Fading Instructional Scripts: Preventing Relapses into Novice Strategies by Distributed Monitoring

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Abstract: During the fading of instructional scripts learners might relapse into their initial novice strategies after script prompts are withdrawn. One possibility to overcome this problem could be a learning partner providing distributed monitoring of the performance of the strategy suggested by the script. In a 2-factorial experiment with the factors fading and distributed monitoring that involved 126 students of educational science we investigated whether during the fading of an instructional script there is a moderating effect of distributed monitoring on the performance of the strategy and thereby on the acquisition of the cognitive skill of argumentation. Strategy knowledge was fostered best by the combination of fading and distributed monitoring. Distributed monitoring also kept the performance of some aspects of the strategy at higher levels during fading, which was positively related to the acquisition of strategy knowledge.

Theoretical background

Argumentation as a cognitive skill

In the literature on cognitive skill acquisition, a skill is typically regarded as a system of procedural knowledge that can be described by a set of production rules (e. g. Newell, 1990; Anderson & Lebiere, 1998). Each single procedural knowledge component described by a production rule can fulfil at least one of two functions: It can regulate the execution of the skill by setting subgoals, or it can directly contribute to performance by helping accomplish these subgoals (cf. Anderson, 1987). The main mechanism for acquiring a unit of procedural knowledge according to these theories is applying it (Anderson & Lebiere, 1998).

Argumentation competence can be regarded as a cognitive skill. On the basis of a cognitive task analysis, the ability to arrive at a counterargument against the relevance of someone else's argument for a specific claim (as one aspect of argumentation competence) can be described as a series of subgoals that can be accomplished by procedural knowledge that implements argumentation schemes (Wecker, 2008): (1) the identification of a claim in someone else's utterance, (2) the identification of an argument put forward to support the claim, (3) the identification of the type of the claim, (4) the identification of the type of the argument, (5) a check of the fulfilment of the conditions of relevance of the argument with respect to the claim, and (6) the formulation of a counterargument on the basis of the results of the analysis conducted in steps 1 to 5. Accordingly, the specific aspect of argumentation competence mentioned above involves strategy knowledge about this series of steps.

Learners may be supported by means of an instructional script to apply such a strategy while engaging in collaborative learning (e. g. Stegmann et al., 2007). As long as they do not master the strategy, they use general-purpose productions to interpret these instructions (Taatgen, Lebiere & Anderson, 2006) and set the corresponding subgoals in accordance with them. In this phase, learners do not yet apply the strategy knowledge themselves since control of performance is exerted completely by the script that guides them. Consequently, this kind of perfomance contributes little to the acquisition of strategy knowledge according to the assumptions of skill acquisition theories mentioned above. In order to strengthen strategy knowledge, learners need to use it to self-regulate their performance. Fading can provide them with opportunities to do so.

The fading of instructional scripts

Very diverse kinds of instructional support can be faded, ranging from stimuli and prompts (Riley, 1995) to steps in worked-out examples (Renkl & Atkinson, 2003). In most of these cases, fading proved effective for learning (e. g. Schunk & Rice, 1993; Renkl, Atkinson & Große, 2004). However, the kinds of instructional support faded in these studies are quite unlike instructional scripts. These are more akin to scaffolds; collaboration scripts can actually be regarded as a kind of socio-cognitive scaffolding (Carmien, Fischer, Fischer & Kollar, 2007).

Fading has always been regarded as an integral part of scaffolding (Wood, Bruner & Ross, 1976; Pea, 2004; Puntambekar & Hübscher, 2005). So far, only a couple of studies on the effects of the fading of scaffolds have been conducted, with mixed results. Leutner (2000) conducted two experiments on the effects of fading on the acquisition of software skills. One provided evidence for beneficial effects of fading, the other indicated decreased performance in the process of fading. McNeill, Lizotte, Krajicik and Marx (2006) demonstrated a marginally significant positive effect of fading on knowledge about the principles of scientific explanations. In a

study by Lee and Songer (2004) the fading of scaffolds had no effect on the quality of explanations in the posttest, but the quality of explanations during learning decreased over time while scaffolds were faded.

From the perspective of cognitive skill acquisition these results do not come as a surprise: As long as there is unfaded support, learners do not practice the application of strategy knowledge to self-regulate their performance. As soon as support is faded, they are immediately required to jump in and exert self-regulation of their performance, which they had no opportunity to practice before. A way out of this paradox may be available in collaborative situations.

The role of distributed monitoring

When support previously available from an instructional script is gradually withdrawn, successful performance requires learners to take over control of their activities. A full cycle of control involves planning, monitoring and adapting one's steps as part of a strategy. This task may overwhelm learners if they are supposed to take responsibility for all of its parts at once. In such a situation, the idea of distributed metacognition (King, 1998) proves useful: Specific components of control may be distributed among collaborating learners. For example, a learner can be freed from the task of monitoring his or her own application of a strategy and receive feedback on the performance from a learning partner. As soon as he or she wanders off track, such feedback can be used in subsequent cycles to plan the single steps in accordance with the strategy to be internalized.

Research questions

Accordingly, this study focused on the following research questions:
(1) What are the effects of fading and distributed monitoring on the acquisition of strategy knowledge?
(2) What are the effects of fading and distributed monitoring on the performance of the strategy suggested by the script in the course of time?
(3) What is the relation between the performance of the strategy and the acquisition of strategy knowledge?
It was assumed that fading will play out its full potential to foster the acquisition of strategy knowledge only when combined with distributed monitoring. The hypothesized mechanism behind this effect is self-directed (i. e. unguided) performance of the strategy suggested by the script, which may be kept up by distributed monitoring.

Methods

Participants

The participants of the study were 126 students in courses in educational science and teacher preparation who attended a lecture with the title "Introduction to Educational Psychology". On average, they were 23.3 years old (SD = 3.9). Of them, 73.8 % were female and 26.2 % were male. They were randomly paired to dyads who discussed on separated online discussion boards during a collaborative learning phase.

Design

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

Table 1: Design of the study.

Distributed monitoring	**Fading**	
	Unfaded script	*Faded script*
Without distributed monitoring	15 dyads/30 persons	18 dyads/36 persons
With distributed monitoring	13 dyads/26 persons	17 dyads/34 persons

Learning task, material and environment

The two learners in each group dealt with cases on the application of Weiner's attribution theory in a text-based online discussion board. 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 any questions that came up during this task on the discussion board. In fact, six case analyses with at least two questionable claims were posted to the board under the names of two simulated group members at fixed points of time. As a preparation for this collaborative learning session, the learners read a three-page text on Weiner's attribution theory and a four-page text on how to generate counterarguments for the critical replies.

A script supported the learners in all four conditions in the process of formulating counterarguments against the prepared case analyses by providing instructions on how to analyze the argumentation in the case

analyses to discover problematic assumptions. The script contained three kinds of information: sequence information, argument schemata and application support (see figure 1). *Sequence information* describes the process of analyzing the argumentation in the prepared case analysis and the construction of a critical reply to it. The steps of the strategy to arrive at a counterargument were mirrored in the interface as prompts that changed according to the state of the editing, and specified the next step. *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. They were implemented by means of selection fields for the type of the claim and the argument as well as by a prompt for the assessment of the conditions of relevance. *Application support* was provided by means of 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. They were displayed in the interface directly next to the respective control elements.

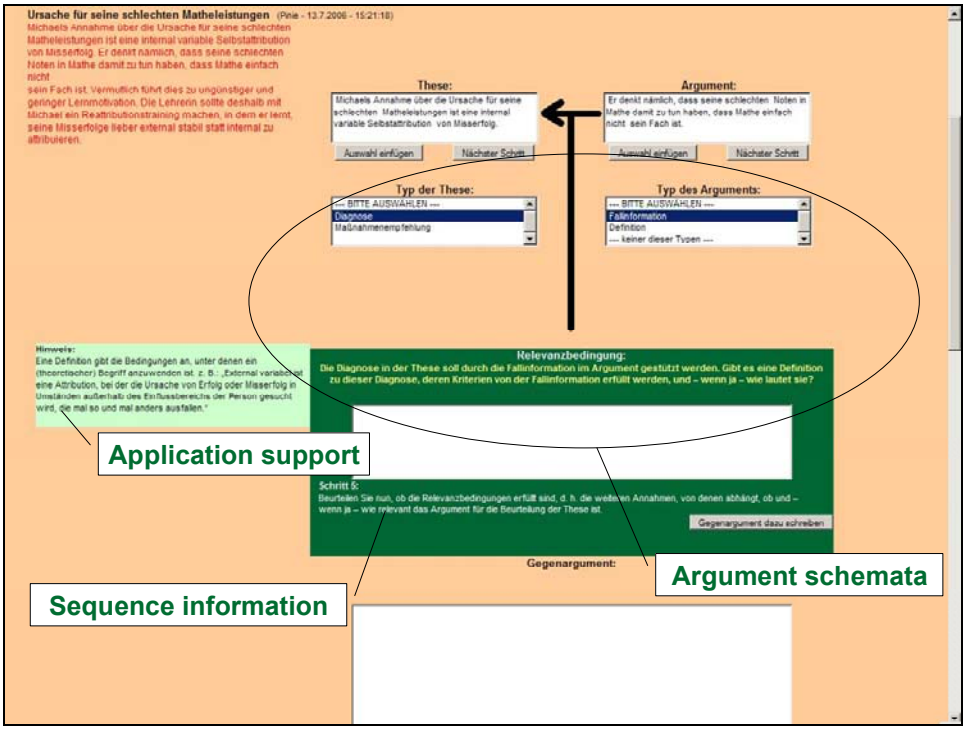

Figure 1. Implementation of the script for the formulation of counterarguments.

Independent variables

Fading

In the conditions *with faded script* components of the interface were removed based on the number of critical replies posted. The following fading regime was used: The *application support* disappeared completely after two critical replies had been written. *Sequence information* prompts were faded by replacing two randomly chosen prompts per round by the request "Please perform this step on your own.", starting with the composition of the third critical reply. This means that after five critical replies only this unspecific request was shown before each step. With respect to the *argument schemata* "later" elements had to be faded first because for the branching of the support for different argument schemata unequivocal input was required: First the specific question concerning the fulfilment of the conditions of relevance (step 5) was replaced by an unspecific one. From the forth critical reply on, the dropdown 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. From the fifth critical reply on, the dropdown 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 five critical replies had been posted, the interface did not change as a function of the number of critical replies any more, no matter how many messages were written. 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.

In the conditions *with unfaded script* the interface for the composition of critical replies remained unchanged throughout the learning phase.

Distributed monitoring

In the conditions *with distributed monitoring*, one of the learnings had the task to provide the other one with feedback for each of his or her critical replies, based on which the other learner was asked to revise his or her critical reply. During the formulation of this feedback, the learning partner was supported by the interface: By simply clicking on check boxes, a message about the completeness of the six steps of the strategy 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 conditions of relevance could be composed. Furthermore there was the opportunity to add text remarks. In the condition with faded script and distributed monitoring, the distributed monitoring was continued after the fading had started.

In the conditions *without distributed monitoring*, the learning partners were neither asked nor supported to provide feedback on the critical replies.

Dependent variables

Strategy knowledge

Strategy knowledge was measured by means of a task with open answering format. The learners were asked to describe their strategy for checking the relevance of an argument for a claim and formulating a counterargument against it. The learners' unsegmented answers were coded for the occurence (0 – absent/1 – present) of each of the six steps of the strategy implemented in the script. One further coding item captured the correctness of the sequence. The agreement of two coders for these coding variables ranged from 76 % to 90 % (median: 86 %); Cohen's κ ranged from .46 and .70 (median: .51). Therefore, the objectivity of the codings can be regarded as sufficient (cf. Orwin, 1994, p. 152). The seven coding items were added up to form the scale for strategy knowledge with a possible range from 0 to 7. The seven items were internally consistent (Cronbach's $\alpha = .93$).

Performance of the strategy

Performance of the strategy was measured based on five single variables indicating for each critical reply for each of five of the six steps of the strategy whether this step had been performed (1) or not (0). The last step was omitted since it coincided with composing the message, which is performed in any reply irrespective of the strategy applied. For the first four steps, the corresponding adherence variables were taken directly from logfiles. The adherence variable for the fifth step of the strategy was coded (percentage agreement: 99 %, Cohen's $\kappa = .98$).

The overall scale for the performance of the strategy was formed in two steps: First, for each of the five steps the proportion of all messages in which the step had been performed was calculated (also separately for all messages before and after the fading of support). Finally, the indicator for overall performance of the strategy was computed by adding the five variables for the performance of the single steps and could range from 0 to 5. Its reliability was rather high (Cronbach's $\alpha = .86$).

Procedure

Data were collected in a series of sessions of three hours of length with up to 20 students each. These were distributed over two rooms; 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 for control variables and read printed texts on attribution theory and on how to construct counterarguments. They could keep them until the end of the learning phase. The collaborative learning phase started with a demo video on how to use the learning environment. After a short break, an 80-minute collaboration phase in the different experimental conditions followed. Finally, the learners completed online post-tests.

Statistical analysis

Data were analyzed with individual students as the units of analysis. From each dyad, one member was selected who had not provided distributed monitoring. Furthermore, a hierarchical-linear analysis of the performance of the strategy over the course of time was conducted with single messages (the critical replies) as the units of analysis. The significance level was set to 5 % for all analyses.

Results

Effects of fading and distributed monitoring on the acquisition of strategy knowledge

The descriptive results for the acquisition of strategy knowledge in the four conditions are displayed in table 2. An analysis of variance with strategy knowledge as the dependent variable and fading and distributed monitoring as independent factors shows that strategy knowledge was significantly higher in the faded script conditions than in the unfaded script conditions, which corresponded to a medium size effect of fading, $F(1; 62) = 6.32$; $p < .05$; partial $\eta^2 = .09$. Likewise, a significant medium to large size effect of distributed monitoring

on strategy knowledge in favour of the conditions with distributed monitoring compared to the conditions without distributed monitoring was detected, $F(1; 62) = 8.20$; $p < .01$; partial $\eta^2 = .12$. The small to medium size interaction effect of these two independent variables was marginally significant, $F(1; 62) = 3.21$; $p < .10$; partial $\eta^2 = .05$. However, the main effects are largely due to the superiority of the condition with the faded script along with distributed monitoring. Students in this condition significantly outperformed the students in the three other conditions on the strategy knowledge test.

Table 2: Means and standard deviations of strategy knowledge in the experimental conditions.

Distributed monitoring	*Fading*	*N*	*Strategy knowledge*	
			M	*SD*
Without distributed monitoring	Unfaded script	15	0.79	1.81
	Faded script	18	1.47	2.13
With distributed monitoring	Unfaded script	13	1.46	2.30
	Faded script	17	4.24	2.88

Effects of fading and distributed monitoring on the performance of the strategy suggested by the script

Research question 2 asked whether fading and distributed monitoring affect the performance of the strategy suggested by the script in the course of time . The temporal development of the performance of the strategy was analyzed by means of a hierarchical-linear analysis. The level-1 growth model predicted the performance of the strategy during the formulation of message t from person i on the basis of the temporal position of message t:

$$y_{ti} = \pi_{0i} + \pi_{1i} \cdot (\text{number of message}_t) + e_{ti}$$

Intercepts (base levels) and slopes (growth rates) varied substantially between students, intercepts: $\chi^2(62) = 229.73$; $p < .001$; $\rho = .34$; slopes: $\chi^2(62) = 120.79$; $p < .001$; $\rho = .02$. As can be seen from the intercept for number of message presented in table 3, however, on average there was neither an increase nor a decrease in the performance of the strategy suggested by the script over time.

The explanatory level-2 model used the experimentally manipulated variables fading and distributed monitoring to predict both the base level (intercepts π_{0i}) and the growth rates (slopes π_{1i}) of the performance of the strategy for person i:

$$\pi_{0i} = \beta_{00} + \beta_{01} \cdot (\text{fading}_i) + \beta_{02} \cdot (\text{distributed monitoring}_i) + r_{0i}$$
$$\pi_{1i} = \beta_{10} + \beta_{11} \cdot (\text{fading}_i) + \beta_{12} \cdot (\text{distributed monitoring}_i) + r_{1i}$$

As can be seen from table 3, the base level did not vary significantly as a function of either fading or distributed monitoring. The average individual growth rate in the condition with the unfaded script without distributed monitoring (basal growth rate), however, was significantly below zero, indicating a decrease in performance of the strategy in this condition. While fading did not significantly affect this growth rate, distributed monitoring significantly raised this negative growth, yielding an approximately constant level of performance of the strategy in the corresponding conditions (-0.08 + 0.11 > 0). The proportion of variance in slopes accounted for by the explanatory model was 6 %, which was still significant, $\chi^2(62) = 117.59$; $p < .001$, indicating that there may be further factors that substantially contribute to it.

Table 3: Hierarchical-linear analysis of the development of the performance of the strategy triggered by the script as a function of fading and distributed monitoring.

Growth model: Prediction of the performance of the strategy y_{ti}	π_1	*t*	*p*
Number of message	-0.03	-1.18	.24
Explanatory model:			
Prediction of the base level π_{0i} in the growth model	β_{0q}	*t*	*p*
Fading	0.21	1.39	.17
Distributed monitoring	0.09	0.57	.57
Prediction of the growth rate π_{1i} in the growth model	β_{1q}	*t*	*p*
Basal growth rate (without fading and distributed monitoring, *intercept* β_{10})	-0.08	-2.19	.03
Fading	0.01	0.24	.81
Distributed monitoring	0.11	2.45	.02

The role of distributed monitoring for the performance of the strategy suggested by the script was analyzed separately in the conditions with the faded script by means of an analysis of variance for repeated measures with performance of the strategy as the dependent variable, distributed monitoring as a between-subjects factor and fading as a within-subjects factor with the two values before fading and after fading, i. e. the performance of the single steps of the strategy was averaged over all messages from each participant written before support for the particular step was faded and over all messages written after support for the particular step was faded, and aggregated over the five steps of the strategy (see figure 2).

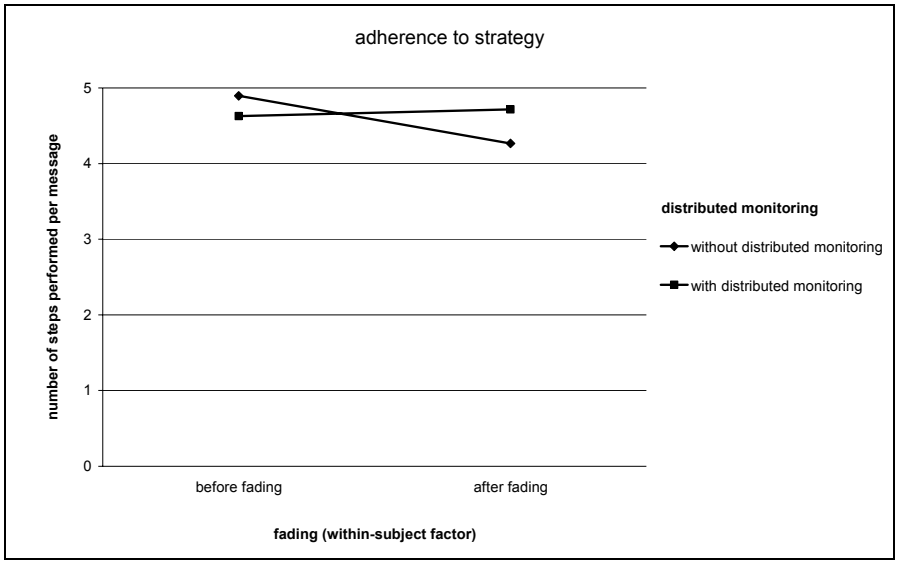

Figure 2. Average proportions of messages in which the strategy as a whole was performed before and after fading (separated for the conditions with and without "distributed monitoring").

A decrease in the performance of the strategy was found that reached the boundary of significance, $F(1;\ 31) = 4.16$; $p = .05$; partial $\eta^2 = .12$. However, this decrease occurred only in the condition without distributed monitoring, as indicated by a significant interaction between the within-subjects factor fading and distributed monitoring, $F(1; 31) = 7.38$; $p < .05$; partial $\eta^2 = .19$.

Exploratory analyses on the level of individual steps of the strategy revealed that these effects were mainly due to the learners' performance of the last two steps of the strategy: Both for the identification of the type of the argument and the check of the fulfilment of the conditions of relevance there was a decrease after the fading of the corresponding support in the condition without distributed monitoring, identification of the type of the argument: $t(15) = 1.97$; $p < .05$ (one-sided), check of the fulfilment of the conditions of relevance: $t(15) = 2.32$; $p < .05$ (one-sided). For the identification of the type of the argument the interaction effect between the within-subjects factor fading and distributed monitoring was marginally significant, $F(1; 31) = 3.06$; $p < .10$; partial $\eta^2 = .09$, while for the check of the fulfilment of the conditions of relevance the corresponding interaction was significant $F(1; 31) = 5.27$; $p < .05$; partial $\eta^2 = .15$.

Relation between the performance of the strategy and the acquisition of strategy knowledge

Between the performance of the strategy and the acquisition of strategy knowledge there was a significant small correlation, $r = .22$; $p < .05$. Because on average there were no differences in the performance of the strategy between the four experimental conditions, this finding does not explain the differences in the acquisition of strategy knowledge between the experimental conditions.

As argued before, the performance of a strategy while learners are guided through its single steps rather than performing them in a self-directed way, should contribute little to the acquisition of strategy knowledge. What is expected to contribute to the acquisition of strategy knowledge is the performance of the strategy in phases in which support has been withdrawn and learners have the opportunity to practice the self-regulation of these steps, which occurred to a larger extent when they received distributed monitoring, as described in the previous section. Accordingly, separate correlations between the performance of the single steps *before and after* the fading of the corresponding support and strategy knowledge about these specific steps were calculated. These are reported for the last two steps because, as described above, for these two there were differences in performance in the course of time between conditions with and without distributed monitoring: Performance of the step of the identification of the type of the argument before the fading of the corresponding support and strategy knowledge about it were not significantly correlated, $r = -.15$; *n. s.*, whereas performance of it after the

fading of the corresponding support was marginally correlated with the corresponding knowledge, $r = .30$; $p < .10$. Most importantly, the difference between these two correlations was significant, $z = 1.71$; $p < .05$. Similarly the performance of the step of checking the fulfilment of the conditions of relevance before the fading of the corresponding support and strategy knowledge about this step were uncorrelated, $r = .00$; *n. s.*, while performance of it after the fading of the corresponding support again was marginally correlated with strategy knowledge about it, $r = .33$; $p < .10$. In this case, the difference between the two correlations was marginally significant, $z = 1.59$; $p < .10$.

Discussion

The main findings of this study indicate that the performance of the strategy implemented in a script may decline over time, especially if components of the script are faded. It could be demonstrated however, that it can be kept on a continuously high level by means of peer support such as distributed monitoring. The performance of the strategy was shown to be related to the acquisition of strategy knowledge, particularly in phases in which components of the scripts have been faded and accordingly the learners have the opportunity to practice the self-regulation of the steps of the strategy. This provides an explanation for the beneficial effect of the combination of a faded script with distributed monitoring on the acquisition of strategy knowledge.

The current study extends our understanding in several ways. With respect to the effects of collaboration scripts, it replicated the finding that scripts are appropriate means to trigger specific learning activities (Weinberger et al., 2005; Kollar et al., 2007; Stegmann et al., 2007), even after the fading of components of the script. It could be shown, however, that the level of performance of the script can be kept at an even higher level by providing distributed monitoring.

With respect to fading, thereby an important condition of its effectiveness was identified: Learners may need further support to take advantage of the opportunity to self-regulate their performance. This finding might contribute to a clarification of the reasons for the varying effects of fading reported in previous studies on fading (cf. Lee & Songer, 2004; McNeill et al., 2006; Leutner, 2000).

This opportunity to practice the self-regulation of the steps of a strategy may not be sufficient if learners fail to take advantage of it. Distributed monitoring can be regarded as one potential way to raise learners' self-regulatory activities in accordance with the strategy implemented in a script even after the fading of the components to support it. Accordingly, distributed monitoring can be one way to make use of collaboration during the acquisition of complex skills in computer-supported collaborative learning. It is also one option for adapting support to the current needs of learners because the learning partner providing distributed monitoring will only jump in with corrective feedback when there is divergence from the strategy to be internalized.

This study went beyond standard practice in research also in a methodological respect by analyzing learning activities diachronically by means of multi-level analyses of the temporal development of specific quality aspects of learning activities instead of aggregating indicators of the quality of learning activities over the whole learning phase (e. g. Weinberger et al., 2005). Thereby it can more closely account for the causal structure of the single learning events influenced *by the independent variables.* This should be pushed even further by relating single learning events to learning outcomes since the way in which learning activities might affect *learning outcomes* was still analyzed on the basis of such aggregated indicators. How this can be done is a topic for further discussion.

It is an important limitation of the present study that argumentation skill was not measured on the basis of perfomance in argumentative situations but by means of a declarative test of strategy knowledge about how to arrive at a counterargument against a position advanced by a learning partner. Furthermore, the study captured only rather short term effects of learning with a faded script and distributed monitoring. As it was conducted under laboratory conditions, the claims put forward in this paper still are in need of validation for more natural learning environments.

Accordingly, future research should focus on effects of fading and distributed monitoring not only on declarative strategy knowledge but also its application in the context of executing argumentation skill. Effects of longer-term interventions on immediate learning outcomes as well as their retention over more extended periods of time should be studied, preferably in field contexts with more authentic kinds of collaboration. Further research should also test the theoretical claims put forward in this study with other domain-general learning outcomes such as online search competence, which is currently being undertaken (Wecker, Kollar, Fischer & Prechtl, 2010). Finally, ways to adapt the fading of a script to a learner's current competence level would be a very promising direction to explore.

Based on the findings from this study it can be recommended that scripts should be faded out to provide learners with the opportunity to practice the self-regulation of skilled performance (as suggested by Pea, 2004; Puntambekar & Hübscher, 2005; and others). This recommendation has to be supplemented by the caveat, however, that it is important to keep learners' performance of the strategy to be acquired at a high level in these self-regulated phases. Collaboration may be exploited to accomplish this goal.

Thus, fading may be a way to move from a high degree of support to self-directed learning with authentic tasks. In this process the acquisition of competence can be considered as an internalization of control that has been exerted socially by peers before.

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