner. The actual design of the communication interface might, however, at least suggest the specific roles learners should perform. For example, a communication interface can offer sentence starters that prompt learners to assume the role of an explainer or a questioner.

Concerning the *type of representation*, most approaches for face-to-face learning use textual (e.g., prompt cards) and auditive representations (e.g., the teacher explaining the specific instructions). However, most of the script instructions can be assumed to be represented mentally because learners are supposed to internalize them before collaboration. In collaboration script approaches for computer-mediated learning, instructions are often represented textually or graphically. In some cases, the interface is designed to only allow for one specific activity or sequence to be carried out without actually representing that script component externally.

As we have argued, collaboration scripts for computer-mediated learning typically focus on facilitating communicative and coordinative processes. These are processes that operate on the intersubjective level. By focusing on communication and coordination, the primary targets of the script instructions are the interactions between the group members rather than their cognitive processes. Thus, research on collaboration scripts for computer-mediated learning generates knowledge about *interactional essentials*, that is, how to structure learning environments that enable learners' smooth interaction. Research on collaboration scripts for face-to-face learning, on the other hand, focuses more directly on individuals'elaborative activities, that is the *learning enhancers* of collaborative learning that enable learners to deeply elaborate content information. When insights from the two lines of research come together, better collaboration script approaches might be developed in the future to facilitate smooth communication and coordination, as well as higher-order individual learning (Rosenshine & Meister, 1994).

Further points of cross-fertilization between collaboration script research for computer-mediated vs. face-to-face learning can also be found on a theoretical level. Authors of collaboration script approaches for face-to-face learning often refer to cognitive learning theories and information-processing models that regard knowledge construction as a process in which an individual integrates incoming information with pre-existing knowledge structures. In contrast, research on collaboration scripts for computer-mediated learning often refers to sociocultural (Vygotsky, 1978) and situated theories (e.g., Lave & Wenger, 1991) of cognition. Sociocultural and situated approaches emphasize the importance of social practices in a community of learners. From this perspective, collaboration scripts should be designed to guarantee that individuals can fruitfully participate in these practices. Supporting participation in group activities on the one hand and enhancing individual cognitive processes on the other is, however, not contradictory. Well-designed collaboration scripts may be able to support both individual and group processes simultaneously. There is a danger, however, of providing learners with too much instruction and the wrong instruction. "Over-scripting" (Dillenbourg, 2002) might prove more detrimental for some learners than for others. For example, adults might have developed internal scripts for collaboration (Kollar et al., 2005) that are highly specific and only useful for specific situations. Imposing too much structure is likely to produce reactance (Brehm, 1966) and motivation loss (Kollar, 2001). For adult learners, one solution could be to design collaboration scripts that allow them to rely on their own experiences and strategies to structure their collaboration processes.

Correspondingly, research has not yet focused enough on the question of how structured a collaboration script should be. This is a crucial question, since Dillenbourg (2002) and Cohen (1994) have pointed to the dangers of micro-structuring processes of collaborative learning, especially in sophisticated tasks that require creative problem solutions. In such tasks, highly structured collaboration scripts can reduce the learners freedom and limit high-level discourse. Furthermore, learners with varying characteristics might require differently structured collaboration scripts. As previous research has indicated, One critical learner characteristic is their domain-specific prior knowledge (Dochy, Moerkerke, & Segers, 1999). Learners with low domain-specific knowledge might learn best with highly structured collaboration scripts, whereas learners with high domain-specific knowledge may learn best with minimally structured collaboration scripts. Maybe of even higher importance for collaborative learning processes is the individuals' domain-general knowledge that they bring with them and that guides them in their collaborative actions (Kollar et al., 2005). Research needs to examine what specific collaboration knowledge individuals bring to a collaborative learning situation and whether an externally provided collaboration script activates adequate knowledge or compensates for deficient knowledge. We view this interplay between individuals' prior knowledge about collaboration and their externally provided collaboration scripts as a core issue for both the design of collaboration scripts and future theory building. Therefore, we develop a conceptual framework on learning with collaboration scripts that includes the learners' domain-general knowledge on collaboration.

A Person-plus Framework of Collaboration Scripts: Future Directions for Theory Building and Empirical Research

Although research on collaboration scripts originally derived the term script from cognitive psychology (Schank & Abelson, 1977), most researchers in the field departed from the individualistic notion of scripts as internal memory structures. Maybe as a consequence, research on collaboration scripts for face-to-face and for computer-mediated learning has largely neglected the importance of the individual and his or her procedural knowledge that guides actions in collaborative situations. In collaboration script approaches that are less highly structured, however, effective collaboration depends strongly on how the learning partners structure their collaboration on their own. According to Schank and Abelson (1977), individuals develop internal knowledge structures or scripts through repeated participation in particular situations. These structures or scripts guide their understandings and actions within these situations. Applied to collaborative learning, cognitive scripts about how to engage in collaboration develop as an individual repeatedly engages in collaborative situations beginning in early childhood. This domain-general knowledge about collaboration may be termed internal collaboration scripts. It can be argued that the structure of the learners' internal collaboration scripts is one central determinant of collaborative learning and that it interacts with the structure of an externally provided collaboration script (see Carmien, Kollar, Fischer, & Fischer, in press).

To conceptualize the interplay between internal and external collaboration scripts, we derive valuable ideas from theoretical approaches on distributed cognition (e.g., Derry, DuRussel, & O'Donnell, 1998; Hewitt & Scardamalia, 1998; King, 1998; Moore & Rocklin, 1998; Pea, 1993; Perkins, 1993; Salomon, 1993). In his person-plus-surround concept, Perkins' (1993) distinguishes between the *person-solo* and the *person-plus*; both are involved when an individual is asked to solve a task in conjunction with other persons and/or an external artifact (e.g., a collaboration script). The person-solo describes

Table 3 Main factors and subcategories involved in a collaborative learning group solving a task

Main factor	Subcategories
Activity	Objective of activity
	Type of sub-activities
	Sequencing of sub-activities
	Collaboration roles
Knowledge	Type of representation
	Accessibility characteristics
Executive function	Goal setting control
	Performance control

the individual as one component of the system. The person-plus describes the whole system that comprises both the individual and his or her social and artifactual surround. In this way, cognition or "intelligence" (Pea, 1993) is viewed as distributed between individuals and artifacts, thereby challenging the traditional cognitive stance that knowledge and intelligence are solely represented "within the head" of an individual (cf. Anderson, 2000). Although the notion of distributed cognition that Perkins (1993) advocates is not without criticism (e.g., Moore & Rocklin, 1998; Newell, 1990), it helps conceptualize the interplay between internal and external collaboration scripts.

When accepting the notion that knowledge is distributed between a person-solo and the surround, it can be asked where the knowledge necessary for task accomplishment actually is located – in the cognitive system of the individual (the person-solo) or in the surround? For Perkins (1993), however, this question is secondary. More important are the *accessibility characteristics* of that knowledge (i.e., how easily this knowledge is accessible for the person-plus system; (Perkins, 1993). For the system's task performance, no qualitative difference is assumed when the necessary task-relevant knowledge is located in the person-solo or in the surround. For Perkins, what is more important than the question concerning the location of task-relevant knowledge within the person-plus system is the question concerning what system component has metacognitive control over the system (*executive function*; Perkins, 1993). This function can be adopted by either the person-solo (e.g., a learner who sets learning goals and monitors his or her individual progress and the group process) or the surround (e.g., an external collaboration script that sets rules and goals and monitors their accomplishment). In other cases, the surround might support the individual in adopting the executive function over the system. In this case, both internal and external scripts contribute to controlling the system.

Perkins' (1993) conception is helpful in understanding how groups of learners engage in collaboration tasks because it includes both the individual learners and their specific knowledge about collaboration and external support systems, such as collaboration scripts, as contributors to the collaborative activity (see also King, 1998). By adopting a person-plus view, the previous components of our analysis can be expanded using core concepts of Perkins' person-plus approach (e.g., accessibility of knowledge; executive function). The resulting conceptual framework takes the contributions of internal and external collaboration scripts into account. This framework (Table 3) can be useful for integrating previous research on collaborative learning with collaboration scripts and for stimulating more research.

To develop a person-plus framework of collaboration scripts, it is useful to first determine the main factors involved when a group of learners tries to accomplish a collaboration task. On a general level, at least three factors can be distinguished: (a) a global collaborative activity (or a set of global activities) the system needs to perform to solve the task, (b) knowledge about collaboration required to conduct these activities, and (c) the system's executive function that sets the goals and monitors the processes of collaboration. When mapping the five conceptual components of collaboration scripts identified earlier onto these three main factors, the following picture of collaboration can be drawn.

The *activity* learners are engaged in can initially be described in terms of the main *objective* that underlies it. For example, as in the approach by Baker and Lund (1997), the activity's objective might be to construct collaboratively a model of energy flow. The whole activity might then be broken down into several *sub-activities* needed to pursue that goal. In the Baker and Lund script, these activities include "give a proposal to change the energy chain model," or "ask for your partner's agreement." These activities might need to occur in a specific *sequence*. Applied to the learning scenario in the Baker and Lund approach, the script might instruct the learners to start by providing a proposal on how to change the current model. Then, the learner can ask his or her learning partner if the proposal is acceptable and change the energy chain model accordingly. In addition, the sub-activities might be attached to *collaboration roles* such as problem-solver and commentator.

The *knowledge* dimension should include at least two sub-categories. First, knowledge about how to act in collaboration tasks can be characterized by the *type of representation*, which was one of the five conceptual script components introduced earlier. The type of representation can for example be mental, graphical, oral, or textual. For example, a learner may hold a mental representation of collaboration that guides him or her to first discuss how to approach the task. In another case, textual instructions on a sheet of paper may explicitly state how the learning partners should act to pursue the goal of collaboration. As a second knowledge sub-dimension (Perkins', 1993) person-plus perspective suggests that knowledge about collaboration can also be characterized with respect to its *accessibility characteristics*. Accessibility is presumably a central determinant of successful task accomplishment. If the knowledge required to solve the collaboration task is not accessible in either the internal or the external collaboration script, then a system consisting of two or more individuals and an external collaboration script will fail to accomplish the collaboration task. If the knowledge is represented in the external collaboration script, then learners can use it to guide their activities and solve the collaboration task. If one of the collaborators has the required knowledge accessible in his or her internal script, then this internal knowledge might translate more quickly into appropriate collaborative action.

With respect to the *executive function*, an analysis must focus on how (a) the *planning and control of goal setting* and (b) the *planning and control of performance* are achieved. Goal setting planning and control can be made explicit in an external collaboration script ("Create an energy chain model!"). Goal setting may also be less specified in the external collaboration script and be transferred to the learners themselves (e.g., when learners are given the opportunity to set their own goals, such as "Choose a hypothesis you would like to defend in class"). Performance planning and control can similarly be either specific or more open. The Hron et al. (1993) approach, for example, can be regarded as specific because the modeling window is blocked so long as partners do not agree on the next solution step. Reciprocal Teaching, in contrast, can be regarded as open with respect to performance planning and control. For example, the teacher asks learners to be aware of specific communication skills, which, in the end, are largely subject to the learners' internal collaboration scripts.

Potential of a Person-plus Framework of Collaboration Scripts

What are the areas of potential for a person-plus framework of collaboration scripts? First, when there is acknowledgement that collaborative learning processes are partially guided by internal scripts, partially by external scripts, and partially by their interaction, the resulting framework can help define differences among existing collaboration script approaches more clearly. We assume that learner differences, such as their sequencing behavior or their engagement in particular activities, are a function of the interplay between their internal scripts and the external collaboration script. For example, CaMILE induces sub-activities, such as generating a new idea or commenting on an existing idea, in an explicit manner by providing learners with a limited selection of possible message types to choose from. This means that sub-activities are largely determined by the external collaboration script. In contrast, CaMILE provides learners with a great deal of freedom to decide how to sequence sub-activities. Thus, in the sequencing dimension, collaboration in a CaMILE scenario is largely driven by the learners' internal collaboration scripts. As another example, the ASK to THINK – TEL WHY script specifies sub-activities such as asking probing questions or giving explanations. In contrast, performance planning and control depends on the teacher or on the learners themselves.

In general, relating different collaboration script approaches to the dimensions of the person-plus framework of collaboration scripts might support a more thorough interpretation of the often inconsistent findings associated with external collaboration scripts. One outcome could be that external collaboration scripts that strongly guide the learners' sub-activities are effective for some learners but detrimental for others.

Second, the person-plus framework of collaboration scripts can be used as a guideline for designing external collaboration script approaches. By explicitly acknowledging the importance of learners' internal collaboration scripts, the person-plus framework encourages designers to consider the characteristics and specific needs of the actual users working with the collaboration script. However, the learners' internal collaboration scripts must be assessed in a reliable way. Therefore, adequate instruments need to be developed.

Third, the person-plus framework of collaboration scripts can provide an opportunity to better align research efforts in the field. As the variety of collaboration script approaches presented in this article indicates, research on collaboration scripts is diverse, making it hard to integrate the different results obtained. In our view, a pressing research question is "What collaboration script information should be distributed between the person-solo and the surround and how should it be distributed?" (see King, 1998). According to Perkins (1993), knowledge about higher-level processes should be kept in the person-solo (e.g., create arguments), whereas lower-level processes should be shifted to the surround (e.g., performing an addition equation by using a hand calculator). Instructions concerning low-level operations like "Now click the OK-button" or "Wait until the diagram is released for further manipulation" might not be part of the learners' internal scripts nor a relevant objective for internalization from a pedagogical point of view. On the other hand, at certain stages of collaboration, it might be beneficial to omit certain aspects of the external script. One can assume that learners, through interaction with the external script, develop and refine knowledge about how to structure their collaboration, thereby gradually integrating procedures represented in the external collaboration script into their internal scripts.

Finally, future research should address and investigate the dynamics of the interplay between internal and external collaboration scripts (Kollar et al., 2005). There are at least three different patterns of how internal and external collaboration scripts might interact. One possibility is that external collaboration scripts supplant internal scripts. This might happen when an external collaboration script does not allow for any task procedures other than the ones intended by its designer. A second possibility is that external and internal collaboration scripts have additive effects, such that external scripts trigger existing internal collaboration scripts that would not be activated without external support. Thus, a system including scripts located in the person-solos and the surround would be superior to a system in which learners only have their person-solo collaboration scripts available. A third possibility is that there are interactive effects between internal and external collaboration scripts. As learners interact more and more with external collaboration scripts, a gradual internalization of script contents is likely to take place. As learners internalize these external script contents more and more, the specificity of the external script may be gradually reduced to ensure that learners are not given unneeded instructions. The process of reducing the amount of external instruction is known as fading (see Pea, 2004). Effective fading however requires sophisticated methods for online assessment. The learners' interaction patterns must be assessed to determine which portions of the external collaboration script should be faded out when learners have internalized them. In environments for Computer-Supported Collaborative Learning (CSCL), this could be increasingly achieved through computerized language analysis tools that record and analyze the learners' interaction and adjust the structuredness of an external collaboration script accordingly. Dönmez et al. (2005) showed that algorithms developed in the field of applied linguistics can analyze online discussions on a specific topic with reliabilities comparable to independent human coders. Adaptive external scripts could be developed if the results of these automated analyses were fed back into the design of the external collaboration script. The findings would then lead to fading specific components as appropriate. In face-to-face learning, this assessment has always been the task of the teacher and is based on his or her observations of a group's learning processes. For classroom settings, computer-supported online knowledge assessment techniques, as developed by Dönmez et al. (2005), might help teachers make decisions about the best collaboration script structure for a specific group. This way, collaboration scripts provided by a computer and scripts provided by a teacher can combine to provide optimum support for collaborating groups – an instance that has been described as "synergistic scaffolding" (Tabak, 2004).

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References

Anderson, J.R. (2000). *Cognitive psychology and its implications* (Fifth edition). Worth Publishing: New York.

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

Bell, P. (2004). Promoting students' argument construction and collaborative debate in the science classroom. In: Linn, M.C., Davis, E.A., & Bell, P. (eds.), *Internet environments for science education*. Erlbaum: Mahwah, NJ, pp. 114–144.

Brehm, J.W. (1966). *A theory of psychological reactance*. Academic Press: New York.

Carmien, S., Kollar, I., Fischer, F., & Fischer, G. (in press). The interplay of internal and external scripts. A distributed cognition perspective. In: Fischer, F., Kollar, I., Mandl, H., & Haake, J.M. (eds.), *Scripting computer-supported collaborative learning: Cognitive, computational, and educational perspectives*. Springer: New York.

Cohen, E.G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review Educational Research*, *64*(*1*), 1–15.

Cohen, E.G., & Lotan, R.A. (1995). Producing equal-status interaction in the heterogeneous classroom. *American Educational Research Journal*, *32*, 99–120.

Derry, S.J., DuRussel, L.A., & O'Donnell, A.M. (1998). Individual and distributed cognitions in interdisciplinary teamwork: A developing case study and emerging theory. *Educational Psychology Review*, *10*(*1*), 25–56.

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

Dillenbourg, P., & Jermann, P. (in press). Designing integrative scripts. In: Fischer, F., Kollar, I., Mandl, H., & Haake, J.M. (eds.), *Scripting computer-supported collaborative learning: Cognitive, computational, and educational perspectives*. Springer: New York.

Dillon, A., & Gabbard, R. (1998). Hypermedia as an educational technology: A review of the quantitative research literature on learner comprehension, control and style. *Review of Educational Research*, *68*, 322–349.

Dochy, F., Moerkerke, G., & Segers, M. (1999). The effect of prior knowledge on learning in educational practice: Studies using prior knowledge state assessment. *Evaluation & Research in Education*, *8*, 345–367.

Dönmez, P., Rosé, C.P., Stegmann, K., Weinberger, A., & Fischer, F. (2005). Supporting CSCL with automatic corpus analysis technology. In: Koschmann, T., Suthers, D., & Chan, T.-W. (eds.), *Computer supported collaborative learning 2005: The next 10 Years*. Lawrence Erlbaum, Mahwah, NJ, pp. 125–134.

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 an individual's prior knowledge on collaborative knowledge construction and individual learning outcomes in videoconferencing. In: Koschmann, T., Suthers, D., & Chan, T.-W. (eds.), *Computer supported collaborative learning 2005: The next 10 Years*. Lawrence Erlbaum, Mahwah, NJ, pp. 145–154.

Fabos, B., & Young, M. (1999). Telecommunication in the Classroom: Rhetoric versus Reality. *Review of Educational Research*, *69*(*3*), 217–260.

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

Graesser, A.C., & Person, N.K. (1994). Question asking through tutoring. *American Educational Research Journal*, *31*, 104–137.

Guzdial, M., & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *The Journal of the Learning Sciences*, *9*(4), 437–469.

Hewitt, J., & Scardamalia, M. (1998). Design principles for distributed knowledge building processes. *Educational Psychology Review*, *10*(*1*), 75–96.

Hron, A., Hesse, F.W., Reinhard, P., & Picard, E. (1997). Strukturierte Kooperation beim computerunterstützten kollaborativen Lernen [Structured collaboration in computer-supported collaborative learning]. *Unterrichtswissenschaft*, *25*, 56–69.

Hythecker, V.I., Dansereau, D.F., & Rocklin, T.R. (1988). An analysis of the processes influencing the structured dyadic learning environment. *Educational Psychologist*, *23*(*1*), 23–37.

Johnson, D.W., & Johnson, R.T. (1994). Constructive conflict in schools. *Journal of Social Issues*, *50*(*1*), 117–137.

King, A. (1997). ASK to THINK – TEL WHY ®©: A model of transactive peer tutoring for scaffolding higher level complex learning. *Educational Psychologist*, *32*(4), 221–235.

King, A. (1998). Transactive peer tutoring: Distributing cognition and metacognition. *Educational Psychology Review*, *10*, 57–74.

King, A. (2002). Structuring peer interaction to promote high-level cognitive processing. *Theory into Practice*, *41*(*1*), 33–39.

Kollar, I. (2001). *Gewissheits- und Ungewissheitsorientierung beim kooperativen Lernen in Videokonferenzen – der Einfluss verschiedener Strukturierungsmaßnahmen*. [Uncertainty orientation in video-mediated cooperative learning – effects of different structural supports]. Unpublished master thesis, Ludwig-Maximilians-University, Munich, Germany.

Kollar, I., Fischer, F., & Slotta, J.D. (2005). Internal and external collaboration scripts in web-based science learning at schools. In: Koschmann, T., Suthers, D., & Chan, T.-W. (eds.), *Computer supported collaborative learning 2005: The next 10 Years*. Lawrence Erlbaum, Mahwah, NJ, pp. 331–340.

Lambiotte, J.G., Dansereau, D.F., O'Donnell, A.M., Young, M.D., Skaggs, L.P., Hall, R.P., & Rocklin, T.R. (1987). Manipulating cooperative scripts for teaching and learning. *Journal of Educational Psychology*, *79*(4), 424–430.

Larson, C.O., Dansereau, D.F., O'Donnell, A., Hythecker, V., Lambiotte, J.G., & Rocklin, T.R. (1984). Verbal ability and cooperative learning: Transfer of effects. *Journal of Reading Behavior*, *16*(4), 289–295.

Larson, C.O., Dansereau, D.F., O'Donnell, A., Hythecker, V., Lambiotte, J.G., & Rocklin, T.R. (1985). Effects of metacognitive and elaborative activity on cooperative learning and transfer. *Contemporary Educational Psychology*, *10*, 342–348.

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

Mayer, R.E. (2001). *Multimedia learning*. Cambridge University Press: Cambridge, MA.

Miao, Y., Hoeksema, K., Hoppe, H.U., & Harrer, A. (2005). CSCL Scripts: Modelling features and potential use. In: Koschmann, T., Suthers, D., & Chan, T.-W. (eds.), *Computer supported collaborative learning 2005: The next 10 Years*. Lawrence Erlbaum, Mahwah, NJ, pp. 423–432.

Moore, J. L., & Rocklin, T. R. (1998). The distribution of distributed cognition: Multiple interpretations and uses. *Educational Psychology Rev*iew, *10*(*1*), 97–113.

Newell, A. (1990). *Unified theories of cognition*. Harvard University Press: Cambridge, MA.

Nuthall, G. (2000). The role of memory in the acquisition and retention of knowledge in science and social studies units. *Cognition and Instruction*, *18*(*1*), 83–139.

O'Connaill, B., & Whittaker, S. (1997). Characterizing, predicting, and measuring video-mediated communication: A conversational approach. In: Finn, K.E., Sellen, A.J., & Wilbur, S.B. (eds.), *Video-mediated communication*. Erlbaum, Mahwah, NJ, pp. 107–132.

O'Donnell, A.M. (1999). Structuring dyadic interaction through scripted cooperation. In: O'Donnell, A.M., & King, A. (eds.), *Cognitive perspectives on peer learning*. Erlbaum, Mahwah, NJ, pp. 179–196.

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

O'Donnell, A.M., Dansereau, D.F., Hall, R.H., & Rocklin, T.R. (1987). Cognitive, social/affective, and metacognitive outcomes of scripted cooperative learning. *Journal of Educational Psychology*, *79*(4), 431–437.

Palincsar, A.S., & Brown, A.L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction*, *1*, 117–175.

Pea, R.D. (1993). Practices of distributed intelligence and design for education. In: Salomon, G. (ed.), *Distributed cognitions: psychological and educational considerations*. Cambridge University Press: Cambridge, pp. 47–87.

Pea, R.D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The Journal of the Learning Sciences*, *13*(*3*), 423–451.

Perkins, D.N. (1993). Person-plus: a distributed view of thinking and learning. In: Salomon, G. (ed.), *Distributed cognitions: psychological and educational considerations*. Cambridge University Press: Cambridge, pp. 88–110.

Pfister, H.-R., & Mühlpfordt, M. (2002). Supporting discourse in a synchronous learning environment: The learning protocol approach. In: Stahl, G. (ed.), *Proceedings of the conference on computer supported collaborative learning (CSCL) 2002*. Erlbaum, Hillsdale, pp. 581–589.

Plass, J.L., Chun, D., Mayer, R.E., & Leutner, D. (1998). Supporting visualizer and verbalizer learning preferences in a second language multimedia learning environment. *Journal of Educational Psychology*, *90*, 25–36.

Quintana, C., Reiser, B.J., Davis, E.A., Krajcik, J., Fretz, E., Duncan, R.G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences*, *13*(*3*), 337–387.

Reiser, B.J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, *13*(*3*), 273–304.

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

Rewey, K.L., Dansereau, D.F., Dees, S.M., Skaggs, L.P., & Pitre, U. (1992). Scripted cooperation and knowledge map supplements: Effects of the recall of biological and statistical information. *Journal of Experimental Education*, *60*(*2*), 93–107.

Rosenshine, B., & Meister, C. (1994). Reciprocal teaching: A review of the research. *Review of Educational Research*, *64*(4), 479–530.

Rummel, N., & Spada, H. (2005). Learning to collaborate: an instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences*, *14*(*2*), 201–241.

Salomon, G. (1993). No distribution without individuals' cognition: A dynamic interactional view. In:

Salomon, G. (ed.), *Distributed cognitions: Psychological and educational considerations*. Cambridge University Press: New York City, pp. 111–138.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the Learning Sciences*, *1*(*1*), 37–68.

Scardamalia, M., & Bereiter, C. (1993/1994). Computer-support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*(*3*), 265–283.

Scardamalia, M., Bereiter, C., McLean, R.S., Swallow, J., & Woodruff, E. (1989). Computer supported intentional learning environments. *Journal of Educational Computing Research*, *5*, 51–68.

Schank, R.C. (1999). *Dynamic memory revisited*. Cambridge University Press: Cambridge.

Schank, R.C., & Abelson, R.P. (1977). *Scripts, plans, goals and understanding*. Erlbaum, Hillsdale, NJ.

Schellens, T., van Keer, H., Valcke, M., & deWever, B. (2005). The impact of role assignment as scripting tool on knowledge construction in asynchronous discussion groups. In: Koschmann, T., Suthers, D., & Chan, T.-W. (eds.), *Computer supported collaborative learning 2005: The next 10 Years*. Lawrence Erlbaum, Mahwah, NJ, pp. 557–566.

Schnotz, W. (2002). Towards an integrated view of learning from text and visual displays. *Educational Psychology Review*, *14*(*2*), 101–120.

Schwan, S. (1997). Media characteristics and knowledge acquisition in computer conferencing. *European Psychologist*, *2*(*3*), 277–285.

Sherin, B., Reiser, B.J., & Edelson, C. (2004). Scaffolding analysis: Extending the scaffolding metaphor to learning artifacts. *The Journal of the Learning Sciences*, *13*(*3*), 387–421.

Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. (1991). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. *Educational Technology*, *31*(5), 24–33.

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*(*2*), 183–219.

Sweller, J., Van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review 10*(*3*), 251–296.

Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *The Journal of the Learning Sciences*, *13*(*3*), 305–335.

Vekiri, I. (2002). What is the value of graphical displays in learning? *Educational Psychology Review*, *14*(*3*), 261–312.

Vygotsky, L.S. (1978). *Mind and society: The development of higher mental processes*. Harvard University Press: Cambridge, MA.

Vygotsky, L.S. (1992). *Thought and language* (rev. ed.). The MIT Press: Cambridge, MA.

Webb, N.M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, *13*, 21–39.

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

Wood, D., Bruner, J.S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *17*, 89–100.