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144

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Scripts and scaffolds in problem-based computer supported collaborative learning environments: Fostering participation and transfer

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Abstract

This study investigates collaborative learning of small groups via text-based computer-mediated communication. We analyzed how two approaches to pre-structure communication influence participation, individual knowledge transfer, the convergence of participation and the convergence of knowledge among learning partners. We varied the factor "scripted cooperation" and the factor "scaffolding" in a 2x2-design. 105 university students of Pedagogy participated. Results show that scripted cooperation was most and scaffolding least beneficial to individual transfer, knowledge convergence and participation in comparison to open discourse.

Keywords: Computer supported collaborative learning (CSCL), knowledge convergence, shared knowledge, participation, scripted cooperation, scaffolding, cues, cued interaction, computer-mediated communication, text-based communication

Zusammenfassung

Diese Studie befasst sich mit kooperativem Lernen in Kleingruppen über textbasierte computervermittelte Kommunikation. Es wurden zwei Ansätze der Vorstrukturierung von computervermittelter Kommunikation und ihre Auswirkungen auf Partizipation, individuellen Wissenstransfer, die Konvergenz der Partizipation und die Wissenskonvergenz innerhalb einer Lerngruppe untersucht. Dabei wurden die Faktoren "Kooperationsskript" und "Scaffolding" in einem 2x2-Design variiert. 105 Studierende der Pädagogik nahmen teil. Die Ergebnisse zeigen, dass sich das Kooperationsskript am günstigsten und das Scaffolding am wenigsten günstig auf individuellen Wissenstransfer, Wissenskonvergenz und Partizipation im Vergleich zu einer Kontrollgruppe des 'Offenen Diskurses' ausgewirkt hat.

Schlüsselworter: Computerunterstütztes kooperatives Lernen, Wissenskonvergenz, geteiltes Wissen, Partizipation, Kooperationsskript, Scaffolding, Cues, geführte Interaktion, computermediierte Kommunikation, textbasierte Kommunikation

SCRIPTS AND SCAFFOLDS IN PROBLEM-BASED COMPUTER SUPPORTED COLLABORATIVE LEARNING ENVIRONMENTS: FOSTERING PARTICIPATION AND TRANSFER

Problems of participation and transfer in computer supported collaborative learning (CSCL)

In collaborative, problem-oriented learning environments every member within a learning group is supposed to discuss and solve cases in an active and reflective way. However, several studies show that learning groups do not necessarily work well on their own (cf. Salomon & Globerson, 1989). Learning in open discussion rarely seems to result in equal participation on a high level and equally distributed high individual transfer. Collaborative learners often appear to diverge with regard to participation or learning outcome, i.e. some of the learners 'lurk' during group activities (social loafing or free-rider effect; Kerr, 1983). In other words, some learners profit by learning in a group, while other learners of the same group are left behind. Studies on computer-supported collaborative learning (CSCL) show that these negative effects are usually replicated or even increased in learning environments based on new technology (e.g. Fischer & Mandl, 2001; Weinberger & Mandl, 2001). This study investigates instructional means to support participation and individual transfer of knowledge in text-based CSCL environments. Moreover, we analyze to what extent convergence of participation and convergence of individual transfer of the learning partners can be fostered in text-based CSCL.

Participation

Problem-oriented as well as collaborative approaches to learning consider *participation* of learners as a major moderator or even indicator of learning success (Barab & Duffy, 2000; Cohen & Lotan, 1995). Output quantity can be related to the amount of aspects considered and the intensity of effort invested in collaborative reasoning about the learning task. It is well documented, for example, that students who give elaborated explanations to others profit most from collaborative learning environments (Renkl, Stark, Gruber, & Mandl, 1998; Webb, 1989).

Apart from participation per se, the lack of *participation convergence* can be regarded as a major problem for the social coherence of learning groups (Cohen &

Lotan, 1995; Mandl, Gruber, & Renkl, 1996; Weinberger & Mandl, 2001) as well as for the convergence of knowledge, presuming that participation is an indicator for learning success. Therefore, we need to investigate conditions of collaborative learning that foster the equal distribution of high and meaningful participation of learners.

Knowledge transfer

Situational learning approaches outline the idea of knowledge as a set of tools that need to be applied in problem-solving activities. This idea of knowledge stresses the ability to draw inferences about authentic tasks with the help of theoretical concepts. *Individual transfer of knowledge* is supposed to be facilitated by confronting students with problems and causing them to reflect upon problem cases with a given theory, e.g. in collaborative learning environments (Barab & Duffy, 2000; Collins, Brown, & Newman, 1989).

The question of *knowledge convergence* among peers has only recently entered the discourse of the learning sciences (Fischer & Mandl, 2001; Jeong & Chi, 1999). Now, not only the knowledge acquisition and learning outcome of the individual is focused, but also and in particular common ground and shared knowledge: How do learners influence the learning outcomes of their learning partners in the learning process and to what extent is knowledge socially shared in the learning outcome? Both factors can be subsumed under the processes and results of knowledge convergence. Convergence implies the approximation of learners' cognitive responses through collaboration (see Ickes & Gonzalez, 1996). Knowledge convergence among peers can be encouraged by shared resources and shared graphical representation tools (Fischer & Mandl, 2001). Influencing the learning discourse directly with cued interaction in order to facilitate knowledge convergence has not been subject to research yet.

Fostering collaborative learning by scripted cooperation and scaffolding

We assume that discourse activities of students are learning phenomena and learning promoters per se (cf. Leitão, 2000; Scardamalia & Bereiter, 1996; Vygotsky, 1978). We therefore consider the improvement of quantity and quality of the discourse of collaborative learners to be crucial for the learning outcome.

Fostering collaborative learning by scaffolding

Since learners often discuss on a low level and digress or argue about isolated and naive concepts only, interventions to pre-structure the contents appear to be very useful. Pre-structuring contents does not mean, however, to add contents or portray them in more detail. Contextual supports are rather described as a kind of scaffolding given to learners by experts of the domain in order to support them to take all relevant concepts into account (Collins et al., 1989; Winnips, 2001). Scaffolding might be particularly effective when learners are asked to apply theories to authentic problem-cases and vice versa.

Fostering collaborative learning by scripted cooperation

Apart from the content-oriented aspect of cognitive responses, a meta-communication component might be relevant for learning. As learners' spontaneous co-operation strategies often prove sub-optimal (Webb, 1989), educational researchers, e.g. O'Donnell (1999), pre-structured the learning discourse by means of scripts that provide learners with roles and induce them to perform particular interactions at a specified time.

Implementing scripted cooperation and scaffolding in computer-mediated communication

Scripted cooperation and scaffolding in traditional settings are accompanied by certain efforts, for example the effort of a didactic leader to model problem solutions or the need to train students in advance of any form of cooperation. Text-based, computer-mediated communication offers the possibility to structure the learners' discourse (Baker & Lund, 1997; King, 1998; Scardamalia & Bereiter, 1996) and can be designed to guide users through certain successive activities. Scaffolding and scripted cooperation can be implemented with the help of cues that are inserted into the messages of the learners beforehand in order to pre-structure communication and to possibly influence commitment to the collaborative learning task, reflection of the relevant concepts and thus also learning outcomes (for a description see below). The advantage of scaffolding and scripted cooperation realized with the help of cues which serve as a means to pre-structure discourse, is obvious: In contrast to well-known scaffolding and scripted cooperation methods, *cued scaffolding* and *cued cooperation scripts* can substitute extensive training and adaptive feedback by co-present experts. However, it has barely been subject to empirical investigation to what extent scripted cooperation and scaffolding implemented into the interface of an online learning environment may foster active participation of learners. Research is also necessary concerning the effectiveness of these methods in facilitating individual knowledge transfer and knowledge convergence among peers in a learning group.

Goals of the study

Based on this background, the study investigates the effects of cued scaffolding and scripted cooperation and their combination with regard to (1) participation and the convergence of participation within a learning group and (2) the individual knowledge transfer and knowledge convergence.

Method

Sample and design

105 students in their first semester of Pedagogy from the Ludwig-Maximilians-University of Munich participated in this study. The students, who were attending a mandatory introduction course, participated in an online learning session about attribution theory as a substitute for one regular session of the course. The theory of attribution (Weiner, 1985) is a standard curriculum content. Students were invited individually – each student to one of three different laboratory rooms. Each triad was randomly assigned to one of the four experimental conditions in a 2x2-factorial design. We varied the factors "scripted cooperation" (none vs. scripted co-operation) and the "scaffolding" (none vs. scaffolding).

Procedure

After having filled out a questionnaire and a pre-test consisting of a case task (20 min), the students were asked to individually study a three page description of the attribution theory (15 min). Then, the learners were briefly introduced to the respective cues and/or the handling of the learning environment (20 min). After this individual phase, the learners worked together on three cases (80 min). The collaboration was followed by an individual post-test which paralleled the individual pre-test, and another questionnaire (30 min). Time-on-task was 2 hours and 45 minutes in all four conditions.

Learning environment

In the collaborative phase, students in all conditions had to work together in applying theoretical concepts to three case problems, i.e. to jointly prepare an analysis for each case by communicating via web-based discussion boards (see Figure 1). They were asked to discuss the three cases against the background of the attribution theory and to jointly compose at least one final analysis for each case together, i.e. they usually drafted initial analyses, discussed them, and wrote a final analysis. The cases portrayed typical attribution problems of university students, e.g. a student interpreting his failure in an important test:

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

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

Cued scaffolding

When composing a new message, i.e. the initial contribution to a discussion thread, content-specific cues of scaffolding pre-structured the input window (see Figure 1), i.e. the learner's message already contained cues. These cues were questions about the case and are aimed at supporting the learners to identify the relevant case information, apply the concepts of attribution theory to case information, and make predictions and proposals for pedagogical interventions regarding the case. Thus, the students' task was basically to respond and jointly elaborate on the given cues.

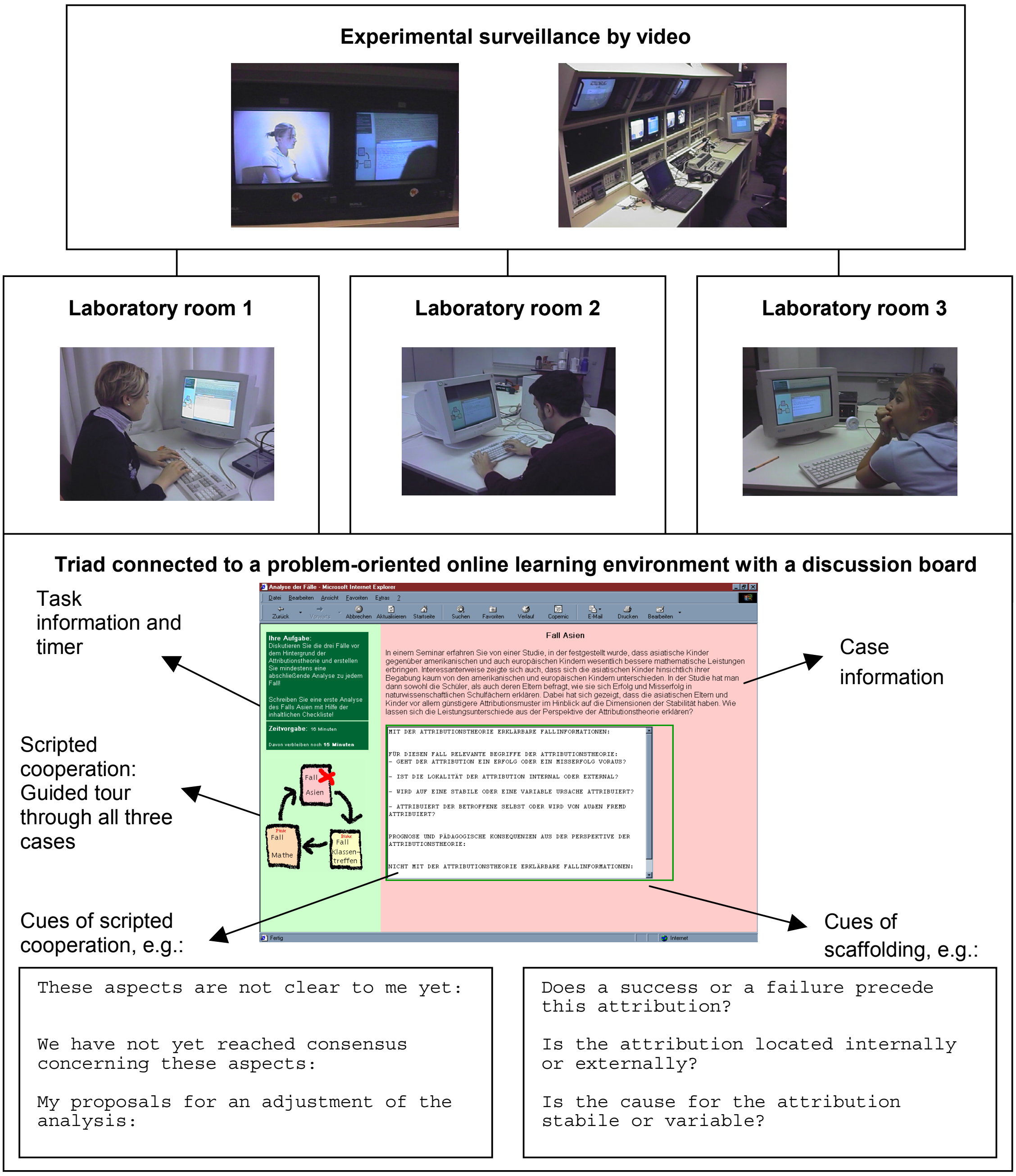

Figure 1: The experimental setup and the online learning environment. In the upper part you can see pictures of the video control center where the experiment was monitored. In the middle part you can see three participants in separate rooms communicating via a discussion board which is shown in the lower part of the figure.

Cued cooperation script

Each student in the scripted cooperation condition was assigned two roles: (a) analyzer for one of the cases and (b) constructive critic for the other two cases. Role (a) included taking over the responsibility for a preliminary and a concluding analysis of one case and responding to criticism by the learning partners. In their function of a constructive critic (role (b)), the learners had to criticize the analyses of the two other cases presented by the learning partners. These activities were supported by the cues of the cooperation script (see Figure 1), which were automatically inserted into the critics' messages and into the analyzer's replies in order to help learners successfully take over their roles. Students were given a time limit for each of the required activities. All in all, these activities lasted 80 minutes as in the groups without the script. The students were guided through all three cases and were asked to alternately play the role of the analyzer and of the critic.

Table 1: Result of the cooperation script for one of the three cases

Student A (analyzer)	Student B (critic)	Student C (critic)
Initial analysis		
	Constructive critique	Constructive critique
Replies to both critics		
	Constructive critique	Constructive critique
Final analysis		

The cooperation script determined the number of messages being produced for each case (see Table 1): All learners had to draft an initial analysis for one of the three cases (1st message), continue with the second case and write a critique of an initial analysis of one of the learning partners (2nd message), carry on with the third case and write another critique of an initial analysis of the other learning partner (3rd message), return to the 'own' case and compose two replies to the two critiques the learning partners have written in the meantime (4th and 5th message), carry on with the second case and respond critically to the defense of the analyzer of the second case (6th message), move on to the third case and do likewise (7th message), return to the own case and compose a final analysis (8th message). In a nutshell, the script suggested learners to write eight messages for each case: an initial analysis of the case, 4 critiques in total, 2 replies, and another final analysis.

Variables and data sources

In the following part, we will present all measures for participation, participation convergence, individual knowledge transfer and knowledge convergence. (1) *Participation*. During the learners' cooperation in the text-based communication learning environment, they produced written messages on a web-based discussion board. The number of these messages and the quantity of text produced by the learners, i.e. all words the participants wrote except the quoted content of prior messages, serve as measures for participation. (2) *Convergence of participation*. As an indicator for (un)equal distribution of participation in the triads, dissimilarity scores on the basis of standard deviations of participation were used. Thus, the convergence of participation was measured by the divergence of participation, i.e. the more divergence regarding participation, the less convergence and vice versa. Similar approaches are described in Cooke, Salas, Cannon-Bowers, and Stout (2000) and used in Fischer and Mandl (2001). (3) *Individual knowledge transfer*. After the cooperation, the learners were asked to analyze another case individually. They were asked to relate the concepts of the attribution theory to a transfer case. The analyses were then segmented and classified. The correct inferences were identified on the basis of an expert solution of the case. Inferences are defined as those segments of the learner's analysis, in which the learner relates theoretical concepts and case information. The inferences of the participants were weighted (non-elaborated and elaborated) and compared to the inferences in the expert solution. The sum of all correct inferences generated the learning outcome measure of transferred knowledge (Cronbach's α = .54). (4) *Knowledge convergence among peers*. The knowledge convergence score is based on the sum of shared inferences of the individual transfer case, i.e. inferences, which two or three participants of one group had in common in the individual transfer case (Cronbach's α = .61).

Controlled variables

With the help of a questionnaire we assessed prior knowledge, learning strategies, anxiety, uncertainty orientation, attitudes towards computers, interest and motivation.

An α-level of .05 was used for all statistical tests.

Results

Learning prerequisites

The individual experimental groups did not differ systematically with respect to prior knowledge, learning strategies, anxiety, uncertainty orientation, attitudes towards computers, interest or motivation.

Participation

The effects of the two factors and their combination are presented below with regard to *participation*, which was measured by the number of messages and the quantity of text (number of new words per minute). The script for cooperation actually determined the number of messages being produced. Eight messages were supposed to be written (see above for description). The minor deviations (see Table 2) can be explained by mistakes of operations or additional postings in the individual time frames. Due to the influence of the scripted cooperation, the equal distribution of variances of the number of messages is not warranted. We used the Kruskal-Wallis-Test for the analysis of this participation measure since the requirements for parametric tests are not met.

Table 2: Participation in the experimental conditions.

Measure of participation	Open discourse M (SD)	Scaffolding M (SD)	Scripted cooperation M (SD)	Scaffolding + Scripted Cooperation M (SD)
Number of messages	15.93 (7.23)	11.07 (6.09)	8.50 (0.93)	8.22 (1.45)
Quantity of text (words per min.)	6.11 (2.84)	7.61 (3.21)	9.50 (2.39)	8.19 (2.07)

Table 2 suggests that in open discourse more messages were sent with fewer new words compared to the other experimental conditions. The differences, portrayed in this table, are significant with $\chi^2(3) = 38.08$ ($p < .05$) concerning the number of messages. With regard to the quantity of text by words per minute, portrayed in Table 2, one can observe a main effect of the script ($F(1,101) = 14.42$; $p < .05$) and an interaction effect of both treatments ($F(1,101) = 7.24$; $p < .05$). The scaffolding shows no effect ($F(1,101) = 0.29$; n.s.) regarding the quantity of text.

In open discourse, the learners were not restricted to a certain amount of messages. Considering the quantity of text being produced, the learners apparently needed to post small coordinating messages. Furthermore, this ratio of produced messages to words suggests 'me-too'-messages, i.e. messages that quoted original postings and contained a short sign of agreement like "I agree" or "Me too" in open discourse. This needs to be verified by a detailed discourse analysis. The script facilitated participation and supported the learners in producing more text.

The effects of the two factors and their combination are presented below with regard to the *convergence of participation* or divergence respectively, which is measured by the standard deviations of the number of messages and the quantity of text. Again, the non-parametric Kruskal-Wallis-Test was used due to unequal variances of the number of messages.

Table 3: Divergence concerning the participation within groups (please note: low divergence scores indicate high convergence).

Measure of participation	Open discourse M (SD)	Scaffolding M (SD)	Scripted cooperation M (SD)	Scaffolding + Scripted Cooperation M (SD)
Divergence of number of messages	4.62 (2.67)	3.77 (3.57)	0.55 (0.68)	0.94 (0.66)
Divergence of quantity of text	2.41 (1.33)	1.87 (1.11)	2.01 (0.62)	2.20 (0.64)

The script causes the learners to diverge less with respect to the number of messages (see Table 3). However, the learners with the scaffolding showed more convergence concerning the quantity of text than the groups with open discourse. The differences regarding the convergence of the number of messages are significant $\chi^2(3) = 18.49$ ($p < .05$), but no significant differences are found for the convergence of quantity of text, i.e. there are neither main effects of the scaffolding ($F(1,31) = 0.27$; n.s.), or the script ($F(1,31) = 0.10$; n.s.), nor is there an interaction effect ($F(1,31) = 1.19$; n.s.).

The trend of the participation convergence shows that the scripted cooperation condition fosters the convergence regarding the numbers of messages, but the scaffolding appears to have enhanced the convergence of participation regarding the actual quantity of text (see Table 3). Of course, it is easier to reach convergence on a lower than on a higher level and learners did produce less text in the scaffolding than in the script condition.

Knowledge transfer

The effects of the two factors and their combination are presented below with regard to the *individual transfer of knowledge*. Measures are represented by z-scores.

Table 4 shows that the learners in the experimental group provided with scaffolding gained less knowledge than learners of any other group. A main effect of the scripted cooperation results, however, in a greater gain of knowledge compared to the other treatments.

Table 4: Individual learning outcomes in the experimental conditions.

	Open discourse M (SD)	Scaffolding M (SD)	Scripted cooperation M (SD)	Scaffolding + Scripted Cooperation M (SD)
Transferred knowledge	-.06 (.73)	- .35 (.63)	.70 (1.41)	- .21 (.82)

An univariate analysis of the transferred knowledge showed two main effects of the script and the scaffolds. However, as Levene's test of equality of variances proves significant, the non-parametric Kruskal-Wallis-test has to be applied. This test proves that the differences shown in Table 4 are substantial ($\chi^2(3) = 8.58$; $p < .05$). The triads with the scripted cooperation use significantly more and the triads with the scaffolding fewer correct inferences than the triads in open discourse.

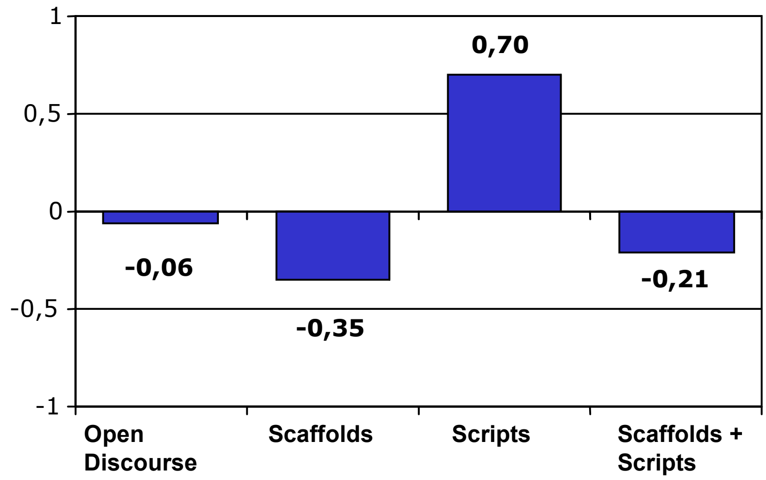

Figure 2: Individual learning outcomes in the experimental conditions.

So far, the findings suggest that individual learning transfer was fostered by scripted cooperation, in comparison to open discourse (see Figure 2). The learners with the cued scaffolding did not draw as many correct inferences in the transfer case as the learners in the open discourse.

Effects of the two factors and their combination with respect to *knowledge convergence* are presented below with z-scores.

Table 5: Convergence of transferred knowledge within the groups.

	Open discourse	Scaffolding	Scripted cooperation	Scaffolding + Scripted Cooperation
	M (SD)	M (SD)	M (SD)	M (SD)
Knowledge convergence	- .15 (.67)	-.45 (.72)	.96 (1.34)	- .25 (.68)

The scripted cooperation affects the convergence of knowledge ($F(1,31) = 4.85$; $p < .05$), as well as the scaffolding ($F(1,31) = 6.41$; $p < .05$). The combination of both, however, does not show a substantial effect ($F(1,31) = 2.39$; n.s.).

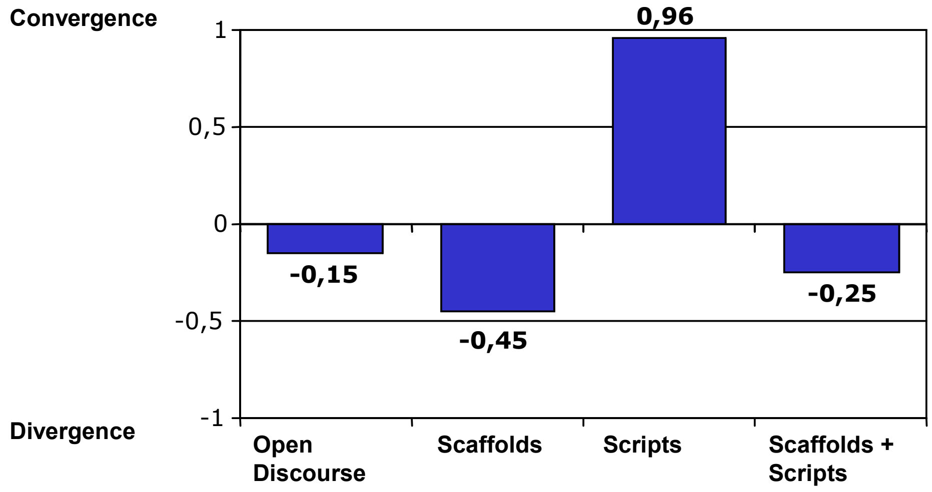

Figure 3: Convergence of transferred knowledge within the groups.

These results (see Figure 3) suggest that scaffolds and scripts may influence knowledge convergence in a learning group. The scaffolding seemed to be least beneficial to knowledge convergence, while the script induced more knowledge convergence.

Conclusion and outlook

The findings show that participation, participation convergence, individual knowledge transfer and convergence of knowledge can be influenced not only by the preliminary training and moderation of collaborative learning, as studies have shown before (O'Donnell, 1999; Scardamalia & Bereiter, 1996), but also by the cue-based implementation of scripted cooperation and scaffolding into an online learning environment that structures the learning discourse itself.

The cued cooperation script proved to support the learners substantially compared with the open discourse. Regarding *participation*, it was found that fewer messages with more words were sent in the scripted discourse. This may indicate that the learners provided with the script were relieved of coordination tasks and were able to focus on the task at hand to jointly analyze the cases. Since meaningless chat affects the variable of participation, too, this may only give a first orientation. Still, the learners provided with the cued cooperation script participated substantially more since they produced more text. Furthermore, the results clearly show that a *convergence of participation* regarding the number of messages could be attained with the help of the script. Encouraging results of the cued cooperation script were also found with respect to *individual knowledge transfer* – it was possible to replicate the positive effects of former research on scripted cooperation (Rosenshine, Meister, & Chapman, 1996) with scripted cooperation implemented with cues. Subsequent research questions should focus on how scripted cooperation influences the individual transfer of alternative and incorrect inferences. Maybe scripted cooperation promotes unintended individual transfer as well, depending on what is discussed in the learning group. Apart from the individual learning outcomes, the script obviously facilitated *knowledge convergence* as well. The learners appeared to be encouraged to confront their ideas with their partners' perspectives, reflect on the differences of perspectives, and sometimes modify their initial point of view.

A *cued scaffolding* of problem-oriented collaborative learning did not show substantial effects on *participation* or *participation convergence*, but was significantly least beneficial to the *individual knowledge transfer* in comparison to the other treatments. This can be ascribed to several reasons: While the scaffolding may have supported the participants in solving cases during the collaborative phase, it might not have fostered the transfer since important processes of learning failed to take place. The learners probably relied too much on the scaffolding after all. The scaffolding may have substituted processes of reflective thinking about the cases. Like a checklist, it may have facilitated the identification and problem solving, but did not support the participants in developing a conceptual understanding of their own. Another explanation could be that the list of scaffolding cues needs to be adapted to a novice perspective. To clarify these hypotheses, two steps are necessary: First, the analyses of the cases solved collaboratively have to be considered. The learners given the scaffolding might have drawn more correct inferences during their work on the collaborative cases than during the individual post-test cases. The integral part of scaffolding must then be the fading of this support as outlined by Collins et al. (1989). Second, in order to refine the scaffolding, the reasoning of novice learners while solving problem cases needs to be documented and taken into account. Furthermore, the scaffolding reduced the *convergence of knowledge* substantially. Maybe the scaffolding rather fostered individual approaches to solve the cases. A joint effort to reflect on the application of theoretical concepts to case information may not have appeared relevant to the learners as the scaffolding suggested an individual approach to solve the cases. This, too, needs to be confirmed or rejected by process analyses.

To extend the focus to the quality of the processes of collaborative learning is vital to the analysis of knowledge convergence. Therefore, we are currently investigating the discourse regarding collaborative knowledge construction. Discourse will also be analyzed concerning the focus of contents and the formal structure of the collaborative reasoning in text-based CSCL. As stated above, the concept of knowledge convergence is deeply rooted in the idea of discourse as externalization of reasoning. Therefore, with the analysis of the quality of the discourse regarding content and collaborative reasoning, conclusions can be drawn for the processes of sharing knowledge.

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