# Fading Scripts in Computer-Supported Collaborative Learning: The Role of Distributed Monitoring

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**Abstract:** Computer-based collaboration scripts constitute a form of distributed control and disburden the learners from the regulation of their performance, which they must internalize in order to acquire cognitive skills such as argumentation. Accordingly, without further support, e. g. by distributed monitoring by a learning partner, fading may be ineffective. Therefore we examined whether fading fosters skill acquisition only in combination with collaborative support. In an experimental study with the factors fading and distributed monitoring, learners were supported in an online discussion forum by a collaboration script for the production of counterarguments. Results show that fading fostered the acquisition of declarative knowledge about argumentation only in combination with distributed monitoring, whereas with regard to procedural knowledge about argumentation there were no differences. These results indicate that fading supported by aspects of computer-supported collaboration can increase the effectiveness of fading for skill acquisition even in early stages of skill acquisition.

## Collaboration Scripts as Process-related support in CSCL to foster the acquisition of cognitive skills

Forms of process-related support have been developed for computer-supported collaborative learning to induce productive collaborative activities, such as the resolution of socio-cognitive conflict, transactive discussions or well-grounded argumentation, and thereby increase the acquisition of knowledge and skills (King, in press). One specific type of process-related support are collaboration scripts (Kollar, Fischer & Hesse, in press; cf. also Kobbe et al., subm.): Collaboration scripts are directed towards specific *goals* for learning in the collaborative situation, specify *activities* that are functional for these goals, *sequence* them and assign them to different *roles*. Furthermore, collaboration scripts can be *represented* differently. These representations may be "internal" as knowledge of the persons involved in the collaboration (scripts as format for the representation of knowledge, cf. Schank & Abelson, 1977), or "external", e. g. on prompt cards or as prompts in the graphical user interface of a computer-supported learning environment. In the case of external representation collaboration scripts constitute a form of distributed control (cf. Perkins, 1993) of collaborative activities (Carmien, Fischer, Fischer, & Kollar, in press): The externally represented script contains the information necessary to coordinate the collaborative activities of the participants. To conduct these activities, however, the participants have to rely on their own knowledge on how to perform the activities induced.

Often, collaboration scripts are not primarily aimed at fostering the acquisition of domain-specific knowledge, but at the same time also the acquisition of skilled performance of the collaborative activities shaped by the script. From the perspective of theories of cognitive skill acquisition, the acquisition of a cognitive skill often departs from a process of problem-solving by using *declarative knowledge* that is then gradually transformed into *procedural knowledge* after repeated performance (VanLehn, 1989). Of this knowledge, one type is required to construct a hierarchy of sub-goals necessary to solve the problem at hand, whereas a second type of knowledge is related to how to accomplish the single sub-goals (cf. Anderson, 1987, p. 198). While the knowledge necessary for the accomplishment of the sub-goals is presupposed by computer-supported scripts that specify activities that are supposed to be mastered by the learners, the second type often is represented in the elements of the interface used to implement the script (e. g. text boxes, prompts, graphical representations of a procedure) to a large extent and needs to be internalized by the learners to acquire the strategy contained in the script. To be sure, also aspects of declarative domain-specific knowledge may be represented in scaffolds provided by the interface, but these may be less likely to negatively affect the acquisition of cognitive skills, as we assume against this theoretical background.

In the current context, we investigate a skill that is central to CSCL research: the skill of argumentation. In this study, we particularly focus on one specific aspect of argumentative skills, i. e. the skill to contribute counterarguments. In an online-discussion, counterarguments can be contrived by means of a strategy that comprises the following steps: Identifying a claim in a contribution of a learning partner, identifying a corresponding argument, de-

termining the type of the claim, determining the type of the argument, checking the conditions required for the argument to be relevant for the claim (cf. Naess, 1966) and formulating the answer. The learners are supposed to transform this sequence into a cognitive skill.

Types of claims that frequently occur in problem-based learning in the domain of psychology are, for example, diagnoses and recommendations of interventions. What can be regarded as a good argument for or against a specific claim depends on the type of the claim at issue (cf. Toulmin, 1958). Claim-specific knowledge about argument schemata is used during skill execution to adapt the following sub-goals in a content-specific manner depending on the previous processing: For example, after determining the type of a claim one can set the sub-goal to check whether the argument belongs to one of the argument types that fit the claim type.

## Fading of collaboration scripts – can the learning partner help?

It is regarded as important to reduce external support gradually (fading) in order to leave room for self-directed performance of the skills to be acquired (e. g. Pea, 2004; Puntambekar & Hübscher, 2005). The idea of fading originated from behavioural approaches and has been research intensely in the area of learning disabilities (Demchak, 1990). However, it has also been taken up by cognitively-oriented researchers: A cognitive line of argument for the necessity of fading for learning claims that also the retrieval of knowledge has to be practiced and therefore the informational content of prompts needs to be reduced in order to provide the learners with opportunities to practice the retrieval of knowledge for the regulation of their behaviour (Riley, 1995). In the context of situated approaches, fading is considered in close relationship with scaffolding: Learners are supported in dealing with tasks that would be too difficult to them without support. By gradually reducing the support, however, they build the necessary competencies (Collins, Brown & Newman, 1989). In the area of the acquisition of cognitive skills, fading is applied successfully to learning from worked examples (Renkl & Atkinson, 2003). In this context, in a series of analogously structured worked examples, more and more steps of the problem-solving process are left out (e. g. Atkinson, Renkl & Merrill, 2003). A further example from the field of cognitive skills is Leutner's (2000) „double-fading support" approach. Here fading is regarded as an opportunity to learn the "management of mistakes" and takes place on two levels: On the one hand, the degree of detail in the instructions for the use of a software application is gradually decreased, on the other hand, the degree of simplification of the application by the blocking of functions is reduced. Also in this context fading has proven effective for learning. These studies provide some preliminary support for the idea that fading may also foster the acquisition of cognitive skills by means of scripts.

However, approaches to cognitive skill acquisition assume that the acquisition of procedural knowledge is based mainly on knowledge application during problem-solving (e. g. Anderson, 1982). Furthermore we assume that the type of knowledge responsible for the control of the execution of the skill is provided by the script, which delivers the sub-goals to the learner in a "ready-made" fashion, and is accordingly taken over by it to a large extent, Therefore, one would have to expect that the learners will not internalize control knowledge *before* the fading starts and fail to control the performance of the skill to be acquired *after* the fading starts. This may even hold for declarative knowledge underlying the skill, which is assumed to play an important role in early phases of skill acquisition (Anderson, 1982).

Therefore the question arises how learners can be supported early in the learning process to take over the control of their performance. According to the approaches to skill acquisition outlined above, the kind of knowledge required for this would most likely be acquired if learners were stimulated to use and *apply* this knowledge themselves, i. e. to derive sub-goals themselves independently of the prompts in the script already while the complete script is still available.

Interestingly, the role of collaboration in fading and in skill acquisition has rarely been explored. Ideally, computer-supported collaboration may play a crucial role in fading. One obvious possibility to encourage learners to derive sub-goals could be monitoring by a learning partner in the sense of distributed metacognition (King, 1998). Being monitored in one's performance might facilitate to think of the steps to be performed already during the formulation of their contributions in order to avoid negative feedback from their learning partners. An effect of this kind has already been demonstrated for feedback by teaching persons: In a study by Vollmeyer and Rheinberg (2005), the mere expectation of feedback increased the quality of the strategies applied. Moreover, the feedback on one's own performance is likely to improve performance significantly (Kluger & DeNisi, 1996). In CSCL environments, there are several interesting possibilities to enhance this process of distributed monitoring. In particular, technology can support the monitoring partner to access and review specific information about the process of the colla-

borator's performance. For instance, specific information that makes transparent how a learner proceeded in contriving a critical reply, can be made available to the learning partner. Furthermore, the learning partner can be supported by elements in the interface to provide focused feedback on the learners' performance. In addition, monitoring can be supported by the technology through prompting and hinting with respect to the aspects of the performance that should be focused on.

It is the *goal of this study* to investigate, how fading of collaboration scripts affects the acquisition of a cognitive skill, and to what extent computer-supported collaboration – implemented in the form of distributed monitoring– would mediate these effects.

## Research questions
The research questions of this study were the following:

(1) Do the fading of scripts and distributed monitoring interact with respect to the acquisition of declarative knowledge underlying a cognitive skill?

(2) Do the fading of scripts and distributed monitoring interact with respect to the acquisition of procedural knowledge underlying a cognitive skill?

It was expected that the acquisition of the both the declarative and the procedural knowledge underlying a skill is fostered by fading only in combination with distributed monitoring.

## Method

### Participants and design
The participants of the study were 120 students in courses in educational science and teacher preparation who attended a lecture with the title "introduction to educational psychology". They were randomly grouped in dyads who discussed on separated online discussion boards during the collaborative learning phase.

A 2x2 design with the factors fading and distributed monitoring was implemented (see table 1).

Table 1: Design of the study.

| | | Fading | |
|---|---|---|---|
| | | No | Yes |
| Distributed monitoring | No | 12 dyads | 18 dyads |
| | Yes | 13 dyads | 17 dyads |

### Learning environment and material
The two learners in each group dealt with cases on the application of Weiner's attribution theory in a text-based online discussion board (described, e. g., in Weinberger, 2003). They were told that they were discussing analyses of these cases in groups of four and that two of the other learners had the task to write these analyses. The learners themselves were asked to write critical replies to each of theses analyses and could discuss online any questions that came up during this task. In fact, six case analyses that were developed on the basis of authentic material from earlier studies with at least two questionable claims in each were posted to the board under the names of the two would-be group members at fixed points in time. As a preparation for this cooperative learning session, the learners read a three-page text on Weiner's attribution theory and a four-page text on how to construct counterarguments in the critical replies.

The script supported the learners in the process of formulating counterarguments against the prepared case analyses by providing instructions on how to analyze the argumentation in the case analyses and to discover proble-

matic assumptions. It was implemented in the interface (cf. figure 1), which contained three kinds of script-related information: sequence information, argument schemata and application support. In the upper left-hand corner, the case analysis to be criticized was displayed.



Figure 1. Implementation of the script in the interface of the online discussion board
Important terms:
"These" – claim, "Typ der These" – type of claim, "Typ des Arguments" – type of argument,
"Relevanzbedingung" – condition required for the argument to be relevant for the claim,
"Gegenargument" - counterargument

*Sequence information* described the process of analyzing the argumentation in the prepared case analysis and the construction of a critical reply to it. It specified the next step in the sequence already mentioned: Identifying a claim in a contribution of a learning partner, identifying a corresponding argument, determining the type of the claim, determining the type of the argument, checking the conditions required for the argument to be relevant for the claim, and formulating the answer. Sequence information was implemented in the interface as prompts that changed according to the state of the editing. These prompts were displayed in darkly coloured areas that highlighted the interface element in which the step should be performed, as shown in figure 1 for the step of checking the conditions required for the argument to be relevant for the claim

*Argument schemata* contained information on what types of argument are appropriate to support the identified type of claim and what conditions of relevance need to be fulfilled for an identified pair of argument and claim, which was crucial for the assessment of the argumentation in the case analysis. These schemata were implemented by means of selection fields for the type of the claim and the argument, which constitute the second row of boxes in figure1, as well as by a prompt for the assessment of the condition of relevance, displayed above the highlighted box for the assessment of the conditions required for the argument to be relevant for the claim in figure 1. The options in

the field for the argument type was adapted according to the type of claim selected in the corresponding selection field, and so were the prompts for the assessment of the conditions of relevance according to the type of argument selected in the corresponding selection field. Accordingly, the specific content of script support branched depending on the selections made by the students on earlier steps.

*Application support* was provided by explanatory sentences for the terms used in the prompts and selection fields of the script as well as examples for the respective types of propositions (in accordance with the text on how to construct counterarguments in the critical replies). They were shown in the interface directly next to the respective control elements in lightly coloured text areas, as shown to the left of the box for the assessment of the conditions of relevance in figure 1.

At the bottom, the interface contained a textbox for editing the message, which was pre-composed based on selection and inputs made on earlier steps, as shown at the bottom of figure 1.

## Operationalization of the independent variables

### Fading.
As the specific content of the script support branches depending on the identified types of claim and argument, the elements of the script could be faded only after the learners could be expected to have selected the respective branch at least one time. Based on the design of the prepared case analyses, this could be expected after the posting of two contributions. For the branching of the specific content of the script support, unequivocal input was required. Accordingly, the interface elements corresponding to earlier steps of the script (e. g. the selection box for the classification of the claim) could not be faded befor the interface elements corresponding to the later steps of the script (especially the prompts aimed to support the checking of the conditions required for the argument to be relevant for the claim). The fading conforme dot the following schedules for the three kinds of information contained in the script:

The *application support*, i. e. the explanatory sentences designed to clarify the terms used in the prompts and selection fields of the script as well as examples for the respective types of propositions, disappeared completely after the second critical reply a learner posted with support of the script.

The *sequence information* prompts were faded in the following way: Ater the second critical reply posted with support of the script, two randomly chosen prompts for the next step were replaced by an unspecific prompt in each round. This unspecific prompt read as follows: "Please perform this step on your own." This entails, that after five critical replies posted with support of the script only this unspecific request was shown before each step.

The *argument schemata* were gradually reduced in a "backward" fashion after the second critical reply a learner posted with support of the script: On the third occasion, in which the learners constructed a critical reply a learner with support of the script, the specific question concerning the fulfilment of the condition of relevance (step 5) was replaced by an unspecific one. Starting with the fourth occasion, the selection field for the type of the argument did no longer contain any options, but the learners had to fill in the type of the argument themselves. Starting with the fifth critical reply constructed with support of the script, the selection field for the type of the claim did no longer contain any options, but the learners had to fill in the type of the claim themselves. After 70 minutes, finally the students were provided only with a simple text box for the formulation of their critical replies to the case analyses as customary in asynchronous discussion boards.

### Distributed monitoring.
In the conditions with distributed monitoring, one of the learning partners had the task to provide the other learner with feedback for each of his or her critical replies to the case analyses, based on which the other learner was asked to revise his critical reply. During the formulation of the feedback, the learning partner was supported by the interface: By simply clicking on check boxes, feedback on the completeness of the six steps of the sequence for the construction of a counterargument, on the appropriateness of the identification of the types of claim and argument, and on the correctness of the answer to the question concerning the condition of relevance could be given. Furthermore there was the opportunity to add free text remarks. The distributed monitoring was continued after the start of the fading, i. e. the learners in these conditions were continuously provided with feedback on their procedure during the formulation of critical remarks.

## Procedure

The collection of data was conducted in a series of sessions of three hours of length with 20 students each. These were distributed over two rooms in such a way that the learning partners who collaborated online sat in different rooms. After a short introduction into the purpose and procedure of the study, the participants filled in an online questionnaire (5 min) and read the texts on attribution theory (8 min). Then they were asked to write critical remarks against an attribution-theory-based analysis of a case from educational practice (10 min). After that, they read a text on how to construct counterarguments (12 min), which was printed on worksheets they could keep until the end of the learning phase. The collaborative learning phase started with an introduction and a demo video on how to use the learning environment (11 min). After a short break, the collaboration phase in the different experimental conditions followed (80 min). Finally, online post-tests for declarative and procedural knowledge about the construction of counterarguments as well as several control-measures were administered (40 min).

## Dependent variables and instruments

The test for *declarative knowledge about the construction of counterarguments* asked for information given in the text on how to construct counterarguments and in the script (e. g. "Please enumerate the steps necessary to produce a counterargument."). The free answers were coded according to mentions of the steps of the script (see above). The number of correctly remembered elements was used as the test score.

For the measurement of *procedural knowledge about the construction of counterarguments*, the learners were individually given a case analysis as during the collaborative learning phase and had the task to produce as many counterarguments against it as possible. Then, with respect to one of the counterarguments that were possible in the reply to the case analysis, they were asked for the results of the single cognitive operations regarded as necessary to contrive this counterargument (e. g. "Please identify the type of the following sentence: 'Therefore, also in the forced course of bioinformatics she will not be motivated much.'"). These five items were intended to measure independent procedural knowledge components underlying the cognitive skill to produce counterarguments. Accordingly, it should not be possible to aggregate them to form one internally consistent scale. Rather, they should be included as distinct indicators of procedural knowledge about the construction of counterarguents in multivariate analyses.

## Results

### Research question 1: Interaction between fading and distributed monitoring with respect to the acquisition of declarative knowledge underlying a cognitive skill

The results for research question 1 concerning the interaction between fading and distributed monitoring with respect to the acquisition of declarative knowledge underlying a cognitive skill are presented in figure 2. The x-axis displays the two values of the fading factor, while the separate lines in the graph represent the distributed monitoring factor. On the y-axis, the score in the test for declarative knowledge about argumentation that asked for a description of the six steps involved in contriving a counterargument is displayed. Scores could range from zero to six. As we had hypothesized, the learners in the condition with both fading and distributed monitoring outperformed those in the group with fading only. Learners in the condition with fading only scored higher than the groups without fading and distributed monitoring and without fading and without distributed monitoring. The interaction between fading and distributed monitoring was significant ($F(3; 56) = 6.80$; $p < 0.01$; $\eta^2 = 0.267$). We further tested, whether the group with both fading and distributed monitoring demonstrated more declarative knowledge underlying the skill in the post-test than the three other groups. As the prerequisites for parametric tests were not fulfilled, a Mann-Whitney U test was applied. The difference between the learners in the combination condition and the learners in the other three conditions turned out to be significant ($U = 162.5$; $Z = -3.60$; $p < 0.001$).

### Research question 2: Interaction between fading and distributed monitoring with respect to the acquisition of procedural knowledge underlying a cognitive skill

With respect to the procedural knowledge underlying a cognitive skill, the items measuring the occurrence of the single cognitive operations hypothesized to underlie the skill turned out to be independent from each other as intended. This means that, as intended, they did not constitute an internally consistent scale. Accordingly, they were used as separate indicators of procedural knowledge about argumentation in a multivariate analysis of variance. This analysis showed that there were no significant differences between any of the experimental conditions with respect to procedural knowledge about argumentation (Hotelling's Trace: $F(15; 149) = 0.388$; n. s.; $\eta^2 = 0.038$).
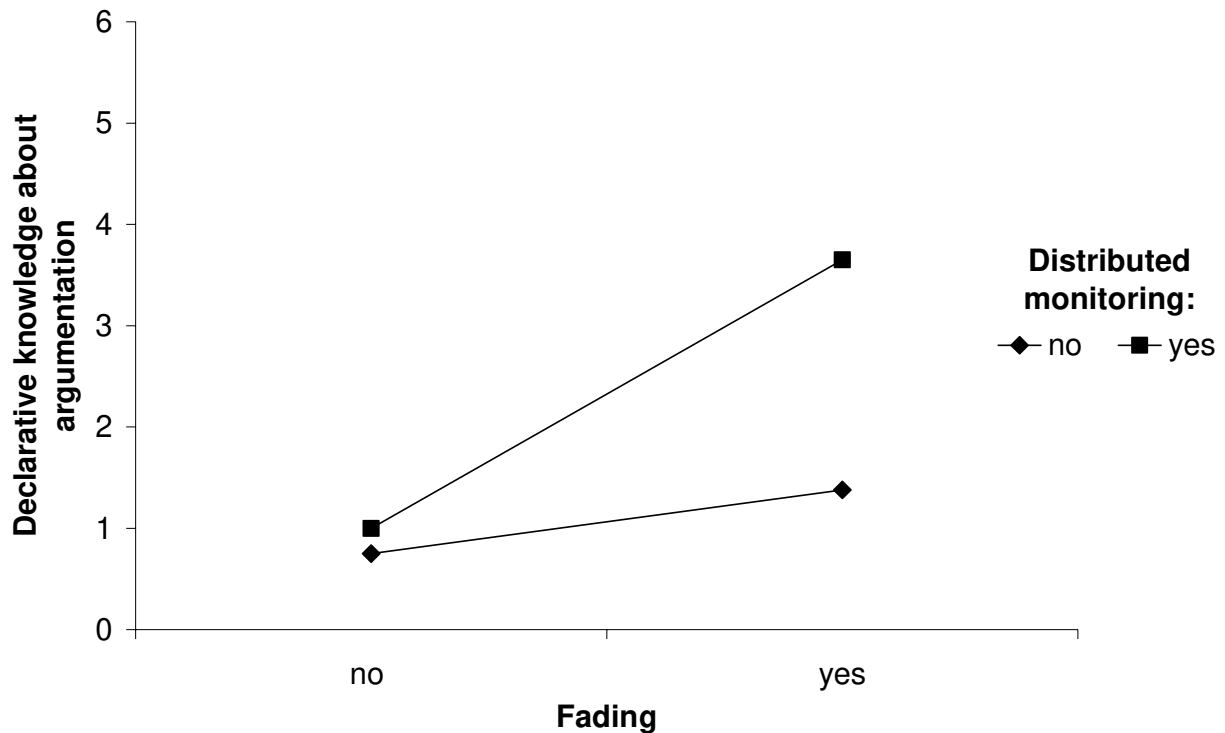
Figure 2: Declarative knowledge about argumentation in the four conditions

## Discussion

With respect to the declarative knowledge underlying the cognitive skill of producing counterarguments, the results of this study confirmed our expectation that fading fosters learning only in combination with additional support such as distributed monitoring. Here computer-supported collaborative learning can add to the effectiveness of skill acquisition by coordinating the distribution of metacognitive aspects relevant for the internalization of knowledge embodied in a script. In particular, learners may receive support for taking over the control of their activities early in the learning process through collaboration that is facilitated by computer support.

With respect to the procedural knowledge underlying the cognitive skill, the corresponding hypothesis could not be confirmed. This negative finding could be possibly explained by the duration of the learning phase that might have not allowed most learners to enter the stage of skill acquisition in which declarative knowledge becomes proceduralized (Anderson, 1982). However, contrary to assumptions in the fading literature according to which fading should be most effective in later phases of skill acquisition (e. g. Renkl & Atkinson, 2003), our findings indicate that, under certain conditions, fading can bring advantages already in early stages of skill acquisition. These conditions include additional support for learners to take over the control of the performance of the skill to be acquired while the entire script is still available. Thereby it could be demonstrated that collaboration, in particular distributing aspects of metacognition such as monitoring among learners, can play an important role in helping learners to take over the self-regulation of their behaviour while support is gradually decreased. In some cases at least, merely reducing the support does not seem to be enough.

At least one further explanation for the negative result concerning procedural knowledge is possible: The students in the condition with both fading and distributed monitoring might have learned what to do and when to do it without having learned how and why to do it (cf. Brown, 1978; Veenman, Van Hout-Wolters & Afflerbach, 2006). This touches on two issues:

On the one hand, the script may have provided the learners with a strategy the components of which are not in the repertoire of the learners. So the failure of the students in the conditon with both fading and distributed monitoring to perform according to their declarative knowledge (i. e. demonstrate the corresponding procedural know-

ledge) may be a result of a lack of lower-level procedural knowledge, e. g. on how to check the conditions required for the argument to be relevant for the claim. Information about how to achieve this was provided in the introductory text on how to construct counterarguments as well as in the script, but it may not have been proceduralized in the course of the collaborative learning phase. Accordingly, higher-level procedural knowledge could not have been demonstrated in the post-test.

On the other hand, the learners may have failed to acknowledge the usefulness of the strategy contained in the script compared to their own prior argumentative competencies. For example, they may regard the skill to produce counterarguments as unimportant or the strategy itself as not helpful, believe that they will have resources similar to the script available when they will have to produce counterarguments in the future, or be rather confident in their own argumentative competencies. Each of these beliefs might lower the willingness to go beyond the acquisition of declarative knowledge underlying the skill to produce counterarguments.

Further analyses of the processes of learning and collaboration are required, both for providing a more detailed description of the learning processes that lead to differences in the acquisition of declarative knowledge and for deciding between the explanations offered for the absence of differences with respect to the acquisition of procedural knowledge. In order to establish whether failures in acquiring procedural knowledge are due to the unavailability of the operations that make up the strategy contained in the script, these analyses should focus on whether the learners' activities while they are guided by the script correspond to what was intended by the design of the script. In order to assess whether distributed monitoring functions in the way hypothesized, the learners' performance on steps that are no longer specifically prompted in the process of fading needs to be evaluated according to its correspondence with the strategy from the script. Furthermore, as studies show that these competencies develop over longer periods of time, (Kuhn, Shaw & Felton, 1997) the investigation of the acquisition of argumentative competencies supported by scripts and their fading should also be stretched in time to capture growth that occurs more slowly.

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