INTERNAL AND EXTERNAL SCRIPTS IN COMPUTER-SUPPORTED COLLABORATIVE INQUIRY LEARNING

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Abstract

We investigated how differently structured external scripts interact with learners' internal scripts concerning individual knowledge acquisition in a Web-based collaborative inquiry learning environment. 90 students from two secondary schools participated. Two versions of an external collaboration script (high vs. low structured) supporting collaborative argumentation were embedded within a Web-based collaborative inquiry learning environment. Students' internal scripts were classified as either high or low structured, establishing a 2x2-factorial design. Results suggest that the high structured external collaboration script supported the acquisition of domain-general knowledge of all learners regardless of their internal scripts. Learners' internal scripts influenced the acquisition of domain-specific knowledge. Results are discussed concerning their theoretical relevance and practical implications for Web-based inquiry learning with collaboration scripts.

Keywords: Collaboration scripts, internal scripts, computer-supported collaborative learning, inquiry learning, science education, learning environments.

Internal and External Scripts in Computer-Supported Collaborative Inquiry Learning

Over the last years, several studies have shed light on the way learners benefit from collaboration when learning science (Kaartinen & Kumpulainen, 2002; Kneser & Ploetzner, 2001; Howe, Tolmie, Duchak-Tanner, & Rattray, 2000). There is considerable evidence, however, that students often have difficulty engaging in fruitful collaborative argumentation. For example, they rarely relate scientific evidence to theoretical explanations (e.g., Bell, 2004; Sandoval, 2003). Also, 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. Even more, low-level argumentation might be reflected in poor elaboration of learning content 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 (e.g., Bell, 1997; van Bruggen, Kirschner, & Jochems, 2002; Baker, 2003; Munneke, van Amelsvoort, & Andriessen, 2003; Suthers, Toth, & Weiner, 1997). Suthers et al. (1997), for example, developed Belvedere, a graphical argumentation tool by aid of which 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 in Web-based inquiry projects.

Another promising approach to structure collaborative argumentation processes in computer-supported collaborative learning is providing learners with collaboration scripts (e.g., Kollar, Fischer, & Hesse, 2006). Collaboration scripts provide collaborators 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 about the collaboration process. Weinberger, Fischer, and Mandl (2004) demonstrated that collaboration scripts can be designed and implemented in a Web-based learning environment in order to evoke specific argumentation processes, and that by engaging in those processes, learners can acquire knowledge about argumentation that can be used in other domains as well, provided that the individual holds adequate domain-specific knowledge as well.

We argue that collaboration scripts are a particularly promising approach when they are implemented in computer-based collaborative inquiry learning environments. In existing environments like BGuiLE (Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001), CoLAB (Savelsbergh, van Joolingen, Sins, de Jong & Lazonder, 2004), or WISE (Slotta, 2004; Slotta & Linn, 2000), learners are provided with significant support concerning content 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. Since students are often required to work collaboratively with one or more peers in such activities, the lack of explicit scaffolds for collaboration may result in unequal participation of learning partners, ineffective argumentation, and little learning of the content at hand. We claim that externally provided collaboration scripts can be designed to significantly improve both processes and outcomes of collaborative argumentation.

Yet, learners may enter instruction with widely varying ideas about collaboration and different capabilities in argumentation. Such differences may call for differently well-structured collaboration scripts in order to achieve the benefits of scaffolding described above. In the present study, we focus on the impact of differently structured externally provided collaboration scripts on knowledge acquisition of learners holding differently structured internal scripts (Schank, 1999; Schank & Abelson, 1977) concerning argumentation, meaning their individual procedural knowledge that guides their behaviour and understanding in argumentation situations. The interaction of differently well-structured internal and external collaboration scripts is investigated with respect to both the acquisition of (a) domain-general knowledge about argumentation and (b) domain-specific knowledge.

Knowledge Construction in Collaborative Argumentation

Collaborative argumentation is a core activity in collaborative inquiry learning. 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 content of their discussion (e.g., "arguing to learn" -- Andriessen, Baker, & Suthers, 2003). In formulating an argument, learners need to 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 scattered (see Stein & Albro, 2001), with at least two different approaches to argumentative knowledge construction. On the one hand, some researchers aim 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 its different sequences like "arguments, counterarguments, and replies" (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 both written and oral arguments (e.g., Bell & Linn, 2000; Cobb, 2002) 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 can consist of up to six components. First, it can be 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 (Marttunen & Laurinen, 2001; McNeill et al., 2004), 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*. In her model, 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 aim to improve knowledge construction of individuals working together in small groups by changing collaboration processes. That way, collaboration scripts can be regarded as a specific type of scaffolding (Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, & Soloway, 2004; Tabak, 2004) that differ from scaffolds aiming at improving knowledge acquisition by introducing conceptual help (e.g., through giving content-specific prompts like "How does force affect motion?"). Collaboration scripts might rather be referred to as realizing "socio-cognitive structuring" (Ertl, Fischer, & Mandl, in press).

As main characteristics of collaboration scripts can be regarded that they (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 engage in the related activities (see Kollar, et al., in press). 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 with the script’s contents. External collaboration scripts have been developed for both face-to-face (e.g., O’Donnell & Dansereau, 1992; King, 1997; Palincsar & Brown, 1984) and computer-mediated settings (e.g., Baker & Lund, 1997; Pfister & Mühlpfordt, 2002; Reiserer, Ertl, & Mandl, 2002), largely being successful with respect to improving collaboration processes and individual learning outcomes. When reviewing existing collaboration script approaches, it appears that they can vary with respect to their *degree of structuredness*. While some approaches provide rather rough constraints for specific activities, sequences, and roles, other approaches can be considered as being rather high structured, including very detailed instructions concerning which activities should be shown and when this should be the case. An example for a rather low structured collaboration script is the script developed by Baker and Lund (1997). In this approach, dyads of learners are supposed to collaborate in a distributed learning environment in which they have to collaboratively build a shared energy flow diagram they both can manipulate. The learners can communicate via a chat connection. For the support of the collaboration process, the chat system includes a variety of textual prompts a learner can paste into his or her chat window. Some of these prompts represent complete messages like “OK” or “Do you agree?”, whereas others provide learners with a sentence starter to be completed like “I think that…” or “I propose to…”. However, in the study by Baker and Lund (1997), the learners did not receive explicit instructions concerning when and in what sequence to use which prompt and were not explicitly asked to adopt particular collaboration roles. Yet, the design of the different prompts sometimes might implicitly trigger specific sequences and roles. For example, clicking on the button “Do you agree?” does not make sense before one learning partner has made a change to the shared energy flow model. Likewise, clicking on the button “I think that…” implies the adoption of an explainer role. In an empirical examination of the effectiveness of their script, Baker and Lund (1997) found no qualitative differences concerning the energy flow diagrams that were constructed with or without the collaboration script. However, the collaboration script almost doubled the amount of task-related interactions and slightly increased the amount of reflective activities conducted by the learners. No measures for individual knowledge construction were used in this study.

As an example for a rather high structured collaboration script, the Learning Protocol approach by Pfister and Mühlpfordt (2002) can be considered. In this approach, groups of up to five learners (including one tutor) are supposed to discuss philosophical or geological texts via a prestructured chat tool. This tool explicitly specifies the sequence according to which each learner is supposed to contribute to a message by guaranteeing that learners take turns through blocking the chat windows of all learners except the one who is supposed to make a contribution. Further, in order to guarantee for a high coherence of discussion, the learner who is about to write a message is requested to draw an arrow to the particular message in the shared chat window he or she is referring to. After that, the system offers three message types in a pull-down menu the learner has to classify his or her message as (comment, question, or explanation). These characteristics of the script cannot be changed by the learners. Thus, the script represents a highly structured way of guiding learners in a collaborative task. However, with respect to how to exactly carry the intended activities of explaining, questioning, and commenting out, learners still are not guided very intensively. In other words, the script might even be higher structured with respect to the concrete collaborative activities the learners are supposed to engage in. Empirically, the Learning Protocol approach has yielded mixed results. For example, positive effects on the individual acquisition of domain-specific knowledge have been observed for the domain of geology, but not for the domain of philosophy. Possible effects on learning processes were not examined (Pfister, Müller, & Mühlpfordt, 2003).

Although previous research on external collaboration scripts indicates that scripts can vary in their degree of structuredness, the question how structured an external collaboration script in the ideal case should be has hardly been investigated empirically. Also, the mixed results of both the Baker and Lund (1997) and the Mühlpfordt and Pfister (2002) approaches prohibit a straight-forward answer to this question. Although detailed script instructions can potentially improve collaboration processes better than less detailed instructions, from a design perspective, Dillenbourg (2000) points to the dangers of providing too detailed support. By using the term "over-scripting", he argues that breaking collaboration tasks down into too many steps can make those tasks become artifical and lead to less fruitful collaboration processes than might occur naturally. Furthermore, such high structured external collaboration scripts can also yield non-intended side-effects. For example, Weinberger, et al. (in press) demonstrated that a collaboration script aiming at improving the likelihood of specific argumentation moves in a text-based collaborative learning environment led learners to construct arguments also with irrelevant contents, thereby not facilitating the acquisition of domain-specific knowledge.

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 procedural knowledge about collaborative argumentation into argumentative situations, which they have build up and continuously refined in earlier instances of argumentation. Procedural knowledge refers to knowledge about appropriate actions in a specific situation that helps learners in progressing from one problem state to the next (de Jong & Ferguson-Hessler, 1996). This knowledge may either have a specific, domain-bound or a more domain-general character. In the context of this article, we are concerned with procedural knowledge on argumentation people possess and typically use in a variety of contexts.

According to Schank and Abelson (1977), who coined the term “script” in cognitive psychology, individuals are holding procedural knowledge that guides them to understand and act in specific everyday situations. This knowledge is mentally organized in scripts, which represent a special form of cognitive schemata (see Farrar & Goodman, 1990; Ginsburg, 1988; for further differentiations of the script concept see Schank, 1999). For example, most individuals will hold a “restaurant script” that guides them in their understanding of and acting in restaurant episodes. For example, this script specifies that after entering the restaurant, one has to follow the waiter to a table, take the menu, choose an item from it, wait until the meal is brought to the table, etc.

Empirical evidence for scripts as individual knowledge structures has mainly come from two strands of research. First, developmental research on how children and adults of different ages store and recall particular event sequences has demonstrated that generalized knowledge structures play a crucial role in these processes. For example, Fivush (1984) observed that first year school children generate highly generalized and abstract descriptions of a typical school day already after their first day at school. Also, children seem to use their general memory structures to reconstruct their memories for single school events. A second line of script research has developed in social and personality psychology focussing on the question how scripts guide relationships between individuals. For example, by analyzing patients' reports during psychoanalytical session, Andrew and McMullen (2000) identified five differently structured "anger scripts" that may be activated by individuals when finding themselves in conflict situations in their personal relationships. Thus, structurally, cognitive scripts can have a high inter-individual variability, a claim that also has been made by Schank (1999).

On the basis of this research, in this article we argue that individuals are holding procedural knowledge about how to act in situations requiring argumentation, and that this procedural knowledge is cognitively organized in the form of scripts that have developed through repeated experience with argumentative situations. The term "internal script" shall be used to describe individuals' generalized knowledge structures that come to guide their understanding of and actions in a specific class of situations, in our case argumentation situations. They are built upon the individual's concrete experiences with situations in which the script was activated. Thus, and in compliance with the study by Andrew and McMullen (2000) we assume that internal scripts on collaborative argumentation exhibit inter-individual differences with respect to their *degree of structuredness.* To determine this degree of structuredness, we focus on the individual scripts' compliance with the theoretical argumentation models described above. For example, some individuals might know that reasons should be made explicit in arguments (representing an indicator for a high structured internal script) whereas others do not (representing an indicator for a low structured internal script). Likewise, some individuals might have the aim to persuade their discourse partner by producing arguments that do not connect to the partner's arguments (low structured internal script). Others might rather aim to find a consensus in a two-sided argumentation, resulting in an integration of the different standpoints (high structured internal script). It is then unclear, how differently structured internal scripts play together with differently structured external scripts and how this interplay affects individual learning through collaborative argumentation.

Goals of the Study

The objective of this study is to analyze the effects of differently structured internal and external scripts on the learning outcomes of students' collaborative argumentation during learning in a Web-based inquiry learning environment (Web-based Inquiry Science Environment; Slotta, 2004; Slotta & Linn, 2000). More specifically, we focus on the individuals' acquisition of domain-general knowledge on argumentation and of domain-specific knowledge. Since previous research did not yet examine this interplay, different result patterns can be expected. Therefore, we set up two competing hypotheses:

Interactive effects hypothesis: A high structured externally provided collaboration script will support the acquisition of domain-general and domain-specific knowledge of learners holding low structured internal scripts, whereas a low structured external script will have negative effects on them. Vice versa, learners with high structured internal scripts will benefit from a low structured external collaboration script more than from a high structured one. If true, this hypothesis could result from either the high structured external script compensating for the deficits of the low structured internal scripts, or from the high structured external script unnecessarily putting 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 of their internal scripts' degree of structuredness, because even the contents of a high structured internal script will play out only if additional instructional support is provided.

Method

Participants and Design

90 students (grades 8 to 10; M_{age} = 15.3 years; *SD* = 0.99) from five classes of two German Gymnasiums participated in the study. An experimental 2x2-factorial design was established with the structuredness of learners' internal scripts on collaborative argumentation (high vs. low structured) and the structuredness of the external collaboration script (high vs. low structured) as independent variables.

Table 1

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 "poor" 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 3.49 (*SD* = 2.38) 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 42 learners classified as holding a low structured, and 48 learners as holding a high structured internal script on collaborative argumentation. The different number of learners holding low and high structured internal scripts was due to the removal of outliers with respect to their overall argumentation activity during their work on the inquiry learning unit.

However, since we described internal scripts as both guiding *understanding of* and *acting in* argumentative situations, the classification of the learners' internal scripts as low vs. high structured was further validated by analyzing the components of single arguments and argument sequences students with low vs. high structured internal scripts created in the low structured external script condition during their collaborative work on the inquiry project (see below). That way, we connect to research that used participants' actual verbal behavior to assess their internal scripts (e.g., Andrew & McMullen, 2000).

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 completed questionnaires assessing 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 unit “The Deformed Frogs Mystery” (Linn, Shear, Bell, & Slotta, 2004; see Fig. 1). They were introduced to the phenomenon that many frogs with massive physical deformities had been found in the late 90’s. For these deformities, several possible explanations exist. The unit 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 unit was segmented into five content-specific activities, e.g. “What’s the problem?”, “Where are the deformed frogs?”, or “What’s in the water?”. Learning partners of each dyad collaborated in front of one computer screen and could talk face-to-face. A teacher was not present.

Figure 1

External Collaboration Script

The two versions of the external collaboration script were implemented in the “Deformed Frogs Mystery” unit. At the end of each content-specific activity, 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 collaboration script, learning partners did not get further support beyond being asked to discuss the two hypotheses on the basis of the information of the particular activity.

Figure 2

In the *high structured* (see Figure 2) 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 demanded 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, the script instructions were continuously faded out to avoid the problem of "over-scripting" (Dillenbourg, 2002). For example, at the end of the second activity, 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* demanded 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, which were grouped to two dimensions of domain-specific knowledge. The reason for conducting analyses on the subscale level was to identify possible negative side-effects of external collaboration scripts that have been reported in previous research (Weinberger, et al., 2004). 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 (one point for only stating that experiments have to be conducted to four points when naming one or more variables that needed systematical variation and a comparison between experimental and control group). The resulting scale was termed *knowledge about scientific methods.* We also computed an overall test score for domain-specific knowledge, in which we included all items of the domain-specific knowledge test, establishing the *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).

Validation of Low vs. High Structured Internal Scripts Through Measures of Argumentation Processes

In addition to measuring learners' internal scripts by having them analyze a fictitious argumentative dialogue, we validated our classification by examining students' argumentation processes during the inquiry project. These process measures allowed us to analyze whether learners who were classified as holding a high structured internal script based on the initial test indeed also showed more sophisticated argumentation processes than learners who were classified as holding a low structured internal script. Only learners in the low structured external script condition were included in this analysis. The dialogues of dyads were tape-recorded concomitantly with a record of the learners' on-screen actions. We transcribed ten intervals of five minutes each per dyad and analyzed the discourse with respect to the completeness of single arguments and of argument sequences. After separating argumentative talk from non-argumentative talk (with an interrater reliability of two independent raters of Cohen's $\kappa = .78$), the two raters proceeded by segmenting the argumentative talk into discrete arguments. One main problem in segmenting arguments in discourse is to specify their boundaries, i.e. to determine where they begin and where they end, acknowledging that they can develop over multiple turns and speakers. For the segmentation procedure, we therefore set a rule that for identifying a new argument, the rater needs to at first detect a new claim in the discourse corpus. A claim was defined as an implicit or explicit assertion a speaker was making that connected to the question why so many frogs were deformed (e.g., "I think the parasite hypothesis is correct.") After that, further argument segments that were connected to the claim should be searched and be treated as additional components of the particular argument. Following a procedure proposed by Strijbos, Martens, Jochems, and Broers (2004), both raters, who were blind to the experimental condition, independently segmented ten percent of the data corpus. Interrater agreement on the identified segments was 81,0 % from rater A's perspective resp. 79,7 % from rater B's perspective (for a detailed description of the procedure see Strijbos, et al., 2004). Disagreements between the two raters were resolved through discussion, and the rules for segmentation were further adjusted. The remaining 90 % of the discourse material was rated by only one of the two raters, according to the revised instructions. After the discourse material had been segmented, the raters independently coded each argument with respect to whether they supported the claim by including data and/or a reason. Data were defined as more or less concrete observations or pieces of evidence that learners took from the learning environment or from their prior knowledge on deformities that supported the claim that they made (e.g., "There were more deformed frogs on the west coast than on the east coast."). A reason was defined as an attempt to specify the relationship between the stated claim and the piece of data that was used to support it (e.g., "…because the parasite may be locally bound to the west coast".). Interrater reliability was sufficient (Cohen's κ = .68). With respect to the structure of single arguments, we looked at three variables: (a) *arguments that only contained a claim*, (b) *arguments that contained a claim and data supporting it* and (c) *arguments that contained a claim, data, and a reason*.

With respect to the structure of argument sequences dyads produced during their work on the Deformed Frogs Mystery unit, each argument was further coded as either representing a *new argument*, a *counterargument*, or an *integrative argument*. An argument was rated as "new argument", when its claim had not been discussed shortly before and when it did not connect to an earlier argument. An argument was rated as a counterargument, when it expressed doubts concerning an argument (or parts of it) that had been formulated shortly before (e.g., "I think you're wrong in saying that parasites are responsible for the deformities (because)…."). An argument was coded as an integrative argument, when it was evident that it represented a compromise between a formerly produced argument and a counterargument or when it brought parts of these arguments together in a meaningful way (e.g., “Maybe both hypotheses are correct (because)…”). Interrater agreement reached a sufficient $\kappa = .86$.

Statistical Analyses

Concerning both domain-general knowledge on argumentation and domain-specific knowledge, we computed ANOVA’s with the structuredness of internal and external scripts as factors and the individual 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 equivalent 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 ($F(1,88) < 0.70$; *n. s.*). For all analyses, the α -level was set to 5 %.

Results

Validating the Low vs. High Structured Internal Scripts Through Measures of Argumentation Processes

In order to validate the test we had used in the first session to identify the learners’ internal scripts as low vs. high structured, we checked whether the students differed with respect to the structure of single arguments and argument sequences they produced in their oral and written discourse during collaboration. Only learners with high resp. low structured internal scripts were included who worked on the basis of the low structured external script to not confound the effects of internal and external scripts (Tab. 2).

Table 2

One-tailed *t*-tests revealed no statistically significant differences for the number of arguments that only contained a claim ($t(20) = .60$, *n.s.*). Yet interestingly, students whose internal scripts had initially been identified as high structured created significantly more new arguments than students whose internal scripts had been classified as low structured ($t(20) = 3.84$; $p < .01$) indicating a higher overall argumentative activity of students with high structured internal scripts. In addition, as expected, dyads in which students' internal scripts had been identified as high structured by the initial test produced more arguments that consisted of a claim and data ($t(14.42) = 3.32$; $p < .01$), more arguments that consisted of a claim, data, and a reason ($t(15.57) = 3.41$; $p < .01$), more counterarguments ($t(14.49) = 2.57$; $p < .05$), and in tendency more integrative arguments ($t(20) = 1.84$; $p < .10$) than learners whose internal scripts had initially been classified as low structured. We interpret these results as a successful validation of the results of the initial internal scripts test.

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 learners of the "low structured internal/high structured external script" condition ($M = 7.70$; $SD = 2.62$). Next was the "high structured internal/low structured external" group ($M = 7.75$; $SD = 1.85$), followed by learners in the condition "low structured internal/low structured external" ($M = 6.68$; $SD = 2.28$). The main effect for the structuredness of the external collaboration script ($F(1,86) = 9.07$; $p < .01$; $Eta^2 = .10$) was significant indicating that the high structured external collaboration script led learners to acquire more domain-general knowledge about argumentation than the low structured external script. For the structuredness of the learners' internal scripts, also a significant main effect was found

($F(1,86) = 9.70$; $p < .01$; $Eta^2 = .10$) indicating that learners with high structured internal scripts held more domain-general knowledge after collaboration than learners with low structured internal script. However, this result may rather be attributed to the initial differences between the two groups than to learning effects that occurred during collaboration. No interaction effect was found ($F(1,86) < 1.54$; *n. s.*).

Acquisition of Domain-Specific Knowledge

Table 3 presents the mean scores in the domain-specific knowledge tests for each experimental condition. On the *overall measure* of domain-specific knowledge, learners with high structured internal scripts reached higher scores than learners with 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 ($F(1,86) = 9.27$; $p < .05$; $Eta^2 = .10$), favoring high structured internal scripts over low structured internal scripts. No other effects reached statistical significance ($F(1,86) < 1$; *n. s.*).

Table 3

The same pattern could be observed for *knowledge about mechanisms*. Learners holding high structured internal scripts outperformed learners holding 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 main effect for the structuredness of the internal script indicating that learners holding high structured internal scripts acquired significantly more knowledge than learners with low structured internal scripts (F(1,86 = 4.08; p < .05; Eta² = .05). No other effects reached statistical significance (F(1,86) < 1; *n. s.*).

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 the scores for learners with low structured internal scripts who worked with the high structured external script were even lower. An ANCOVA revealed a significant main effect for the structuredness of the external script (F(1,86) = 4.39; p < .05; *Eta²* = .05) indicating that learners who had worked with the low structured external script reached higher scores than learners having been supported by the high structured external script. Neither the main effect for the structuredness of the internal scripts nor the interaction effect reached statistical significance (F(1,86) < 1; *n. s.*).

Discussion

In this study, we investigated the question 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.

In a first step, internal scripts were classified as high or low structured using a dedicated test. In a second step, this initial classification was successfully validated using process analyses of the dyadic discussions.

With respect to both the acquisition of domain-general and domain-specific knowledge, 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 regardless of their internal scripts. It appears that high structured external collaboration scripts (O'Donnell & Dansereau, 1992; O'Donnell, 1999) can be designed to still 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. Concerning both the *overall domain-specific knowledge* and *knowledge about mechanisms*, learners with high structured internal scripts on collaborative argumentative knowledge construction acquired more knowledge about the contents of the learning environment than did learners with low structured internal scripts, regardless of whether they collaborated by aid of the high or the low structured external collaboration script. For *knowledge about scientific methods*, the high structured external collaboration script even tended to undermine learning, a finding that corroborates earlier findings demonstrating non-intended negative side effects of highly detailed collaboration scripts (Weinberger, et al., 2004). It is possible that the design of the high structured external collaboration 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. The result that the learners' (validated) internal scripts on collaborative argumentation had a significant impact on the acquisition of domain-specific knowledge can be explained by referring to the internal scripts conception brought up by Schank and Abelson (1977). It can be argued that the learners' internal scripts that guide them in argumentative situations have developed over long periods of time, by being exposed to argumentative situations over and over again, so they are (a) so stable that it is difficult to influence them by an external script, at least in short intervention periods, and that (b) learners can use these scripts effortlessly just like a very familiar tool when they perceive themselves participating in a collaborative argumentation situation.

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, since subjects in this study generally reached rather low scores in the initial internal scripts test. This is not mysterious taking the rather poor 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 represented in this study's sample) the interactive effects hypothesis might be supported, meaning that such learners would benefit much more from a low structured external collaboration 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 collaboration script.

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 (see Kollar et al., in press). 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 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 out the external script instructions.

From a practical perspective, the results of this study imply that in collaborative inquiry learning environments, external scripts should be used whenever internal scripts on collaborative argumentation 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 on the one hand clearly showed that learners with deeper knowledge on collaborative argumentation might benefit more from inquiry learning in pairs. On the other hand, the findings demonstrated that learners with better argumentation skills were not hampered when provided with a high structured external script. Thus, Web-based collaborative inquiry learning environments can be made more effective by implementing a high structured external script that supports processes of collaborative argumentation. Yet, future research might investigate methods for more dynamic ways of scripting. This is of particular significance against the background that the amount of external scripting might lead to a continuous acquisition of internal scripts, so that a reduction of the external script's degree of structuredness may be warranted. The main problem here is that reliable and timely assessment of actual collaboration processes is needed to adjust the external script's degree of structuredness. In our view, a real innovation would be to develop computer systems that capture and analyze collaboration processes online and as a result adapt the amount of external scripting for the particular learners working on the learning environment. First methods for such an online assessment of student-generated dialogues are already available (Dönmez, Rosé, Stegmann, Weinberger, & Fischer, 2005). Future research might evaluate whether this and other methods can be used for more flexibly scripting collaboration in Web-based collaborative inquiry learning environments.

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Table 1. Design of the empirical study.

		Structuredness of the external collaboration script	
		Low	High
Structuredness of the internal script on collaborative argumentation	Low	N = 20 (10 dyads)	N = 22 (11 dyads)
	High	N = 22 (11 dyads)	N = 26 (13 dyads)

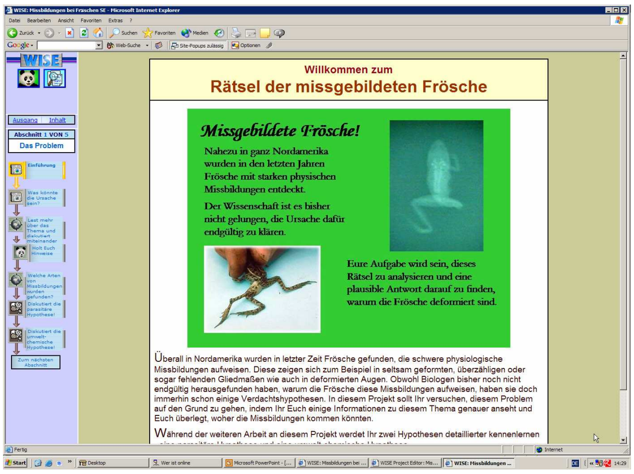
Table 2. Mean frequencies, standard deviations, and effects sizes for the single categories of argument structure and argumentation sequences in oral and written dialogue for learners with low vs. high structured internal scripts in the low structured external script condition,

Dimensions and categories	Low structured internal script		High structured internal script		Effect size
	M	*(SD)*	M	*(SD)*	d
Argument structure					
Arguments containing claims only	10.10	*(4.33)*	11.55	*(6.96)*	0.25
Arguments containing claims and data	14.36	*(6.04)*	28.27	*(12.51)*	1.42
Arguments containing claims, data, and reasons	5.64	*(3.50)*	13.09	*(6.35)*	1.45
Argumentation sequence					
New arguments	17.18	*(5.46)*	28.00	*(8.98)*	1.47
Counterarguments	12.36	*(5.45)*	22.00	*(11.19)*	1.46
Integrative arguments	0.82	*(1.33)*	2.09	*(1.87)*	0.78

Table 3. Mean scores (standard deviations in brackets) 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)	2.64 *(1.40)*	4.82 *(1.92)*	2.30 *(1.38)*	4.90 *(2.02)*	2.50 *(1.48)*	6.00 *(1.65)*	2.50 *(1.32)*	6.12 *(2.03)*
Knowledge about mechanisms	0.41 *(0.59)*	1.77 *(1.34)*	0.65 *(0.75)*	2.20 *(1.51)*	0.58 *(0.70)*	2.31 *(1.62)*	0.63 *(0.88)*	2.83 *(1.49)*
Knowledge about research methods	2.23 *(1.19)*	2.59 *(0.91)*	1.70 *(0.92)*	2.10 *(0.97)*	1.92 *(1.09)*	2.77 *(0.82)*	1.92 *(0.93)*	2.33 *(0.76)*

Fig. 1.


Willkommen zum
Rätsel der missgebildeten Frösche
Missgebildete Frösche!

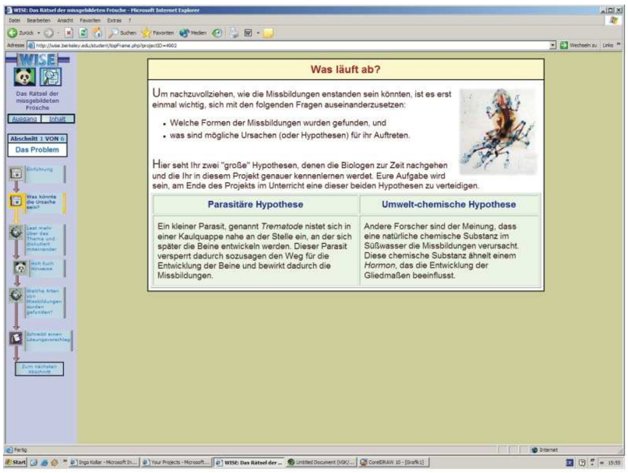

Was läuft ab?
Parasitäre Hypothese
Umwelt-chemische Hypothese

Fig. 2

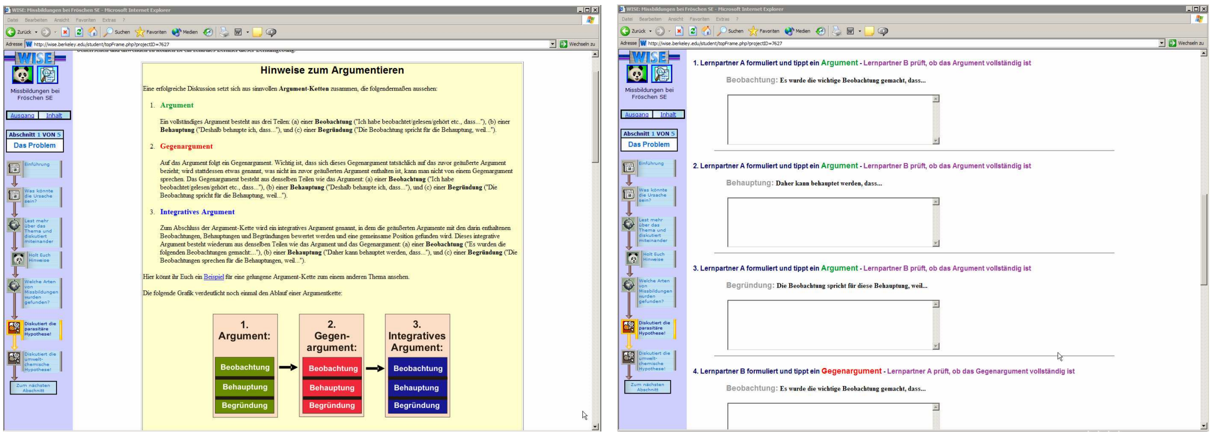

Hinweise zum Argumentieren
1. Argument:
2. Gegen-argument:
3. Integratives Argument:
Beobachtung
Behauptung
Begründung
Beobachtung
Behauptung
Begründung
Beobachtung
Behauptung
Begründung

Figure Captions:

Figure 1. Screenshots of the “Deformed Frogs Mystery” unit. Left screen: Introduction, showing pictures of deformed frogs and a textual description of the phenomenon. Right screen: Two different hypotheses are introduced to explain the deformities.

Figure 2. Screenshots of the high structured external collaboration script. Left screen: Introduction of the argument structure (claim, data, warrant) and the argumentation sequence (argument, counterargument, integrative argument); Right screen: pre-structured text boxes to be filled in by the participants. First, the construction of one single argument with data (first window), claim (second window) and warrant (third window) is prompted for learner A. Then the construction of the counterargument is prompted in the same way for learner B. Finally, they both are asked to construct an integrative argument collaboratively.