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Internal and External Collaboration Scripts in Web-based Science Learning at Schools

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Abstract. Collaboration scripts can help learners to engage in argumentation and knowledge acquisition. However, they might have differential effects for learners holding differently structured knowledge (internal scripts) on argumentation. We investigated how external scripts interact with learners' internal scripts concerning collaborative argumentation. 98 students from two secondary schools participated. Two versions of an external collaboration script (high vs. low structured) supporting argumentation were embedded within a web-based collaborative inquiry curriculum. Students' internal scripts were classified as either high or low structured, establishing a 2x2-factorial design. Results suggest that the high structured external script supported all learners, regardless of their internal scripts, concerning the acquisition of domain-general knowledge. Learners' internal scripts influenced the acquisition of domain-specific knowledge. Results from two case studies reveal differences in argumentation processes attributable to the learners' internal scripts. Results are discussed in terms of their theoretical relevance and practical implications for learning with collaboration scripts.

Keywords: Collaboration scripts, internal scripts, inquiry learning, science education, learning environments.

INTRODUCTION

Several studies have demonstrated that students frequently have problems discussing scientific evidence, particularly in relating evidence to theoretical explanations (e.g., Sandoval, 2003; Bell, 2004). Additionally, students often have difficulty engaging in fruitful argumentation. For example, arguments raised by one student often remain unaddressed by the student's learning partner(s), and obvious disagreements are often left unresolved. If not explicitly scaffolded, learners may fail to show substantive argumentation, leading to little acquisition of domain-general knowledge about argumentation. Low-level argumentation might be reflected in poor elaboration of learning contents and result in a limited acquisition of domain-specific knowledge.

Several instructional approaches have been used by researchers to address these challenges in learning through argumentation. For example, Suthers, Toth, and Weiner (1997) developed and tested Belvedere, a graphical argumentation tool where learners enter hypotheses and evidence into text boxes and specify the relationships between boxes using graphical arrows. This results in a network of nodes and links representing the various pieces of evidence that support or contradict a particular hypothesis. A similar approach has been taken by Bell (1997) in developing the "Sensemaker"-tool to help scaffold students' use of evidence within arguments within Web-based inquiry projects. Another promising approach to structuring collaborative argumentation processes in computer-supported collaborative learning is that of collaboration scripts (e.g., Weinberger, Fischer, & Mandl, 2004). Collaboration scripts provide learners with procedural guidance concerning specific discoursive processes they are to engage in during a particular collaborative learning task, thereby scaffolding the acquisition of procedural knowledge. Weinberger, et al. (2004) demonstrated that collaboration scripts can be designed and implemented within a web-based learning environment in order to evoke specific argumentative discourse processes, resulting in an acquisition of domain-general knowledge about argumentation.

We argue that collaboration scripts are a particularly promising approach when they are implemented within computer-based collaborative inquiry learning environments. In existing approaches like BGuiLE (Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001), CoLAB (Savelsbergh, van Joolingen, Sins, de Jong & Lazonder, 2004), or WISE (Slotta & Linn, 2000), learners are provided with significant support concerning content-related learning, but rarely with specific instructional guidance concerning collaboration and argumentation. Instead, these environments typically provide rather open problem spaces, within which learners are relatively free to choose (a) *what* activities to engage in with respect to the problem at hand, and (b) *how* they want to perform those activities. While students are often required to work collaboratively with one or more peers in such activities, the lack of explicit scaffolds for collaboration could result in unequal participation of learning partners and ineffective argumentation. We claim that externally provided collaboration scripts can be designed to significantly improve both processes and outcomes of collaborative argumentation.

Still, learners may enter instruction with widely varying ideas about collaboration and different capabilities in argumentation. Such differences may call for different collaboration scripts in order to achieve the benefits of scaffolding described above. In the present study, we focus on the impact of learners' differently structured internal scripts (Schank & Abelson, 1977) concerning argumentation, meaning their individual procedural knowledge that guides them in argumentation tasks. We examine how these internal scripts interact with differently structured external collaboration scripts that are designed to help structure collaborative argumentation. This interaction is investigated with respect to both (a) processes and (b) outcomes of collaborative argumentation.

KNOWLEDGE CONSTRUCTION IN COLLABORATIVE ARGUMENTATION

Collaborative argumentation is a core activity practiced by learners who are engaged in collaborative inquiry learning environments. For example, by debating with peers about which piece of evidence supports a particular theory or argument, learners can acquire argumentation skills as well as domain-specific knowledge about the contents of their discussion (e.g., "arguing to learn" -- Andriessen, Baker, & Suthers, 2003). In formulating an argument, learners must explain their reasoning and thereby construct new knowledge (e.g., the "self explanation effect" -- Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Concerning the specific process of argumentation, research is varied (see Stein & Albro, 2001), with at least two different approaches to argumentative knowledge construction. On the one hand, some researchers seek to assess the quality of single student arguments on the basis of the structural components they include. On the other hand, argumentation is often analyzed with respect to the different sequences of arguments like argument, counterargument and reply (Leitão, 2000; Resnick, Salmon, Zeitz, Wathen & Holowchak, 1993).

As an example for the first perspective, the argument scheme developed by Toulmin (1958) can be used to assess either written or oral arguments (e.g., Cobb, 2002; Bell & Linn, 2000) as well as to teach learners how to create complete arguments (e.g., Carr, 2003; McNeill, Lizotte, Krajcik, & Marx, 2004). Driver, Newton, and Osbourne (2000) point out that generating complete arguments leads to a deeper elaboration of the learning material resulting in an acquisition of domain-specific knowledge. According to the Toulmin model, an argument consists of up to six components. First, arguments are based on *data* representing evidence on which the argument relies. Second, arguments usually include a *claim* by which the speaker expresses his or her position. Third, arguments can contain a *warrant* that specifies why the data support the claim. Fourth, in order to highlight the validity of a warrant, arguments can contain a *backing*, which can be a reference to a general law, for example. Fifth, arguments can contain a *qualifier* that constrains the validity of the claim. Finally, an argument can contain a *rebuttal*, by which conditions are specified under which the claim is not valid. Since students in school may have difficulties in applying such a scheme to identify the components of an argument, it is useful to reduce the complexity of Toulmin's model. Therefore, similar to previous research (McNeill et al., 2004; Marttunen & Laurinen, 2001), we focus on three essential components of arguments: data, claims, and reasons (which comprise both warrants and backings)

With respect to the sequence of arguments, Leitão (2000) proposed a model of collaborative argumentation that takes different types of arguments into account. She distinguishes three types of arguments, namely (1) *arguments*, (2) *counterarguments*, and (3) *replies*. An argument represents an assertion that is preceded or followed by a justification. By generating a counterargument, a speaker can (a) shift the topic, (b) doubt the validity of the original argument, or (c) question the relation between the components of the argument (e.g., doubt that the provided data is really supporting the claim). Replies on counterarguments can also take on different forms. They can represent (a) a dismissal of the counterargument, (b) a local agreement with parts of the counterargument, (c) an integrative reply that combines parts of the argument and the counterargument, and (d) an abolishment of the original argument. Leitão (2000) claims that argumentation sequences of the structure "argument – counterargument – (integrative) reply" are most fruitful for collaborative knowledge construction, since they lead both learners to deeply elaborate content information, thereby acquiring domain-specific knowledge. Moreover, by engaging in meaningful sequences of argumentation, learners may internalize these processes and apply this knowledge even when not explicitly asked to do so, thereby acquiring domain-general knowledge about argumentation itself.

SCRIPTS FOR KNOWLEDGE CONSTRUCTION IN COLLABORATIVE ARGUMENTATION

External Scripts for Knowledge Construction in Collaborative Argumentation

Collaboration scripts are complex instructional means that (a) induce certain *activities* to be carried out by the learners, (b) prescribe specific *sequences* concerning when to carry out each activity, and (c) provide learners with *collaboration roles* specifying who of the learning partners is supposed to carry the related activities out (see Kollar, Fischer, & Hesse, 2003). Such scripts are here referred to as "external scripts" because they typically are – at least at the beginning of a collaborative learning situation – not represented in the learners' cognitive systems but rather in their external surround (Perkins, 1993), possibly being gradually internalized the more learners are acting in accordance to the script's contents. With respect to their *degree of structuredness*, external scripts can differ substantially. While some approaches provide rather rough constraints for specific activities, sequences, and roles (e.g., Baker & Lund, 1997), other approaches can be considered as being rather high structured (e.g., Pfister & Mühlpfordt, 2002), including very detailed instructions concerning which activities should be shown and when this should be the case. When reviewing existing collaboration script approaches it appears that scripts can be tailored to very different process and outcome dimensions, often accompanied by non-intended side-effects. For example, Weinberger, et al. (2004) demonstrated that an epistemic script aiming at facilitating content-related activities within triads of learners led to an increase of content-relevant talk but to lower content-specific learning gains and hampered transactivity, i.e. the mutual relatedness of the learning partners' utterances.

Internal Scripts for Knowledge Construction in Collaborative Argumentation

It is reasonable to argue that collaborative argumentation processes are not only guided by externally induced scripts. Learners also bring internal scripts for collaborative argumentation into argumentative situations, which they have build up and continuously adjusted in earlier instances of argumentation. Similar to Schank and Abelson's (1977) notion of "personal scripts", we define internal scripts as the set of process-relevant knowledge that guides individuals in their acting in and understanding of particular situations, in our case in collaborative argumentation situations. We assume that these internal scripts on collaborative argumentation vary between individuals and that they are *structured to different degrees,* i.e. that different individuals have different knowledge about how to act in argumentative situations. For example, some individuals might know that reasons should be made explicit in arguments whereas others do not. Likewise, some individuals might have the aim to persuade their discourse partner resulting in producing counterarguments to all the partner's arguments. Others might rather aim to find a consensus in an argumentative situation, resulting in an integration of the different standpoints. It is then unclear, how differently structured internal scripts play together with differently structured external scripts and how this interplay affects processes and outcomes of collaborative argumentation.

GOALS OF THE STUDY

The objective of this study is to analyze the effects of differently structured internal and external scripts on both processes and outcomes of students' collaborative argumentation during learning in a web-based inquiry learning environment (Web-based Inquiry Science Environment; Slotta & Linn, 2000). On behalf of the *outcomes*, we focus on the individuals' acquisition of domain-general knowledge on argumentation and of domain-specific knowledge. With respect to *processes*, we analyze the effects of internal and external scripts on particular argumentative moves. We set up two competing hypotheses:

Interactive effects hypothesis: A highly structured externally provided collaboration script will facilitate the acquisition of domain-general and domain-specific knowledge of learners holding low structured internal scripts, whereas a low structured external script will lead learners holding high structured internal scripts to acquire more domain-general and domain-specific knowledge. If true, this hypothesis could result from either the high structured external script compensating for the deficits of the low structured internal scripts, or because the highly structured external script unnecessarily puts constraints upon the learning processes of learners with high structured internal scripts.

Additive effects hypothesis: A high structured external collaboration script will support the acquisition of domain-general and domain-specific knowledge of all learners, independently from the nature of their internal scripts on collaborative argumentation, because even the contents of a high structured internal script will play out only when additional instructional support is provided.

In order to better understand the effects of the interplay of high and low structured internal and external scripts, the analyses are enhanced by a qualitative analysis of the discourse of two exemplary dyads.

METHOD

Participants. 98 students (grades 8 to 10) from five classes of two German Gymnasiums participated in the study.

Design. An experimental 2x2-factorial design was established with the internal scripts on collaborative argumentation (high vs. low structured) and the external collaboration script (high vs. low structured) as independent variables. Dyads were homogeneous with respect to the learners' internal scripts and gender and were randomly assigned to one of the two external script conditions. Learners were identified as holding a high or a low structured internal script by assessing their performance in a test, in which they were asked to identify "good" and "bad" argumentative moves (e.g., arguments lacking reasons or too short argumentative sequences) in a fictitious discourse excerpt about a science topic. The median score of 3.33 (*SD* = 2.41) was used as the criterion according to which learners were classified as holding either a low or a high structured internal script. This resulted in 48 learners classified as holding a low structured and 50 learners as holding a high structured internal script on collaborative argumentation.

Procedure. The study was conducted in two sessions. In the first session, which took part about two weeks before the actual collaboration phase, learners had to complete several questionnaires on demographic variables, prior domain-specific knowledge, and collaboration as well as computer experience. Most importantly, learners were asked to answer the test assessing their internal scripts. For the collaboration phase two weeks later, homogenous dyads were established with respect to the degree of structuredness of the learners' internal scripts. They then collaborated on the WISE-project "The Deformed Frogs Mystery", which is described below. Two versions of the "Deformed Frogs" project were realized, one containing the low structured and the other the high structured external collaboration script (see below). Dyads were randomly assigned to one of these two conditions. Time for collaboration was 120 minutes. Immediately after collaboration, learners had to complete questionnaires to assess their domain-general knowledge on argumentation and domain-specific knowledge (see below).

Setting and learning environment. Dyads worked on a German version of the WISE project "The Deformed Frogs Mystery". They were introduced to the phenomenon that many frogs with massive physical deformities had been found in the late 90's, for which several possible explanations exist. The project provided learners with two competing hypotheses, a *Parasite Hypothesis* and an *Environmental-Chemical Hypothesis* to be discussed against the background of various information (e.g., photographs, maps, reports), which learners could explore within the project. The curriculum project was segmented into five content-specific units, e.g. "What's the problem?", "Where are the deformed frogs?", or "What's in the water?". Learning partners of each dyad worked together in front of one computer screen and could talk face-to-face. A teacher was not present.

External collaboration script. The two versions of the external collaboration script were implemented in the "Deformed Frogs" project. At the end of each content-specific curriculum unit, the learning partners were supposed to discuss the two hypotheses on the basis of the information they had just viewed and to type their arguments. The two experimental conditions differed in the way how this typing and discussion phase was structured. In the *low structured* version of the external script, learning partners did not get further support than being asked to discuss the two hypotheses on the basis of the information of the particular unit.

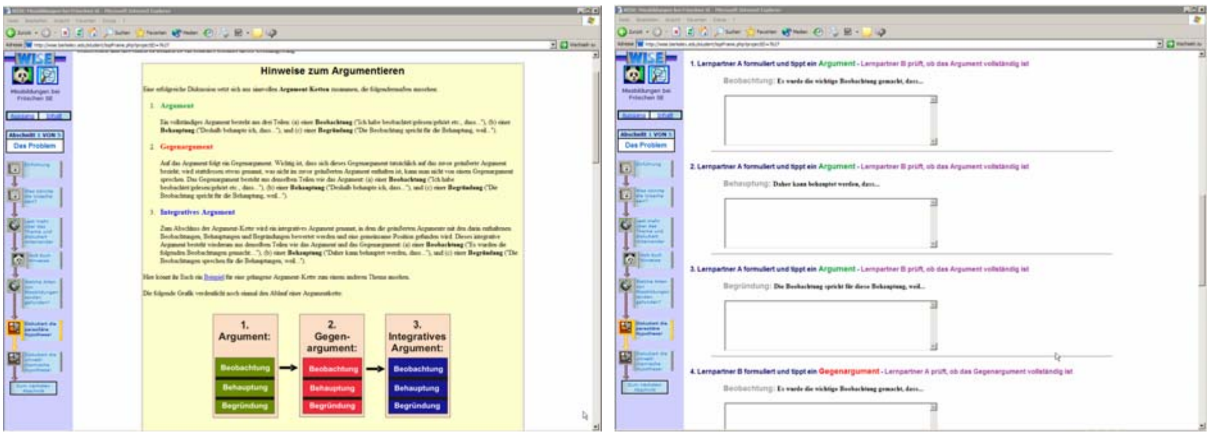

Figure 1: Screenshots of the high structured external collaboration script (left screen: introductory text; right screen: pre-structured text boxes to be filled in by the participants.

In the *high structured* (see figure 1) version of the external script, however, learners received additional guidance in how to discuss the two hypotheses, based on the models of Toulmin (1958) and Leitão (2000). More specifically, learners were prompted to create complete arguments in Toulmin's (1958) sense (data, claim, reason) and argumentative sequences according to Leitão's (2000) model (argument – counterargument – integrative argument). This was achieved by providing learners with an instructional text about these guidelines and by providing them with prestructured blank text boxes into which to fill in the requested argument components (e.g., data in text box 1, claim in text box 2 etc.). For each box, the script specified which learner had to create an argument component and provided him or her with sentence starters (e.g., "It was found that…" for data). In order to avoid biased information processing, the partners' roles concerning who had to advocate which hypothesis were switched several times. Also, script instructions were continuously faded out to avoid the problem of "over-scripting" (Dillenbourg, 2002). For example, at the end of the second unit, the high structured external script did not contain any sentence starters, and the textboxes were reduced to one for each argument, i.e. the interface did not force the learners anymore to split their arguments into data, claim, and reason. Anyway, learners still were reminded of those three components in the instructional text.

Instruments and dependent variables. The *domain-general knowledge about argumentation test* asked learners to mention what components an argument consists of as well as how a complete argumentative sequence looks like and to give examples for complete arguments and argumentative sequences. As a maximum, 12 points could be reached on this measure. Reliability of the measure was sufficient (Cronbach's $\alpha = .72$). The *domain-specific knowledge test* contained five open-ended questions. In the first four questions, learners were asked to reproduce the mechanisms that might cause the frog deformities according to the parasite and the environmental-chemical hypothesis. Learners received points for a reproduction of the mechanisms and for pieces of evidence they were mentioning by which the validity of the particular hypothesis could be assessed. The resulting subscale was termed *knowledge about mechanisms*. Overall, six points could be achieved on this measure. In the fifth question of the domain-specific knowledge test, learners were asked to reason about what could be done to definitely find out the reason for why the frogs are deformed. Here, learners could reach four points as a maximum. The resulting scale was termed *knowledge about scientific methods.* We also computed an overall test score for domain-specific knowledge, in which we added all items of the domain-specific knowledge test, establishing an *overall domain-specific knowledge* measure. The same content-specific knowledge test was also used to assess the learners' prior knowledge. For knowledge about mechanisms the used scale failed to reach sufficient reliability. Therefore, the pretest measure of knowledge about scientific methods was not included in our analyses. Reliabilities of the other measures ranged between .53 and .66 (Cronbach's α).

For the analysis of *processes of collaborative collaborative argumentation*, discourses of the dyads were transcribed and analyzed with a coding scheme aiming to identify arguments and argumentative sequences. Utterances were coded as arguments when they were content-related and when they included at least a *claim* that was made by the speaker. It was accounted for the fact that arguments can develop over time, i.e. arguments are not limited to single turns. Arguments were rated concerning what structural component they included. An argument was rated as containing *data* when it included an observation to make a claim. This observation could both have its origin in the contents of the learning environment and in the learners' prior knowledge. An argument was rated as including a *reason* when it was clear that the speaker aimed to say why (a piece of) data supported the claim of the argument. Further, each argument was rated with respect to the function it had for the context of argumentation. An argument was rated as *argument*, when it marked the beginning of a new topic that had not been discussed before. A *counterargument* was rated when it represented a reply to an argument that still dealt with the same topic and that went beyond a mere confirmation or negation of the argument. An argument was rated as an *integrative reply* when it contained both components of the argument and the counterargument that were uttered before. Thereby, it did not matter, which components of the integrative argument was taken from what earlier argument. In the context of this paper, we focus on how discourse develops when internal scripts are either high or low structured and the external script is low structured.

Statistical analyses. Concerning both domain-general knowledge on argumentation and domain-specific knowledge, we computed ANCOVA's with internal and external scripts as fixed factors and the scores in the specific outcome measures as dependent variables to test the two hypotheses. To determine the effects of internal and external scripts on domain-specific knowledge, the each specific domain-specific prior knowledge measures were included as covariates (except for knowledge about mechanisms because of its low reliability). Learners in the four conditions did not differ significantly concerning their domain-specific prior knowledge ($F(1,95) < 1.06$; *n.s.*). As a covariate for domain-general knowledge on argumentation, the point score in the test for assessing the internal scripts was used. For all analyses, the α -level was set to 5 %.

RESULTS

Acquisition of domain-general knowledge on argumentation

For *domain-general knowledge about argumentation*, learners with the combination of high structured internal and high structured external scripts received the highest scores ($M = 9.67$, $SD = 2.46$), followed by the "low structured internal/high structured external script" condition (*M* = 8.00; *SD* = 2.67). Next was "high structured internal/low structured external" (*M* = 7.46; *SD* = 2.12), followed by "low structured internal/low structured external" (*M* = 6.76; *SD* = 2.17). The main effect for the external collaboration script ($F(1,93) = 12.96$; $p < .01$) was significant indicating that the high structured external script led learners to acquire more domain-general knowledge about argumentation than the low structured external script.

Acquisition of domain-specific knowledge

Table 1 presents the mean scores in the domain-specific knowledge tests for each experimental condition. On the *overall measure* of domain-specific knowledge, learners holding high structured internal scripts reached higher scores than learners holding low structured internal scripts, especially when they collaborated by aid of the high structured external script. The group with the lowest scores in the overall measure of domain-specific knowledge was the "low structured internal/low structured external" group. An ANCOVA revealed a significant main effect for the internal script ($F(1,93) = 10.33$; $p < .05$), favoring high structured internal scripts.

Table 1: Mean scores (standard deviations in parantheses) in the domain-specific knowledge tests (pre- and posttests) in the four experimental conditions.

	Low structured internal script				High structured internal script			
	Low structured external script		High structured external script		Low structured external script		High structured external script	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*
Domain-specific knowledge (overall)	2.58 *(1.33)*	4.69 *(2.05)*	2.32 *(1.32)*	4.91 *(2.02)*	2.50 *(1.48)*	6.00 *(1.65)*	2.50 *(1.32)*	6.12 *(2.03)*
Knowledge about mechanisms	0.42 *(0.58)*	1.77 *(1.34)*	0.64 *(0.73)*	2.14 *(1.46)*	0.58 *(0.70)*	2.31 *(1.62)*	0.63 *(0.88)*	2.83 *(1.49)*
Knowledge about research methods	2.15 *(1.19)*	2.46 *(1.07)*	1.73 *(0.88)*	2.18 *(1.01)*	1.92 *(1.09)*	2.77 *(0.82)*	1.92 *(0.93)*	2.33 *(0.76)*

The same pattern could be observed for *knowledge about mechanisms*. Learners with high structured internal scripts outperformed learners with low structured internal scripts. The most successful group was "high structured internal/high structured external", followed by "high structured internal/low structured external, "low structured internal/high structured external" and "low structured internal/low structured external". An ANOVA yielded a significant effect for the internal script indicating that learners holding high structured internal scripts received significantly higher scores than learners with low structured internal scripts ($F(1,93) = 4.24$; $p < .05$).

For *knowledge about scientific methods*, a different and rather surprising pattern occurred. There, learners holding high structured internal scripts who had collaborated on the basis of the low structured external script reached the highest scores, followed by learners with low structured internal scripts who were provided with the low structured external script. Learners with high structured internal scripts who collaborated on the basis of the high structured external script reached lower scores, but even lower were the scores for learners with low structured internal scripts who worked with the high structured external script. An ANCOVA revealed a marginally significant main effect for the external script ($F(1,93) = 3.18$; $p = .08$) indicating that learners who had worked with the low structured external script acquired more knowledge about scientific methods than learners having been supported by the high structured external script. Post hoc t-tests revealed that learners holding high structured internal scripts who had collaborated on the basis of the low structured external script were significantly better than both groups of learners having collaborated with the high structured external script ($t(70) = 2.42$; $p < .05$).

Processes of collaborative argumentation – examples from two dyads

In order to illustrate how internal scripts unfold in collaborative argumentation, we conducted a qualitative process analysis. The objective of this analysis is to identifiy single arguments as well as argumentative sequences and to assess their completeness in terms of the structural model proposed by Toulmin (1958) and the dynamical model by Leitão (2000). I.e., we were interested in what components single arguments include (data, claim, reason) and what types of arguments were parts of argumentative sequences (argument, counterargument, integrative argument). Below, we present excerpts from the written transcripts of two dyads. Partners of dyad 1

(Christina and Anne) were identified as holding low structured internal scripts, and the internal scripts of the individuals in dyad 2 (Svenja and Lea) were classified as high structured.

It was observed that collaborative argumentation processes of dyad 1 (Christina and Anne; low structured internal scripts), were deficient both with respect to the structural components of single arguments and the sequences of arguments. Christina and Anna rarely generated arguments that contained data, claims, and reasons, and almost never were able to complete an argumentative sequence consisting of an argument, a counterargument, and an integrative argument. The transcript in table 2 illustrates that Christina in turn 3 states a claim saying that the chemical substance is causing the frog deformities. After that, she fails to bring in data, and the reason she gives is rather poor in that it does not go beyond "that is somehow more logical" (turn 5). Her second claim in the second part of turn 5 ("No, earlier I would have said it's the parasites for sure") lacks a reason as well as scientific data that support the claim that parasites are causing the frog deformities. Christina and Anne also fail to create a longer argumentative sequence, although Anne is explicitly stating that she could find reasons for both hypotheses. She suddenly stops talking while starting to develop a counterargument, and Christina (turn 6) does not take up the chance to create a counterargument on one of the two arguments Anne stated before.

Table 2: Excerpt of a discourse of a dyad in the "low structured internal/low structured external" condition.

1. Christina: "Well, I think…"
2. Anne: "Yes?"
3. Christina: "that, well, the chemical substances, that they uhm mainly are responsible for it, because they did not find out a lot about the parasites yet. And, well, that is somehow…"
4. Anne: (interrupts) "Did we really say that?"
5. Christina: (continues) "…more logical after I have read all that stuff. No, earlier I would have said it's the parasites for sure, but the… the biological stuff… that…" (stops talking)
6. Anne: "OK, so we are done then. Click it away."
7. Christina: "What?"
8. Anne: "That site."
9. Christina: "No!"
10. Anne: "Yes!"
11. Christina: "OK." (clicks on an another site)

In the case of dyad 2 (Svenja and Lea; see table 3), collaborative argumentation was qualitatively better both with respect to the structural components of single arguments and the argumentation sequences that could be observed. Svenja and Lea often formulated arguments that contained data, claims, and reasons, and they also showed attempts to generate longer argumentative sequences. In turns 2 and 3, Svenja and Lea collaboratively construct an argument that contains a claim made by Lea (turn 2) and a reason by Svenja (turn 3). In turn 8, Lea adds data to the argument, which Svenja in turn 9 even extends. With respect to argumentative sequences, Svenja is concerned about possible counterarguments to their joint argument (turn 5, first part) but finds again some counterevidence against this possible counterargument (turn 5, second part). However, the two girls do not manage to create an integration of the two conflicting hypothesis in this excerpt.

Table 3: Excerpt of a discourse of a dyad in the "high structured internal/low structured external" condition.

1. Svenja: "So, what do you think is more likely? Chemical or parasite?"
2. Lea: "Well, what do we think? Well, I on my part think that chemical is more likely."
3. Svenja; "Yes, I agree. Because, although the parasite can also attack them (the frogs) but not that strongly. And it can also not block it."
4. Lea: "And also there is… I write it down, ok? (starts typing: "We think that the chemical hypothesis…"
5. Svenja: (interrupts) "Well, but they did block something that one time [inaudible]. But when their heads are shrinked…" […]
6. Lea: (continues typing: "…is more logical") Is more logical, ok? Because…
7. Svenja: "Why do we think so?"
8. Lea: "Firstly it has been growing over the last years a lot, and the chemical stuff has become more, too."
9. Svenja: "Secondly, they also said somewhere that the parasite just can block a part, didn't they?"
10. Lea: "Yeah."
11. Svenja: "Yes, where did we read that?"
12. Lea: "It was somewhere up there (points to screen). That's where they said it. How should I write it?"

DISCUSSION

In this study, we investigated how differently structured internal scripts on collaborative argumentation play together with differently structured external scripts aiming at facilitating collaborative argumentation in a web-based collaborative inquiry learning environment. With respect to both processes and outcomes of collaborative argumentation, we set up two competing hypotheses, an interactive effects hypothesis and an additive effects hypothesis. In general, the results rather support the additive effects hypothesis: At least for the acquisition of *domain-general knowledge about argumentation* it was shown that the high structured external script supported all learners independently from their internal scripts. It appears that high structured external scripts (O'Donnell, 1999) can be designed to help even learners with high structured internal scripts on collaborative argumentation to acquire domain-general knowledge about argumentation. However, contrasting our expectations, the high structured external script did not support the acquisition of domain-specific content knowledge beyond the level that was reached by providing learners with the low structured external script. Concerning both the *overall domain-specific knowledge* and *knowledge about mechanisms*, learners with high structured internal scripts on collaborative argumentation acquired more knowledge about the contents of the learning environment than did learners with low structured internal scripts, regardless if they collaborated by aid of the high or the low structured external script. Thus, argumentation competences can be regarded not only as a goal, but also as a precondition for successful learning in web-based collaborative inquiry learning environments. It appears that when learners already hold higher-level procedural knowledge about argumentation, they can use this knowledge for a deeper elaboration of domain-specific information, thereby acquiring more knowledge. Since learners' internal scripts that guide them in collaborative argumentation can be assumed as having developed over long periods of time by being exposed to argumentative situations over and over again (Schank & Abelson, 1977), it can be argued that learners can use these scripts effortlessly just like a very familiar tool when they perceive themselves as participating in a collaborative argumentation situation. On the other hand, this stability of learners' internal scripts can make it difficult to influence them by the provision of a high structured external script.

However, the question why the high structured external collaboration script did not lead to the acquisition of more domain-specific knowledge deserves further consideration, especially since it even tended to undermine the acquisition of *knowledge about scientific methods*. It is possible that the design of the high structured external script was too much oriented towards inducing specific argumentative moves and that learners were already strongly challenged by following the script instructions so that they were not able to turn the support they received into deep elaborations of the learning material ("over-scripting"; Dillenbourg, 2002). Wanting learners to acquire both domain-general knowledge about argumentation and domain-specific knowledge might be too much to achieve at a time. Maybe the effects of an internalization of the argumentative knowledge inherent in the high structured script would only play out later in a new argumentative situation. This hypothesis will be subject to further research.

It is useful to take a closer look at the learners' talk during the collaborative learning phase. In the presented excerpts, we were able to identify internal scripts on collaborative argumentation "on-line" and observed that they do have effects on collaborative argumentation processes. High structured internal scripts are likely to lead learners to give more complete arguments (data, claim, reason; Toulmin, 1958) and at least to create counterarguments (Leitão, 2000). Learners with high structured internal scripts also seem to be more concerned about backing their arguments up with data and to challenge their own arguments even when both partners actually share a position. In low structured internal script groups it is evident that learners fail to formulate arguments containing data, claims, and reasons, and that obvious conflicts do not become subject of discussion, resulting in a rare construction of counterarguments. This should be validated in further studies and analyses. It is an interesting question if the additivity effect that was found for the acquisition of domain-general knowledge about argumentation will mirror with the results found on the process level.

Finally, it should be noted that generalizations concerning the nature of the interplay of high vs. low structured internal and external scripts should be drawn with caution, because of two reasons. First, subjects in this study generally reached rather low scores in the internal scripts test. This is not mysterious taking the rather bad results of German students from international comparison studies like PISA (Deutsches PISA-Konsortium, 2001) into account. Yet it might be that for learners with very high structured internal scripts (which apparently were not part of this study's sample) the interactive effects hypothesis might be supported, meaning that such learners would benefit much more from a low structured external script than was observed in this study because they can make extensive use of the degrees of freedom they are provided with by the open structure of the external script. Second, it is unclear to what extent internal scripts on collaborative argumentation can be considered domain-general or have to be conceptualized as varying between contexts. Further research is needed to address this issue.

On a theoretical level, we believe that the study can contribute to the development of a framework for describing the impact of internal and external scripts for collaborative learning. Thereby, a distributed cognition perspective (e.g., Perkins, 1993) might be a valuable frame of reference. From this perspective, it is an important question how to orchestrate the different scripts in a way that they promote effective learning. Taking a systemic approach, it is assumed that learners and their (social, artifactual, and also instructional) surround make up a learning system, in which learning is or can be guided by different system components, namely the individual learner, his or her learning partner, the computer-environment and the imposed external script. Since it is likely to assume that individuals will internalize parts of the external script, the resulting framework would also have to account for states of transition of script components from the external to the internal. These internalization processes are then again important with respect to how instruction (i.e., external scripts) should be designed to account for changes in the learners' internal scripts. According to Pea (2004), we urgently need methods to continuously assess the learners' actual state of knowledge, which in turn must inform the degree of fading the external script instructions out.

From a practical perspective, the merit of this study is that it demonstrates that in problem oriented, collaborative learning environments, external scripts should be used whenever internal scripts are not available resp. if argumentation skills of learners can be considered as rather low. With respect to the outcomes of collaborative argumentative knowledge construction, the study even provided evidence that also learners with better argumentation skills are not hampered by providing them with a high structured external script. Web-based collaborative inquiry environments can be made more effective by implementing a high structured external script that scaffolds processes of collaborative argumentation. However, taking process analyses into account, it was demonstrated that learners with low structured internal scripts might have problems in rather open inquiry learning environments that contain only little information concerning how learners should argue with theories and evidence. For learners with high structured internal scripts, in contrast, this open approach to inquiry learning might be suitable.

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