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Adaptable Scripting in Computer-Supported Collaborative Learning to Foster Knowledge and Skill Acquisition

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Abstract: Collaboration scripts have repeatedly been implemented in CSCL with the aim of improving individual acquisition of domain-specific knowledge and domain-general skills. However, it is a delicate compromise between taking the "freedom from" (i.e., constraining the learners' efforts to self-regulate their learning) and providing the "freedom to" learners (i.e., enabling them to collaborate on a higher level) when implementing CSCL scripts. The study reported here aimed to answer the question whether adaptable scripting would be an effective approach to realize flexibility in scripted CSCL. 54 university students participated in this study which compared three experimental conditions (unscripted CSCL, CSCL with a non-adaptable script, CSCL with an adaptable script). Results showed that the adaptable script improved individual knowledge and skill acquisition compared to the other two conditions.

Collaboration Scripts to Support CSCL

To support individual knowledge acquisition in CSCL, group interactions, such as asking thoughtful questions (King, 2007), exchanging arguments (Kuhn, Shaw, & Felton, 1997), and engaging in exposing and reconciling cognitive discrepancies (Roschelle, 1992), have been shown to be effective. Yet, research has demonstrated that such processes do not generally occur spontaneously (e.g., Hewitt, 2005). Therefore, process-related scaffolding approaches have been developed to help learners perform more high-level, productive collaborative activities than without support. Collaboration scripts, as an example of such an instructional approach, have repeatedly been demonstrated to improve CSCL with respect to learners' knowledge acquisition, since they facilitate high-level collaboration processes by specifying, sequencing and distributing learning activities and roles among learners in a small group (Kollar, Fischer, & Hesse, 2006). For instance, Weinberger, Ertl, Fischer and Mandl (2005) used a social collaboration script, which distributed the roles of *case analyst* and *constructive critic* and sequenced sub-activities through *first case analysis*, *critique*, *reply to critique* to *final analysis* in an asynchronous CSCL environment and found that it fostered a variety of high-level online discussion processes and led to higher levels of domain-specific knowledge acquisition than unstructured CSCL.

Usually, collaboration scripts not only aim to foster the acquisition of domain-specific knowledge, but at the same time also domain-general skills (Wecker & Fischer, 2007). From an instructional point of view, focusing on learners' skill acquisition helps answer the question whether the effects of collaboration scripts extend beyond the learning situation in which they were provided, by promoting the capabilities of learners to collaborate in a fruitful way. By using collaboration scripts, the script itself may be internalized so that learners can become self-regulated in their use of it, since according to Vygotskian thinking, the actions of the roles and any verbal prompts can be internalized as inner speech so that learners can apply their acquired knowledge to self-prompt actions in similar situations (Rogoff, 1990). The empirical study presented below investigated the effects of script support on both learners' acquisition of domain-specific knowledge and their acquisition of domain-general skills; and more specifically the possible advantage of adaptable scripting in CSCL.

Adaptable Scripting to Foster Knowledge and Skill Acquisition

Although empirical evidence on the positive effects of classical CSCL scripts on individual knowledge and skill acquisition is ample, scripting approaches have also been criticized for being coercive and not allowing students to self-regulate their learning (Diziol, Walker, Rummel, & Koedinger, 2010). On the one hand, it often seems necessary to provide learners with scripts that impose some structure to enable them to engage in productive interaction. On the other hand, learners may be given too little freedom in scripted CSCL for deeper learning to occur (Rummel & Spada, 2005). Over the years, some efforts towards more open and less restrictive forms of CSCL scripts have been made to optimize the success of the scripting approach. In order to meet individual learners' needs for instructional support and their needs for freedom within a CSCL environment, adaptable instruction is a promising approach which may improve the fit between learner and learning environment. A learning environment is called 'adaptable' when users (i.e. teachers or students) can adjust external support to meet the learners' self- or other-perceived needs (Leutner, 2009). In the field of CSCL, there is a conceptual analysis of the notion of "flexibility", which deals with the concern of coercive scripting (Dillenbourg & Tchounikine, 2007). There, adaptable scripting was argued theoretically as a promising approach to realize flexibility. Whether the argument empirically holds true is one of the questions addressed in the study presented

in this paper. Of course, there are reasons to expect this: by increasing learners' opportunities for self-regulation, adaptable scripting might be beneficial for learners' knowledge acquisition, since self-regulation has been regarded as an influential factor in learning, especially in skill acquisition (Zimmerman, 2008).

Research Questions and Hypotheses

This study aimed to answer the question to what extent an adaptable script can facilitate (1) the individual acquisition of *domain-specific knowledge* and (2) the individual acquisition of *domain-general skills* compared to a non-adaptable script and unscripted collaboration in a CSCL environment. We expected that learning by aid of an adaptable script would lead to higher levels of domain-specific knowledge and domain-general skills than a non-adaptable script, which in turn was expected to lead to better results than unstructured CSCL.

Besides the potential advantage of adaptable scripting on learning outcomes, we were also interested in its effects on learning processes: Therefore, we asked (3) how learners in the adaptable script condition adapted the script compared to the non-adaptable script condition; and (4) how the adaptation in turn affected their script adherence. We expected that learners in the adaptable script condition would do more self-planning and use less support provided by the script than learners in the non-adaptable script condition. The adaptation, yet, would not diminish their script adherence, compared to the non-adaptable script condition.

Method

Participants and Design

To answer these research questions, a one-factorial pre-post test design with three experimental conditions was used. The independent variable was the kind of instructional support. In the unscripted CSCL condition, students collaborated in an asynchronous CSCL environment without an external script. In the non-adaptable script condition, students were guided by a continuous, non-adaptable script, while students who learned in the adaptable script condition could adapt the script to their self-perceived needs (see below for more details). 54 students of Educational Sciences from the Ludwig-Maximilians-University of Munich participated in this study as part of a course assignment. They were randomly assigned to small groups of three, and each group was randomly assigned to one of the three experimental conditions (see Table 1).

Table 1: Design of the experimental study.

Unscripted collaboration	Non-adaptable script	Adaptable script
n = 18 students (6 triads)	n = 18 students (6 triads)	n = 18 students (6 triads)

Task, Setting and Learning Environment

The students' task was to analyze three authentic educational problem cases on the basis of Weiner's (1985) attribution theory. Discussions were led in a web-based CSCL environment, which was a revised version of the CASSIS environment (see Figure 1; Stegmann, et al., 2007). CASSIS is an asynchronous discussion board in which three participants can post messages that, apart from the experimenters, only the members of the learning group could read. The participants were logged in with code names in an effort to warrant anonymity.

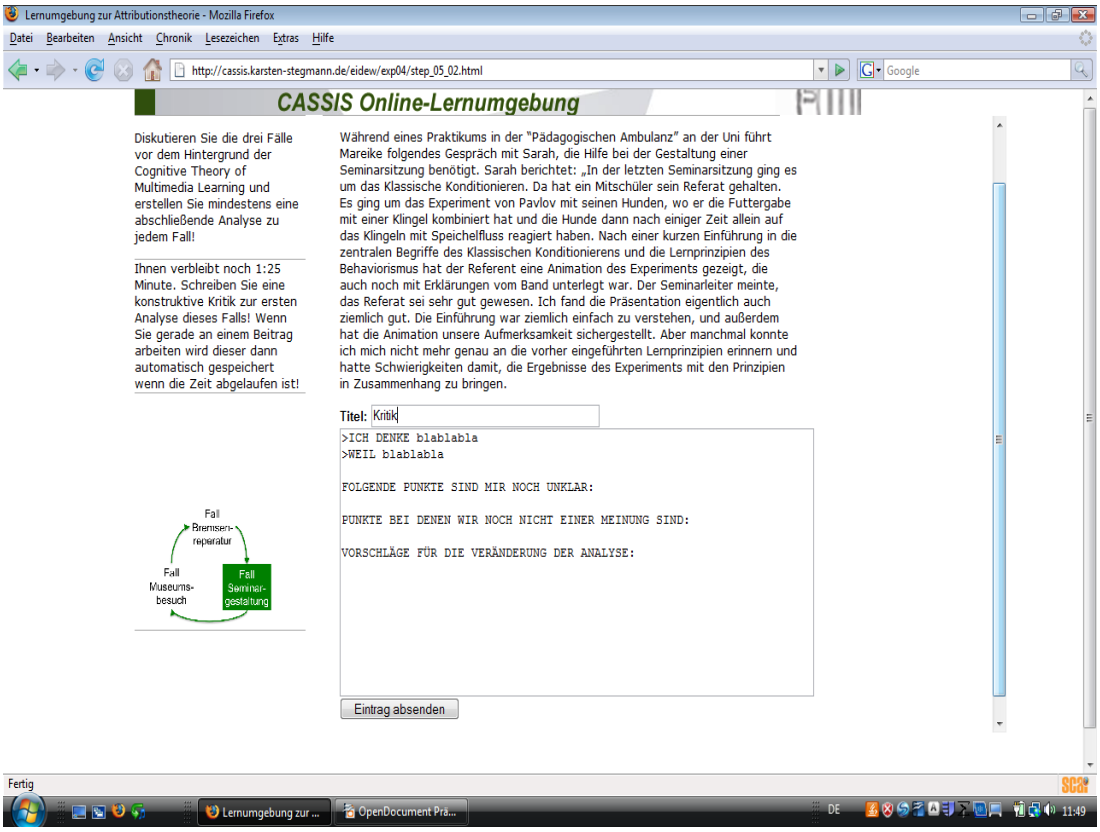

Figure 1. Screenshot of the learning environment CASSIS. Upper left: description of the task (analyze three problem cases with the help of the according theory). Middle left: timer (how much time left for the current task). Lower left: orientation map depicting which case the learner is working on. Upper right: case information. Lower right: discussion board where learners can type in messages (including script prompts).

Procedure and Experimental Conditions

The experiment spanned five phases. (1) *Pre-test and individual learning*: firstly, the participants of the study filled out questionnaires (demographic information and intrinsic motivation) and secondly they read two four-page theory sheets, one about Mayer's (2001) Cognitive Theory of Multimedia Learning and the other one about Weiner's (1985) Attribution Theory. The third step in the pre-test phase, which was the assessment of prior knowledge on collaboration (see below), took place immediately before the CSCL session, when the participants were arranged appropriately in the laboratory room.

(2) *Training*: after pre-test and individual learning, students were guided to a 44-minute training phase, which helped them get a first experience on how to handle the learning environment and how the collaboration script worked. During this phase, students in all three conditions analyzed three problem cases dealing with multimedia design against the background of Mayer's Cognitive Theory of Multimedia Learning, with the support of a collaboration script, which assigned two different roles (role A: analyst for one of the three cases and role B: constructive critic for the other two cases) to individual learners in a small group. Role A (analyst) took over the responsibility for the preliminary and concluding analysis on one case and responding to criticism from the learning partners. In the role of constructive critics (role B), learners were required to criticize their partners' analyses of the two other cases. These activities were supported by interaction-oriented prompts (e.g., "We have not reached consensus concerning these aspects:"), which were automatically inserted into the critics' messages and into the analyst's replies in order to help learners take over their roles successfully (Weinberger et al., 2005). In addition, there was a time limit for each sub-step students had to take.

(3) *Chat*: after a short break, students were guided to apply Weiner's attribution theory to three new problem cases. There was a chat before group work on analyzing the three cases, within which participants were asked to reflect upon their group discussion during training phase and plan for the coming one. In addition, students in the adaptable scripted condition were provided with opportunities to choose the role (analyst or critic) they would like to play for analyses of each problem case.

(4) *Treatment*: after 4 minutes of chatting, students were guided back to the same forum as they worked with during the training phase. In the 70-minute experimental phase, students in the unscripted condition

collaboratively worked on the case analyses without support of external scripts, but the strategies that had been discussed during chat could be used. Students in the non-adaptable script condition learned with the same script as they did during training. Here students could use the strategies that they discussed about only within the boundaries of the script. For students who learned in the adaptable script condition, the collaboration script in the experimental phase was adaptable. "Adaptability" was operationalized by providing learners with control over whether they would like to use the interaction-oriented prompts and the time they would like to spend on each case (time for the whole experimental phase kept the same as that in the other two conditions). Moreover, distribution of responsibilities for case analyses in the adaptable script condition was not determined by the script, but was based on their group decision during chat.

(5) *Post-test*: the experimental phase was followed by an individual post-test on students' knowledge acquisition on attribution theory, in which students were supposed to analyze a new problem case related to attribution theory, and a collaborative post-test on students' acquisition of collaboration skills, in which students were supposed to engage in an unstructured discussion about the post-test case (see below).

Dependent and Control Variables

Dependent variables were individual students' acquisition of domain-specific knowledge (on attribution theory) and individual students' acquisition of domain-general skills (collaboration skills). *Domain-specific knowledge acquisition* was assessed by an in-depth analysis of the individual analyses of a new problem case related to attribution theory during the post-test phase. Two coders independently first segmented 10% of individual analyses of the case into meaningful pieces of messages (Chi, 1997). Inter-rater agreement on segmentation was 94%, amounting to a Cohen's Kappa of κ = .88. The remaining 90 % of the material were then coded by the trained coders individually (the same procedure was applied to all the discourse analyses below). Secondly, each of the resulting segments was coded with the help of a coding system assessing the quality of knowledge construction (developed by Weinberger & Fischer, 2006). This system differentiated between utterances that represented the "construction of problem space" (e.g., "The student in the case thought that she failed in an exam because of low ability."), the "construction of conceptual space" (e.g., "Internal stable attribution of failure has negative effects on learning motivation.") and the "construction of relations between conceptual and problem space" (e.g., "The student is attributing internally stable when she took ability as the reason of her failure."). Inter-rater agreement on coding was 94%, amounting to a Cohen's Kappa of κ = .73. For the current analyses, only the frequency of segments coded as "construction of relations between conceptual and problem space" were included, since this category can be considered as representing the highest level of quality of knowledge construction.

Students' *acquisition of domain-general collaboration skills* was measured by a performance test, which was based on the unstructured group discussion about the post-test case. Individual contributions to the group discussion were first segmented into pieces of messages the same way as it was done for segmenting the individual analyses of the post-test case. Second, each of the resulting segments was assessed with respect to the application of collaboration skills that were introduced by the collaboration script. More specifically, the coding scheme differentiated whether a contribution represented "task specification" (e.g., "I suggest that we read and summarize our analyses in the discussion thread."), "role distribution" (e.g., "I am not sure with your point of view that external attribution is positive.") or "sequencing" (e.g., "We should first work on our own analyses."). The inter-rater agreement regarding coding on collaboration skills was 87%, and the inter-rater reliability was Cohen's κ = .71. The occurrence of these utterances was counted and the resulting sum scores were used as an indicator of individual acquisition of domain-general collaboration skills.

Beyond these outcome measures, we also used three process measures as dependent variables. To measure how learners in the adaptable script condition made use of the adaptability during their learning, their *self-planning* and *use of prompts* were coded. *Self-planning* was coded with the coding scheme from Zimmerman (2008). An utterance was coded as *self-planning* when the learners set goals and did strategic planning in terms of task coordination, time management etc. Since planning mainly takes place before the learning process, only learners' discussion during chat, which took place before the treatment phase, was coded in the current study. The inter-rater agreement regarding coding on learners' self-planning was 96 %, and the inter-rater reliability was Cohen's κ = .85. The indicator of learners' *use of prompts* during their online discussion was the percentage of prompts used by learners to prompts provided by the script. *Script adherence* as a third process variable was measured by counting if a specific sub-activity pre-described by the script showed up during the online discussion within a group. The script in the current study pre-described 8 sub-activities: first analysis, first critique from learning partner 1, first critique from partner 2, response to partner 1, response to partner 2, second critique from partner 1, second critique from partner 2, and final analysis.

As control variables, students' *prior knowledge on collaboration* was assessed individually during pre-test by an open format knowledge test. The test asked learners to describe how they would organize their group work imaging they were going to work in triads in an asynchronous discussion board – the CSCL scenario used in the current study; and more specifically which steps they would take and why. Students' responses were

assessed with the same coding scheme that was used to assess the performance test on individual acquisition collaboration skills during post-test. The inter-rater agreement regarding coding on learners' prior knowledge on collaboration was 87 %, and the inter-rater reliability was Cohen's κ = .71. Furthermore, students' *initial motivation* was assessed after training by the motivation scale from Prenzel et al. (1993). This intrinsic motivation scale included five items (e.g., "During the learning session, I experienced myself as curious or inquisitive.") with Cronbach's α = .85 in the reported study.

Results

Preliminary Analyses

Before performing statistical analyses related to our research questions, we checked whether the learners in the three experimental conditions were comparable with respect to prior knowledge and initial motivation. On none of these measures, we found significant differences in the pre-test (for prior knowledge on collaboration: $F_{(2,51)}$ = 0.11; *n.s.;* for initial motivation: $F_{(2,51)}$ = 0.76; *n.s.)*. However, to avoid biases of effects of our treatment on the post test measures, we used these pre-test measures as control variables in all of the following analyses.

Individual Knowledge and Skill Acquisition

Descriptively, with respect to *domain-specific knowledge acquisition*, students who had learned with the adaptable script outperformed students from the other conditions (see table 2). An ANCOVA with the kind of instructional support as independent variable, group id as a random factor nested in treatment, the point scores on the individual knowledge test as dependent variable, prior knowledge on collaboration and initial motivation as control variables however indicated a non-significant effect for the kind of instructional support ($F_{(2,15)}$ = 3.30; *n.s.*). The effect of group on individual acquisition of domain-specific knowledge was not significant ($F_{(15,35)}$ = 0.60; *n.s.*). From Post-hoc-tests (LSD), it was found that students who had learned with the adaptable script slightly outperformed students from the non-adaptable script condition (p = .08). Students in the unscripted condition also performed slightly better than those from the non-adaptable scripted condition (p = .11).

Table 2: Descriptive values for individual knowledge and skill acquisition.

	Unscripted *M* (*SD*)	Non-adaptable script *M* (*SD*)	Adaptable script *M* (*SD*)	Total
Knowledge acquisition on attribution theory	7.86 (4.82)	5.58 (3.75)	8.12 (3.39)	7.19 (4.12)
Acquisition of collaboration skills	1.02 (1.49)	2.23 (1.59)	2.92 (2.16)	2.06 (1.91)

Paralleling the results on knowledge acquisition on attribution theory, with respect to individuals' acquisition of *domain-general collaboration skills*, the descriptive values depicted in Table 2 showed that students who had learned with the adaptable script outperformed students from the other two conditions. An ANCOVA with the kind of instructional support as independent variable, group id as a random factor nested in treatment, individual acquisition of collaboration skills as dependent variable, prior knowledge on collaboration and initial motivation as control variables indicated a significant effect of the kind of instructional support ($F_{(2,15)}$ = 3.75; $p < .05$). The effect of group on individual skill acquisition was not significant ($F_{(15,34)}$ = 1.57; *n.s.*). From Post-hoc-tests (LSD), it was found that students' acquisition of collaboration skills in the unscripted condition was substantially lower than in the adaptable script condition ($p < .01$) and slightly lower than in the non-adaptable condition (p = .06). There was no statistically significant difference between the non-adaptable and the adaptable script condition (p = .16).

Learners' Use of Adaptability

To answer the third research question about learners' use of adaptability in the adaptable script condition, compared to the non-adaptable script condition, descriptive values about learners' self-planning and their use of prompts were depicted in Table 3. Descriptively, data in table 3 showed that in the adaptable script condition, students did more self-planning and used less prompts than in the non-adaptable condition.

An ANOVA with the kind of instructional support (non-adaptable script vs. adaptable script) as independent variable, group id as a random factor nested in treatment, students' self-planning during chat (frequency) as dependent variable indicated a significant effect of the kind of instructional support ($F_{(1,10)}$ = 21.72; $p < .01$). The effect of group on learners' self-planning was not significant ($F_{(10,24)}$ = 1.38; *n.s.*). Since the

use of prompts was calculated on group level, the procedure that AN(C)OVA with group id as a random factor nested in treatment was not applied. An ANOVA with the kind of instructional support (non-adaptable script vs. adaptable script) as independent variable, group use of prompts (percentage) as dependent variable indicated a significant effect of the kind of instructional support ($F_{(1,10)} = 4.95$; $p < .05$).

Table 3: Learners' use of adaptability.

	Non-adaptable script *M* (*SD*)	Adaptable script *M* (*SD*)
Self-planning	1.39 (1.33)	3.72 (1.36)
Use of prompts	0.31 (0.15)	0.14 (0.12)

Script Adherence

As students in the adaptable script condition were provided with opportunities to switch off the prompts, it ran the risk that they did not follow the scripts well. Analyses of script adherence answered the question how well students in each condition performed the eight sub-activities (first analysis, first critique from learning partner 1, first critique from partner 2, response to partner 1, response to partner 2, second critique from partner 1, second critique from partner 2, and final analysis) pre-described by the scripts. Figure 2 showed that groups in the adaptable script condition engaged overall less in the activities specified by the script than those in the non-adaptable script condition, especially with respect to sub-activity 2 (first critique from learning partner 1) and 3 (first critique from learning partner 2).

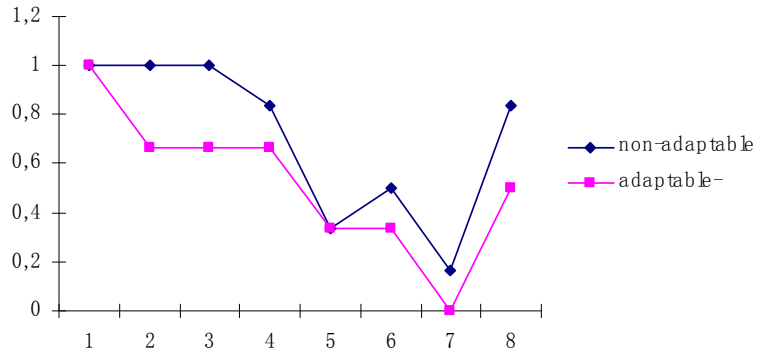

Figure 2. Script Adherence in Non-adaptable and Adaptable Script Condition.

An ANOVA with the kind of instructional support as independent variable and script adhenrence (percentage) as dependent variable indicated a significant effect of the kind of instructional support ($F_{(1,10)} = 7.33$; $p < .05$).

Discussion

In order to benefit from collaboration, students need to interact in productive ways. Collaboration scripts, as a process-related instructional approach, aim at inducing productive interaction in collaborative learning and therefore may improve learning outcomes. However, there are contradictory findings about the effects of collaboration scripts on individual learning outcomes. Many studies (e.g., Kollar et al., 2007) found positive results of CSCL scripts on individual knowledge acquisition, while a few others also (e.g., Weinberger et al., 2005) found negative effects. Against the background of related literature, negative script effects may be interpreted as caused by too high degree of coercion (Diziol et al., 2010). How to implement flexible scripts and thus to maximize the effectiveness of the scripting approach has recently drawn more and more attention. Therefore, we aimed to answer the question whether adaptable scripting is a promising approach to reduce the coercion of scripts without losing the benefit from the process-related support provided by scripts.

With respect to individual acquisition of domain-specific knowledge, the collaboration script used in the current study had slightly negative effects compared to the unscripted CSCL condition. However, when learners were provided with opportunities to reduce the structure imposed by the collaboration script by adapting some parts of the script according to their perceived needs, i.e. in the adaptable script condition, individual knowledge acquisition was enhanced when compared to the non-adaptable script condition. Regarding individual acquisition of domain-general collaboration skills, the collaboration script had slightly

positive effect compared to the unscripted condition. When the script was adaptable, however, individual skill acquisition was substantially enhanced when compared to the unscripted condition. This supports the notion of Dillenbourg and Tchounikine (2007), who argued that "scripts must be flexible" (p.6). The adaptable script in the current study structured the collaboration by specifying and sequencing sub-activities, but left it modifiable to the students, for instance, to choose different roles and switch the prompts on and off. As shown in the results, students in the adaptable script condition benefited from their use of adaptability with respect to their acquisition of both domain-specific knowledge and domain-general skills. Adaptable scripting is therefore a promising approach to realize "flexibility" in scripted CSCL.

Beyond the "flexibility" perspective, positive effects of the adaptable scripting approach on individual learning outcomes may also be explained from the perspective of self-regulated learning (SRL). In line with related research, self-regulation is a significant predictor of students' academic outcomes, since self-regulated students would cognitively and motivationally engage in setting learning goals, using learning strategies and self-monitoring (Zimmerman, 2008). Further analyses of the learning process, which are currently under way, are required to confirm the extent to which the positive effects of adaptable scripting could be explained from the SRL point. For instance, we are interested to find out to what extent adaptability increases SRL, which has been linked to learning outcomes in CSCL (Dillenbourg, Järvelä, & Fischer, 2009; Hadwin, Oschige, Gress, & Winne, 2010).

Regarding the adaptation process, results showed that learners in the adaptable script condition did use the adaptability: they did more self-planning before online discussion and switched more prompts off during online discussion, compared to the non-adaptable script condition. As a consequence of adaptation, however, groups in the adaptable script condition engaged less in a script-like discussion process than groups in the non-adaptable script condition. Nevertheless, the overall decrease of script adherence caused by learners' adaptation of the script did not result in learners' losing the benefit from scripts. More data-sets and further analyses are required to distinguish effective adaptation groups from non-effective ones to examine the prerequisite for successful adaptation in scripted CSCL.

Limitations. The reported study has some limitations. Firstly, the sample size was relatively small. Statistics were done with 54 participants, 18 in each experimental condition. The relatively small sample size leads to constraints concerning statistical power. Therefore, the interpretation of the results should be made with caution. In order to enlarge the statistical power of this study, we are currently continuing data collection. Secondly, it is surprising that - although the same collaboration script was implemented both in the current study and a previous one (Weinberger et al., 2005), we found a slightly negative effect of the collaboration script on individual acquisition of domain-specific knowledge, whereas the previous study found a positive effect of this script on individual acquisition of domain-specific knowledge compared to unscripted CSCL. One main difference between the previous study and the current one is that in the previous study there was no training phase preceding the CSCL session, whereas in the current study, there was a 44-min training phase in advance. A possible explanation for this missing effect could be that the training phase led to some sort of internalization of the script so that learners in the unscripted condition still used parts of the script in the treatment phase. Another explanation from a motivational point of view would be the argument from Oehl and Pfister (2008), which states that scripts implemented in a relatively long term may elicit reactance responses. Possibly, further analyses on the learning processes provide evidence for or against these explanations.

Implications for future research and practice. Despite the limitations discussed above, the adaptable script in the current study is a practical example of realizing flexibility in scripted CSCL, but not the only way. Further ways how to implement flexibility in scripted CSCL may be differentially successful. For example, another line of research on flexible instruction is research on "adaptivity" (as opposed to adaptability realized in our study). An ongoing research (Mu, Stegmann, Mayfield, Rosé, & Fischer, 2010) which aims at realizing automatic adaptation through natural language processing (NLP) technique may provide evidence for the success of a different operationalization of flexibility in scripted CSCL. Flexible instruction, not only in CSCL, but also in other learning environments (e.g., classroom) is an issue that should be investigated in future studies. Finally, the current study showed that learners in the adaptable script condition benefited overall from the adaptability. Nevertheless, it is still an open question whether some students take more advantage out of adaptability than others do. Future studies may look for individual learning prerequisites that may moderate the positive effects of adaptability on knowledge acquisition, like, for instance, individual learning style.

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