Explaining the Effects of Continuous and Faded Scripts on Online Search Skills: The Role of Collaborative Strategy Practice

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Abstract: It has been shown that continuous and faded collaboration scripts can foster important components of scientific literacy such as online search skills. The present paper studies the effects of these types of scripts on learners' practice of the strategy suggested by the script, as well as the relation of the learners' and their learning partners' practice of the strategy to the development of online search skills. Data from a four-week field study with 129 ninth-grade students in three conditions (no script, continuous script and faded script) were analyzed. Findings indicate positive effects of both scripts compared to unsupported collaboration on the practice of the strategy. Learners' own, but not their learning partners' practice of the strategy predicted their development of online search skills. These results indicate that neither mere exposure to the script nor observation of learning partners performing the strategy explain the effects of scripts on learning outcomes.

Prior Research on Collaboration Scripts

In recent years, collaboration scripts have become a main focus of research on computer-supported collaborative learning. Collaboration scripts are socio-cognitive scaffolds that specify activities, sequence them and distribute them among different roles taken over by members of a small group of learners, with the aim to help students advance their domain-specific knowledge about the topic of collaboration and domain-general skills such as the ones that also belong to scientific literacy (Kollar, Fischer & Hesse, 2006). Several studies have demonstrated positive effects of scripts on learning (e.g., De Wever, Van Keer, Schellens, & Valcke, 2009; Kollar, Fischer & Slotta, 2007; Rummel, & Spada, 2005; Slof, Erkens, Kirschner, Jaspers & Janssen, 2010; Stegmann, Weinberger & Fischer, 2007; Weinberger, Stegmann & Fischer, 2010).

Some studies of support for collaborating learners other than collaboration scripts have been conducted in field settings (e. g. Hmelo-Silver, 2006; Walker, Rummel & Koedinger, 2009). However, most research on effects of computer-supported small-group collaboration scripts on learning *outcomes* is done in the laboratory so far. Some lab studies demonstrated beneficial effects of different kinds of collaboration scripts on domain-*general* skills such as argumentation skills during online discussions in a problem-based learning context (Stegmann et al., 2007). In a further study in the context of web-based inquiry learning, a collaboration script that was designed to help students formulate well-grounded arguments, counterarguments and integrations and implemented at specific points of a WISE curriculum unit helped students develop higher levels of the domain-general skill of argumentation, but did not help them reach higher levels of domain-specific knowledge when compared with less structured collaboration (Kollar et al., 2007). Moreover, it appeared that during the learning process the collaboration script only raised argumentation quality as long as it was present. As soon as the script was "switched off", learners relapsed into their previous argumentation style. In other words, development of robust argumentation skill hardly occurred, which may be explained by a rather short learning time of 120 minutes.

To investigate whether computer-supported collaboration scripts produce more robust effects when longer learning phases are studied, we conducted a larger field study in an inquiry curriculum unit in Biology (Wecker, Kollar, Fischer & Prechtl, 2010). One of the main purposes of Science Education is to prepare all students for their role as responsible citizens including participation in societal debates that involve scientific issues, which requires both fundamental knowledge about important scientific principles and the ability to gather and evaluate more specific and recent information that goes beyond what can ever be learned in school. Therefore we selected domain-specific knowledge from Biology and online search skills as the two targeted learning outcomes of our intervention. The curriculum unit was implemented in regular class periods led by the classes' Biology teachers. It comprised seven lessons about Genetic Engineering and lasted about four weeks. A collaboration script for collaborative online search was compared to unscripted collaboration in an experimental design and produced substantial positive effects with respect to the two learning outcomes (Wecker, Kollar et al., 2010). In particular with respect to online search skills, this effect could in principle be due to mere exposure to the prompts included in the collaboration script during the test session rather than their application during collaborative learning. In this paper we present further analyses based on data from this study to clarify the mechanisms behind the beneficial effect of a collaboration script on online search skills. It was assumed that it is the actual practice of the strategy suggested by the collaboration script rather than mere exposure to the prompts that fulfils this role or observation of a learning partner performing the strategy. If the effects of

collaboration scripts on online search skills are mainly due to mere exposure to the prompts contained in the script, the amount of practice of the strategy by the learners themselves should be unrelated to their online search skills in the posttest. If learners develop online search skills mainly because they observe their learning partners perform the strategy suggested by the script, the amount of the learners' partners' practice of the strategy should be related to their own online search skills in the posttest. These potential explanations for script effects are tested by means of the analyses presented in this paper.

A further goal of the study was to investigate the effect of a faded collaboration script compared to the more "classical" continuous one. Fading is the gradual removal of support as learners become more proficient and can take over control of increasing parts of the activity to be learned. Thereby learners get the opportunity to practice not only the details of the execution, but also their regulation. Hence, fading is considered as part and parcel of scaffolding (Pea, 2004; Puntambekar & Hübscher, 2005; Wood, Bruner & Ross, 1976). So far, research on the effects of fading of scaffolds in general is sparse, and the results are mixed. In one of two experiments, Leutner (2000) found evidence for beneficial effects of fading, whereas in the other one performance decreased in the process of fading. In another study a marginally significant positive effect of fading was found with respect to only one of several aspects of knowledge about the principles of scientific explanations (McNeill, Lizotte, Krajicik & Marx, 2006).

Transferring the concept of "fading" to research on collaboration scripts, Wecker and Fischer (2007; 2010) could show in an empirical study in a computer-supported collaborative learning context that the fading of an instructional script alone had no positive effect on learning. If it was combined with "distributed monitoring" (cf. King, 1998), i. e. when the learning partner was asked to monitor whether his or her peer complied with the strategy induced by the script, however, a significant positive effect on students' strategy knowledge in comparison to a continuous script was found. Just like the study by Kollar et al. (2007), however, this study was conducted as a lab experiment with a rather short learning time.

In our field experiment in Biology lessons, we investigated whether a faded collaboration script had a positive effect on the acquisition of online search skills when implemented over a more extended time frame in a field setting. The script contained meta-cognitive aspects such as monitoring of the learning partner's performance as part of the script itself that were faded along with the whole script, accordingly. A positive effect of the faded collaboration script compared to unscripted collaboration was in fact found with respect to domain-general online search skills, but not with respect to domain-specific knowledge. However, the fading of the collaboration brought no additional effect beyond that of a continuous collaboration script with respect to online search skills (Wecker, Kollar et al., 2010). In the present paper we investigate whether this finding can be explained by the learners' practice of the strategy during the fading of the collaboration script.

Research Questions

(1) How are students' and their learning partners' *practice of the strategy* suggested by the script in the context of collaborative inquiry learning in the classroom related to their acquisition of *domain-specific knowledge* and *online search skills*?

We hypothesized that the learners' own practice of the strategy during collaborative learning is more strongly related to the acquisition of online search skills than their learning' partners practice of the strategy.

(2) What are the effects of continuous and faded small-group collaboration scripts for collaborative online search on students' *practice of the strategy* in the context of collaborative inquiry learning in the classroom?

We expected that both a continuous and a faded collaboration script have a positive effect on the practice of the strategy. We did not expect a difference between these two types of scripts in this respect.

Method

Participants and Design

Participants in this study were 129 students from six ninth-grade classes from three urban high schools. Their average age was 14.7 years ($SD = 0.67$); 60 of them were female, 69 were male. Data from the students were only collected if their parents had agreed individually that their child was included in the data collection.

A one-factorial quasi-experimental design with three experimental conditions differing in the type of instructional support for collaborative online search was implemented with the classes as the units of random assignment (see table 1). One condition without collaboration script, one with a continuous collaboration script, and one with a faded collaboration script were compared.

Table 1: Design of the study.

Type of instructional support		
No collaboration script	*Continuous collaboration script*	*Faded collaboration script*
N = 36 students from 2 classes	N = 46 students from 2 classes	N = 47 students from 2 classes

Instructional Setting and Procedure

The study was conducted in an inquiry-based curriculum unit that spanned seven regular biology lessons, which were preceded and followed by a test session, respectively. The students' task was to arrive at a decision about whether they supported or rejected the genetic modification of plants for the purpose of food production. The lessons were led by the classes' regular biology teachers.

After a short introduction to relevant background domain knowledge from Genetics, the students in all three conditions received the same introduction to the strategy of online search. Lessons two through seven consisted of three consecutive learning cycles about three different topical aspects of the discussion about Genetic engineering of plants: one on economic, one on ecological, and one on health aspects. Each cycle comprised three consecutive steps. First, students in dyads collaboratively browsed through an online library in order to gather background information about Genetics and Genetic Engineering relevant to the current aspect of the discussion. In the second step, student dyads conducted collaborative online searches to elaborate or modify their initial argument concerning the current aspect of the discussion. In these phases of collaborative online search, the independent variable was manipulated (see below). In the third step, students exchanged their arguments in a plenary discussion based on the findings from their collaborative online searches.

The online library was implemented as a module in the Web-Based Inquiry Environment (WISE; Slotta & Linn, 2009). The students in each dyad sat next to each other in front of their two computers and communicated face-to-face, but each student had a laptop computer with a mouse for him- or herself. During the collaborative online search phases, the browsers of the students in each dyad were connected via a software tool called S-COL (Wecker, Stegmann et al., 2010). This allowed for collaborative Internet browsing, i.e., during their online searches, both learning partners from each dyad always saw the same web pages, no matter who of them clicked on a link or used the navigation functions of their browser.

Independent Variables

No Collaboration Script

The students in the condition without a collaboration script received no support for their collaborative activities beyond an introduction by their teacher to the strategy of online search at the beginning of the curriculum unit. This information was equivalent to the information presented in the prompts of the collaboration scripts in the other two conditions.

Continuous Collaboration Script

This script was targeted at improving collaborative online search. That is, it was directed at the specific activities required to perform a successful online search, and it divided these activities among two learners in order to induce interaction concerning crucial aspects of the skill to be acquired (Dillenbourg & Jermann, 2007). It was implemented as follows: In addition to connecting the computers of the two partners of a dyad, the S-COL software tool described above was used in the two experimental conditions to display particular prompts on the basis of the type of website the students were accessing at any time (Google start page, Google hit list, any other web site). In each dyad there were two roles (A and B) that switched after returning to Google, which they were required to use for their searches, from any other web page encountered during the search activities. The collaboration script was implemented as complementary text prompts in the scaffolding areas of S-COL in the browsers of both group members (left part of the screen in figure 1). The script contained support for five – partly iterative – steps of collaborative online search: (1) the *formulation of an initial argument and a sketch of the information needed*, (2) the *selection of search terms*, (3) the *evaluation of the hit list*, (4) the *localization of relevant information* on a web page, and (5) a *written formulation of the final elaborated argument*. For example, during the second stage, the *selection of search terms*, learner A was prompted to perform the activities to suggest a set of search terms and discuss them with B, while B had the task to perform the activities to first recall the information they had decided to look for, and comment on A's suggestions for the search terms with respect to their likelihood of yielding suitable as well as inappropriate hits.

Faded Collaboration Script

In the condition with the faded collaboration script the same prompts as in the condition with the continuous collaboration script were used to support collaborative online search, but they were continuously removed, the more online searches the dyad performed. The general fading scheme was that after a series of four external web sites had been accessed, the prompts described above became more unspecific: Initially, the scaffolding area of S-COL contained both the names of the individual activities as well as explanatory text. At the second fading stage, only the names of the activities were displayed. At the final stage, only headings for the actual steps were displayed. In each of the three cycles of the curricular unit, the degree of support initially reverted to a slightly higher level before it was further reduced according to the scheme just described.

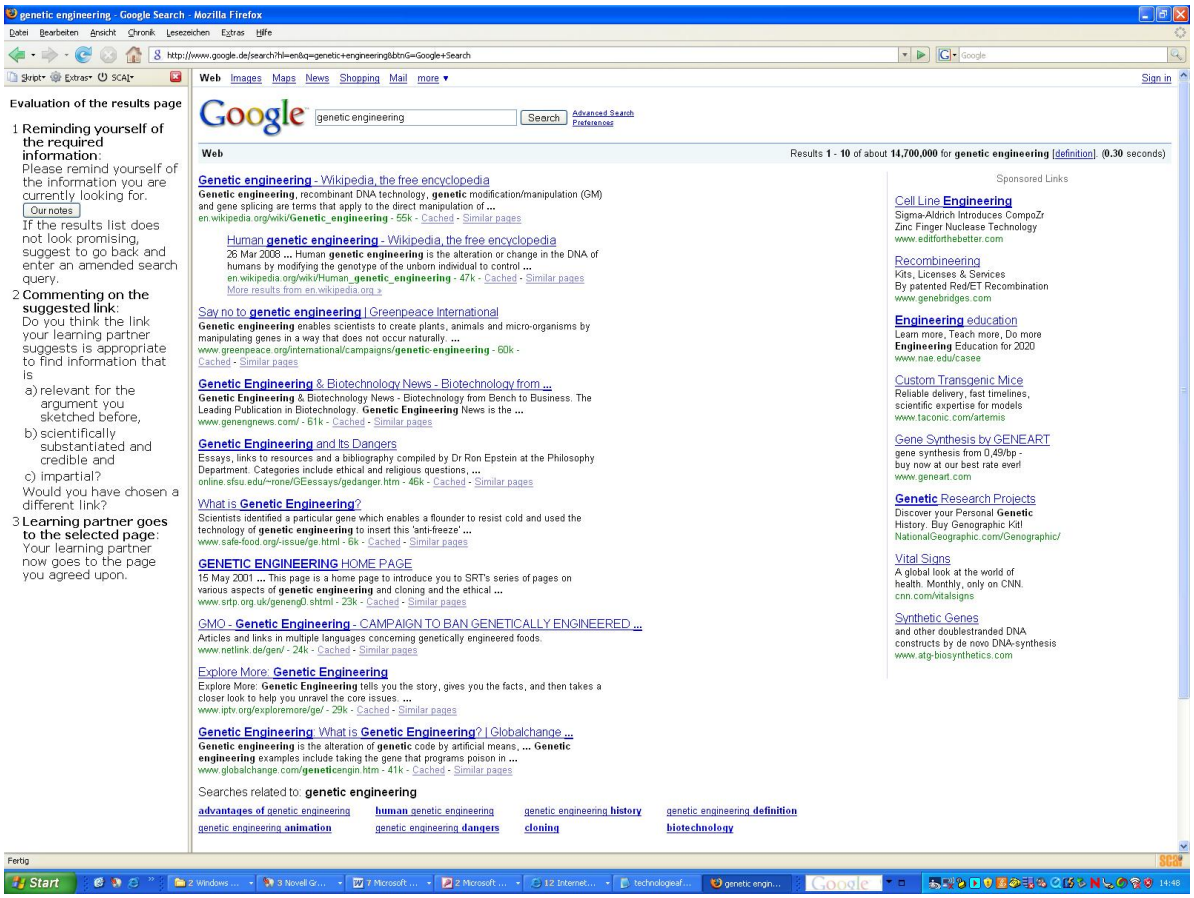

Figure 1. Part of the Continuous Collaboration Script Presented along with a Google Hit List.

Data Sources and Dependent Variables

Practice of the Strategy

Screen-and-audio capturing software was used to record both the learners' utterances during face-to-face collaboration in front of their computers and their activities on their computers. To deal with the vast amount of data, a time sample of 10 minutes from the beginning of the second step of each of the three inquiry cycles, i. e. the online-search, was selected for in-depth analysis from each dyad. The whole online-search phases from which these three 10 minutes time samples were drawn lasted for 45, 30 and 30 minutes, respectively.

To arrive at an indicator of the *practice of the strategy* suggested by the script, the occurrence of the activities suggested by the script was coded separately for both members of each dyad for segments of 10 seconds of length on the basis of the learners' as well as their partners' activities on their computers. A coding scheme with separate, mutually exclusive codes for all activities suggested by the collaboration script was applied to the segments of both learners in a dyad. That is, for each time segment, the coders identified for each of the two learners which activities he or she predominantly performed during this segment.

Because all time samples were drawn from the same stage of the online-search phases in each cycle, namely the beginning of the online-search phases, a subset of activities suggested by the script can be identified that are most appropriate in this early phase. These are the activities subsumed under the step "*formulation of an*

initial argument and sketch of the information needed" (cf. the description of the stages in the section on the continuous collaboration script above). Therefore, the proportion of time spent on the activities belonging to this step was used as an indicator for the extent to which the learners performed the strategy.

The screen-audio-recordings were analyzed by three independent coders who were evenly distributed across the three conditions. A subsample of 11% of the data was coded by all three coders to determine their agreement, which was acceptable (Coders 1 and 2: 70% agreement; Cohen's $\kappa = .67$; Coders 1 and 3: 68% agreement; Cohen's $\kappa = .64$; Coders 2 and 3: 91% agreement; Cohen's $\kappa = .89$).

Based on these codings, the practice of the strategy was operationalized as the frequency of segments within the first ten minutes of each online search phase, in which one of the activities subsumed under the first step of the script was performed, relative to the total length of the time interval included in the analysis. The reliability of this variable as calculated over single variables indicating the relative frequency of the single activities subsumed under the first step of the script was good (Cronbach's $\alpha = .82$).

Online Search Skills

In the tests measuring online search skills, students were asked to describe in as much detail as possible how they would use the Internet to form a position about a specific sample issue without actually doing so. The answers were pre-structured by means of a two-column table with eight rows. The students were instructed to describe the single steps involved in the search in the left hand-column and the evaluative criteria to be applied in combination with these specific steps in the right-hand column. Pre- and posttest were coded for the occurrence of each individual element of a general ideal solution that contained the steps that were also triggered in the collaboration script as well as the evaluative criteria suggested in the script. Each student's responses were analyzed by one of two coders who were blind to condition. The proportions coded by each of them were equal across the three experimental conditions. An overall scale for *online search skills* was formed by counting the coded occurrences of steps and evaluative criteria. Separate scales for *knowledge about single steps* and *knowledge about evaluation criteria* were also formed.

For the assessment of inter-coder agreement, the two coders analyzed 15 % of the data from the pretest and 25 % of the data from the posttest independently of each other. For all participants included in this sample the values of the overall scale as well as the two subscales were calculated from the codings of both coders. Intra-class correlations for single measures amounted to $ICC = .83$ for the overall scale of *online search skills* in the posttest ($ICC = .51$ in the pretest), $ICC = .82$ for *knowledge about single steps* and $ICC = .67$ for *knowledge about evaluative criteria*.

Statistical Analysis

The significance level was set to 5 % for all analyses.

Results

Research Question 1: Relations between Students' and Their Learning Partners' Practice of the Strategy Suggested by the Script and Their Acquisition of Online Search Skills

The learners' practice of the strategy suggested by the script was significantly related to the overall scale of online search skills from the posttest, $r(N = 129) = .27$; $p < .01$ (one-sided), the subscale for knowledge about single steps required to perform a successful online search, $r(N = 129) = .20$; $p = .01$ (one-sided), and the subscale for knowledge about evaluation criteria, $r(N = 129) = .30$; $p < .01$ (one-sided). The same holds for *their learning partners'* practice of the strategy suggested by the script and its relation to the learners' score on the overall scale of online search skills from the posttest, $r(N = 129) = .26$; $p < .01$ (one-sided), the subscale for knowledge about single steps required to perform a successful online search, $r(N = 129) = .21$; $p < .01$ (one-sided), and the subscale for knowledge about evaluation criteria, $r(N = 129) = .26$; $p < .01$ (one-sided). Three regression analyses for the overall scale for online search skills and its two subscales in the posttest as criterion variables with learners' and their learning partners' practice of the strategy suggested by the script as predictors were conducted, while also controlling for prior online search skills. They showed that the learners' own practice of the strategy suggested by the script significantly predicts two of the learning outcomes (online search skills: $\beta = .25$; $p = .02$; knowledge about single steps: $\beta = .19$; $p = .09$; knowledge about evaluation criteria: $\beta = .27$; $p = .02$), while their learning partners' practice of the strategy suggested by the script does not (online search skills: $\beta = .01$; $p = .90$; knowledge about single steps: $\beta = .00$; $p = .99$; knowledge about evaluation criteria: $\beta = .04$; $p = .76$).

Research Question 2: Effects of Continuous and Faded Small-Group Collaboration Scripts on Students' Practice of the Strategy

While students in the condition without a collaboration script engaged in activities subsumed under the first step of the script 3.0 % (*SD* = 0.04) of the time during the first ten minutes of each online search phase, students in the condition with a continuous script performed these activities in 7.3 % (*SD* = 0.06) of the time and students in the condition with a faded script in 7.2 % (*SD* = 0.08). That is, the average time spent on activities related to the formulation of an initial argument and the sketch of the information needed within the first ten minutes of online search was doubled to more then 40 seconds by the use of one of the two collaboration scripts. An analysis of variance with the students' practice of the strategy suggested by the script as the dependent variable and the kind of instructional support and classes nested within the three kinds of instructional support as independent variables revealed a significant medium-size main effect of the type of instructional support, $F(2; 122) = 6.89$; $p < .01$; partial $\eta^2 = .10$.

Planned comparisons revealed significant effects of large size between the condition with continuous collaboration script and the condition with no collaboration script, $F(1; 77) = 15.44$; $p < .001$; partial $\eta^2 = .17$, and of medium to large size between the condition with faded collaboration script and the condition with no collaboration script, $F(1; 78) = 10.41$; $p < .01$; partial $\eta^2 = .12$. However, no significant difference was found between the condition with the faded collaboration script and the condition with the continuous collaboration script, $F(1; 88) < 1$; *n. s*.

Discussion

This field experiment provides evidence that collaboration scripts can foster learning activities that lead to the development of online search skills, which have to be regarded as an important component of scientific literacy. The results indicate in particular that the collaboration script approach (Kollar et al., 2006) could successfully be transferred to structure web-based collaborative inquiry learning in real secondary school classrooms. Typically in laboratory studies the degrees of adherence to the prompts of collaboration scripts (i. e. the proportion of prompts that are responded to appropriately) are as high as about 70 % (Stegmann et al., 2007, p. 434) or 90 % (Wecker & Fischer, 2010). We currently do not have comparable numbers for the present study, but the share of the learners' activities that corresponded to parts of the strategy suggested by the script was below 10 %. This finding particularly highlights the importance of structuring collaboration in educational fields of practice.

It could also be shown that the practice of the strategy suggested by the script during collaborative learning is related to the development of online search skills. It is conceivable that effects of collaboration scripts on online search skills are mainly due to mere exposure to the prompts contained in the script. If this were the case, the amount of practice of the strategy by the learners themselves should be rather unrelated to their online search skills in the posttest. Furthermore it is possible that learners acquire online search skills also because they observe their learning partners perform the strategy suggested by the script. If this explanation were correct, the amount of the learners' partners' practice of the strategy should be related to their own online search skills in the posttest. What we do find, however, is – contrary to the first assumption – that the learners' own practice of the strategy is correlated with their online search skills in the posttest, and that – contrary to the second assumption – the learners' own practice of the strategy significantly predicts online search skills in a multiple regression analysis with the learners' and their partners' practice of the strategy as predictor variables, whereas the learning partners' practice of the strategy does not. This constitutes evidence that in fact the learners' own practice might play the central role for the development of online search skills, and not just the exposure to the prompts of the script or the observation of a partner performing the strategy. It does not, however, constitute definitive evidence that the learning partner does *not* play a role as a model because the insignificant regression coefficient for the learning partners' practice of the strategy could also be due to multicollinearity. This issue should be picked up in future research.

Taken together, the pattern of results presented in this paper offers an explanation why a continuous and a faded collaboration script both have a positive effect on the development of online search skills, while there is no difference between the two script types in this respect. The development of online search skills is correlated with the learners' practice of the strategy suggested by the script, and the pattern of the scripts' effects on the practice of the strategy precisely mirrors the effects on online search skills (Wecker et al., 2010). This suggests the explanation that the two types of scripts affect the development of online search skills via their effects on the practice of the strategy contained in the script.

With respect to the effectiveness of the fading of the collaboration script, however, some aspects require further discussion. The domain-general skills of online search can apparently be positively affected by a faded collaboration script compared to unscripted collaboration. However, no additional effect of fading compared to a continuous collaboration script could be demonstrated. Although some aspects of distributed monitoring (Wecker & Fischer, 2007) were integrated in the collaboration script used in this study (e. g. asking learner B to keep an eye on the sketch of the information the group is currently trying to find), this may be not

sufficient under field conditions, in particular if prompts for these metacognitive aspects are faded along with the other parts of the script. A functional equivalent for distributed monitoring that should be explored in future research may be feedback by a teacher pointing towards the dependency of success and failure in the collaborative task on the adherence to the collaboration script (cf. Schunk & Rice, 1993). Another difference between the present study and the laboratory study by Wecker and Fischer (2007) was the fact that the collaboration script embodied a collaborative strategy (of collaborative online search) that learners were expected to acquire as an individual strategy (of individual online search). Therefore, successful development of the corresponding domain-general skill on an individual level requires the integration of components of the strategy that are distributed over learners in a collaborative situation, which could be difficult without phases of individual practice (cf. Anderson & Lebiere, 1998). Accordingly, the successful development of a domain-general skill previously practiced collaboratively may require phases of *individualization* of the corresponding strategy. This can be regarded as another dimension of fading: Besides withdrawing technologically implemented prompts of a collaboration script, fading may also be constituted by a gradual shift from higher social levels (e.g., dyads) to the individual, which may be closer to the original ideas about scaffolding and fading (Wood, Bruner, & Ross, 1976; Pea, 2004). An example of such an approach that contains fading across social levels is reciprocal teaching (Palincsar & Brown, 1984), but to our knowledge, this aspect of fading has not been systematically varied in an experimental study so far.

In sum, it is still an issue for future research on collaboration scripts to explore under which conditions fading can help learners internalize a collaboration script and yield a positive effect in addition to the effect of collaboration scripts themselves. Candidates for these conditions could be approaches to embedding small-group collaborative learning in the overall instructional setting on different social levels (Dillenbourg & Jermann, 2007; Tabak, 2004), i. e. classroom scripts. Another study from the same project has shown that a classroom script involving phases of small-group collaboration combined with modelling on the plenary level can foster online search skills without the need to permanently structure small-group collaboration (Kollar, Wecker, Langer & Fischer, 2011). It is an open question how such a classroom script interacts with the fading of a small-group collaboration script.

The present paper extends our understanding of collaboration scripts by providing evidence that computer-supported collaboration scripts can be effective also in real-world settings and in interventions with an extended timeframe, and that similar mechanisms as the ones identified in laboratory studies can explain this (Kollar et al., 2007; Stegmann et al., 2007). Computer-supported collaboration scripts have been shown to be effective means to foster important components of scientific literacy such as online search skills. Apparently by means of computer-based collaboration scripts it is possible to create a zone of proximal development involving the learning partner as well as technology and thereby help learners build up domain-general skills supported by the external collaboration script (Carmien, Fischer, Fischer & Kollar, 2007; Pea, 2004; Wood et al.; 1976).

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