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How Internal and External Scripts Guide Argumentative Knowledge Construction in a Web-based Collaborative Inquiry Learning Environment

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Abstract

Collaboration scripts are a powerful means to improve collaborative inquiry learning. More specifically, they can be designed to support argumentative knowledge construction, a core activity in inquiry learning. However, not only externally induced collaboration scripts but also the learners' internal scripts on collaborative argumentative knowledge construction influence the way they argue with scientific concepts and evidence, thereby affecting what kind of knowledge is acquired during collaboration. In this study, 98 students (49 dyads) from two German secondary schools participated. We implemented two versions (high vs. low structured) of an external collaboration script designed to support argumentative knowledge construction into a web-based collaborative inquiry learning environment called WISE. Further, we classified the learners' internal scripts as either high or low structured and composed homogeneous dyads, thereby establishing a 2x2-factorial design. We investigated how external and internal scripts as well as their interaction influenced the acquisition of both domain-general and domain-specific knowledge. Results suggest that for the acquisition of domain-general knowledge, web-based collaborative inquiry learning environments can be improved by implementing a high structured external script. For the acquisition of domain-specific content knowledge, however, the learners' internal scripts on collaborative argumentative knowledge construction appeared to be more influential. Results are discussed concerning their relevance for both theory and practice of learning with collaboration scripts in computer-supported collaborative inquiry learning environments.

Introduction

Over the last years, educational psychology has devoted strong efforts to develop web-based collaborative inquiry learning environments, in which learners can explore scientific phenomena, gather and present data, set up hypotheses etc. (e.g., Schwartz, Lin, Brophy & Bransford, 1999). Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson and Soloway (2004) define “inquiry as the process of posing questions and investigating them with empirical data, either through direct manipulation of variables via experiments or constructing comparisons using existing datasets” (p. 340). Examples for web-based collaborative inquiry learning environments are WISE (Slotta & Linn, 2000), CoLAB (Savelsbergh, van Joolingen, Sins, de Jong & Lazonder, 2004), and BGuILE (Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001). These environments include a variety of scaffolds, which are supposed to channel and to focus the learners’ attention to relevant concepts and mechanisms of the problem at hand (Pea, 2004), thereby stimulating substantial elaborations about the contents of the learning material. For example, in CoLAB, learners can manipulate the amount of water in a tank by changing number values and then run a simulation representing the pressure in the tank and the amount of water flowing out of it when opening a ventile.

However, many of these environments seem to assume that learners generally are able to engage successfully in collaborative learning activities. As a consequence, designers of these environments often do not undertake much effort to structure collaboration and argumentation between the learning partners, even though it is clear that collaborative argumentation is a core activity in collaborative inquiry learning. For example, quite often learners are simply asked to “discuss” at a particular point in a curriculum unit, without getting instructional support concerning how to engage in a fruitful discussion. This is especially regrettable since many studies have demonstrated that students often experience difficulties when supposed to engage in argumentation (Kuhn, Shaw & Felton, 1997; Brem & Rips, 2000). In order to address this problem, in theory and research on computer-supported collaborative learning (CSCL) as well as in instructional psychology, collaboration scripts are considered a powerful means to improve processes and outcomes of collaborative learning (Pfister & Mühlpfordt, 2002; Rummel, Spada, Caspar, Ophoff, & Schornstein, 2003; Kollar, Fischer & Hesse, 2003). For example, Weinberger, Reiserer, Ertl, Fischer and Mandl (in press) demonstrated that collaboration scripts embedded in different net-based learning environments were able to improve the learners’ recall rates of learned information as well as their ability to apply

theory-based knowledge to transfer problems. One main advantage of collaboration scripts is that they can be tailored to support a variety of activities like problem solving, learning from text or learning concrete procedures (see O'Donnell, 1999, for an overview). It is plausible then that collaboration scripts could also be designed to provide instructional support for collaborative argumentative knowledge construction. It is hoped that by implementing a collaboration script that specifies learners' collaborative argumentative processes will engage them in specific patterns of argumentative knowledge construction so that they will acquire domain-general knowledge on how to engage in argumentation, which in turn should enable them to elaborate the domain-specific content knowledge of the specific learning unit more deeply, thereby also acquiring more domain-specific knowledge concerning the content of the learning material (e.g., mechanisms that underlie scientific phenomena).

However, it has hardly been subject to research how the provision of externally induced collaboration scripts interact with the learners' personal scripts with respect to how to accomplish the task at hand. It is reasonable to argue that learners bring different internal scripts (Schank & Abelson, 1977) that guide them in their behaviour to a particular situation and that these scripts interact with the external instructional support that is given. In this paper, we therefore aim to investigate the interaction between external and internal scripts with respect to different dimensions of individual knowledge acquisition in a web-based collaborative inquiry learning environment.

What is argumentative knowledge construction?

Argumentative knowledge construction can be considered as a core activity learners have to engage in during collaborating in a web-based collaborative inquiry learning environment. For example, learners are required to engage in argumentation when setting up hypotheses, when making sense of evidence they have explored etc. Yet, there is a lack of an agreed upon definition of what argumentation actually is, accompanied by the fact that research on argumentation and argumentative knowledge construction appears to be scattered (see Stein & Albro, 2001). At least two different approaches to argumentative knowledge construction can be found. On the one hand, there is a *structural perspective*, which seeks to assess the quality of single arguments on the basis of the structural components they include (Toulmin, 1958). On the other hand, there is a *dynamic perspective* on argumentation, dealing with how argumentation develops in discourse. Each of the two perspectives are presented in the following sections.

Structural perspective on argumentative knowledge construction

Coming from a philosophical background, Toulmin (1958) developed a structural scheme that can be used to judge the completeness of arguments being uttered both in oral or in written discourse. Although often being criticized for being too theoretical, the model had a strong influence on psychological and linguistic research on argumentation (e.g., Cobb, 2002; Stein & Albro, 2001; McNeill, Lizotte, Krajcik, & Marx, 2004). According to this model, an argument consists of up to six components. Firstly, arguments are based on *data* representing evidence on which the argument relies on. Such data can be a single observation or multiple observations of regularities (e.g., a steel chair heats up faster than a wood chair) as well as references to authorities (e.g., newspaper articles or researchers). Secondly, arguments usually include a *claim* by which the speaker expresses his position. Thirdly, arguments can contain a *warrant* that specifies the relationship between data and claim. For example, such a warrant might be “because a black shirt absorbs more light energy” for the claim “a black shirt feels warmer on your skin than a white shirt when sun is shining on it”. Fourthly, in order to highlight the validity of a warrant, arguments can contain a *backing*. For example, a backing can point to Newton’s Second Law to support the warrant that a ball can hit a target because it was thrown with a certain force. Fifthly, arguments can contain a *qualifier* that sets constraints to the validity of the claim. Quite often, such a qualifier consists of a single word like “maybe” or “assumably”. Finally, an argument can contain a *rebuttal*, by which conditions are specified under that the claim is not valid. For example, a speaker could add a sentence like “as long as there is no traffic jam” into his or her argument saying that he or she will be downtown at 6 pm when leaving home at 5 pm.

In a number of studies, Toulmin’s argument scheme has been used either to assess written or oral discourse between learners (e.g., Cobb, 2002; Bell & Linn, 2000) or as a means to teach learners how to argue effectively (e.g., Carr, 2003; McNeill et al., 2004). It is generally assumed that giving more complete arguments should lead to a deeper elaboration of learning materials and finally to better learning than giving incomplete arguments. In the study by McNeill et al. (2004), it was shown that learners were in deed able to learn and apply Toulmin’s argument scheme from a scaffold resulting in giving stronger explanations after the scaffold was removed.

Applying this scheme in oral discussions is not always easy, as is analysis of written or oral discourse by aid of the scheme as well. Stein and Albro (2001) for example state that even experts may experience difficulties in identifying a warrant in an argument because warrants often remain implicit when a speaker assumes that the discourse partner has access

to the information that would be uttered in the warrant. Furthermore, it often appears to be difficult to clearly define the difference between warrants and backings as well as between qualifiers and rebuttals. In line with previous research (McNeill et al., 2004; Marttunen & Laurinen, 2001), we claim it might be reduce the complexity of Toulmin's model. Therefore, we focus on three essential components of arguments, namely data, claims, and reasons (which comprise both warrants and backings).

Dynamic perspective on argumentative knowledge construction

Toulmin's model was often criticized because it neglects the aspect of how an argumentation between two or more persons develops over time. Rather, the model focuses on single arguments, analyzing them in terms of their completeness. In order to account for the function of an argument in its context, Leitão (2000) proposed a model that includes three basic types of arguments: (a) arguments, (b) counterarguments and (c) replies. In her view, an argument represents an assertion that is preceded or followed by a justification. A counterargument can then be of one of three kinds: The first possibility is that it represents a *shift* in the topic, so that the argument in its original form remains intact. For example, speaker A might utter an argument like "Car traffic intensifies global warming because statistics say as traffic increases, more emissions are produced harming the ozone layer", and speaker B might response by saying "Emissions of aeroplanes also intensify global warming", thereby shifting attention to another aspect and leaving the validity of the argument untouched. A second possible form of a counterargument is to *doubt the validity* of the argument, for example by explicitly challenging the claim that was taken in it (e.g., "This is not true because I read it is exactly the other way around"). Finally, a counterargument might also be formulated *questioning the relation between the components of the argument*. For example, an interlocutor might assert that the evidence his or her partner was citing did not support the claim he or she was making.

Next, according to Leitão (2000), replies on counterarguments can also take on several forms: Firstly, they can represent a *dismissal* of the counterargument, when the speaker experiences himself as able to reject the claim that was made in the counterargument because it was not true. Secondly, a reply can represent a *local agreement* in a sense that it agrees with parts of the counterargument but not as strongly that it would fundamentally change the interlocutor's position. Thirdly, speaker A might offer an *integrative reply*, which connects parts of both the original argument and the counterargument. This sort of reply might be considered as most strongly influencing collaborative knowledge construction since it is

collaboratively created by the two interlocutors. Finally, as a fourth form a reply can take on, speaker A might simply *abolish his or her original argument*.

Leitão (2000) then claims that argumentative sequences of the structure “argument – counterargument – (integrative) reply” might be most fruitful for collaborative knowledge construction, since they require both learners to deeply elaborate content information. This deeper elaboration of content information then should in turn lead to higher content specific knowledge acquisition on an individual level (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Moreover, by engaging in meaningful sequences of argumentation, learners might internalize these processes and apply them even when they are not explicitly asked to do so, thereby also acquiring domain-general knowledge about argumentation itself.

In most previous research, these two accounts to argumentative knowledge construction have been treated separately – studies often focused either on the structural (e.g., Means & Voss, 1996) or on the dynamic perspective of argumentative knowledge construction (e.g., Resnick, Salmon, Zeitz, Wathen & Holowchak, 1993). Few studies have considered both perspectives, a research gap that is accounted for in this study.

Scripts for collaborative argumentative knowledge construction in web-based inquiry learning

External Scripts

As mentioned above, one promising way to facilitate students’ argumentative knowledge construction is to provide learners with collaboration scripts (O’Donnell & Dansereau, 1992). Collaboration scripts are complex instructional entities specifying the processes of collaboration by making use of a whole variety of instructional representations like prompts (e.g., King, 1998), graphical representations of interaction patterns (Stegmann, Weinberger, Fischer, & Mandl, 2004) or special programming of communication interfaces in computer-supported collaborative learning environments (e.g., Baker & Lund, 1997). Such collaboration scripts typically induce specific activities to be carried out by the (two or more) learning partners, prescribe a specific sequence according to which these activities are supposed to be carried out, and distribute roles among the learning partners (see Kollar et al., 2003). What activities are induced by a collaboration script depends on what the actual outcome of collaboration is supposed to be. Of course, a collaboration script should be designed in a way that guarantees a match between the induced activities and the desired learning outcomes. It is clear that the constraints that are inherent in the script instructions should have the function to enable the learners to reach these objectives. Yet, too severe constraints or too strict

“chaneling” (Pea, 2004) might restrain learners to engage in activities that also might be beneficial with respect to the intended learning outcomes. In a study by Weinberger, Fischer, and Mandl (2004), for example, it could be demonstrated that an epistemic collaboration script, which provided learners with content-specific prompts with respect to the learning material, had positive effects on conceptual learning but simultaneously inhibited transactivity (Teasley, 1997) as a (non-intended) negative side-effect. In contrast, a social script that specified that learners should consider the contribution of their learning partners, had positive effects on transactivity but negative effects on conceptual learning. Against the background that collaboration scripts can include very different components with very specific effects, it therefore seems adequate to assess different kinds of learning outcomes in order to get a clearer profile of what particular aspects are influenced by the instructions of an externally induced collaboration script.

Internal Scripts

Despite the rather positive effects of collaboration scripts that have been demonstrated in the literature, it does not seem plausible that externally provided script instructions are the only factor that guides collaborative learning processes. Rather, learners can be viewed as possessing knowledge and strategies about how to proceed in a collaborative learning situation on their own. In cognitive psychology, Schank and Abelson (1977) refer to scripts as a form of culturally shared knowledge about everyday events. For example, most people will hold a “restaurant script” telling them that when they go for dinner, they will sit on a table, wait for the waiter to bring the menu, choose one meal, waiting for the meal being brought to the table, eating the meal, etc. However, in contrast to this culturally highly shared “restaurant script”, Schank and Abelson (1977) also speak of “personal scripts” which might not be shared to the same degree but rather be more unique to the individual. For example, it is likely that different individuals will have quite different personal scripts concerning how to write an essay about a political topic. Likewise, we view “argumentation” as one example of an event that does have everyday significance, but about which individuals may hold different scripts that guide their actual behaviour in argumentative discourse. Yet again, differences in the learners’ personal scripts might also lead to different profiles of what individuals learn during collaborative argumentative knowledge construction. For example, an individual with a highly developed personal script on argumentative knowledge construction might be more able to elaborate the learning material more deeply, thereby acquiring more domain-specific content knowledge than an individual with less strategic knowledge about how to engage in

argumentative knowledge construction. In order to differentiate these personal scripts from the externally induced collaboration scripts we were talking before, we will call these internal knowledge structures internal scripts.

As a consequence, in this paper we focus on both internal (cognitive) and external (instructional) scripts, thereby investigating their each specific effects as well as the effects of their interrelation concerning the acquisition of argumentation-specific knowledge (as an instance of domain-general knowledge) and of different types of domain-specific content knowledge during collaborative learning in a web-based collaborative inquiry learning environment.

Goals of the Study

The main objective of this study is to analyze different cognitive outcomes of students' argumentative knowledge construction during learning in a web-based inquiry learning environment. In order to investigate the relationship between external and internal scripts in facilitating collaborative argumentative knowledge construction, we developed two versions of an external collaboration script (low vs. high structured) and implemented them into a curriculum project of the computer-based collaborative inquiry learning environment WISE. It was then our aim to investigate how these externally provided collaboration scripts and the learners' internal collaboration scripts interact with respect to both the acquisition of domain-general knowledge about argumentation as well as different forms of domain-specific content knowledge in inquiry learning environments. As there is not enough evidence available from prior research, we set up two competing hypotheses, (a) an *interactive effects hypothesis* and (b) an *additive effects hypothesis*.

Interactive effects hypothesis: A highly structured externally provided collaboration script will especially facilitate the acquisition of content-specific and argumentation-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. This is either because the high structured external script will compensate the deficits low structured internal scripts obtain or because it unnecessarily puts constraints to the learning processes of learners holding high structured internal scripts.

Additive effects hypothesis: A highly structured externally provided collaboration script will support the acquisition of domain-general and domain-specific knowledge of all learners, independently from the nature of their internal collaboration scripts, because even the contents

of a high structured internal script will play out only when additional instructional support is provided.

Method

Participants

98 students from grades 8 to 10 from five classes of two German Gymnasiums participated in the study. 46 participants were boys, and 52 participants were girls.

Design

An experimental 2x2-factorial design was established with the internal collaboration script (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. Reliability of the used scale was sufficient. The design of the study is presented in table 1.

Table 1: Design of the empirical study.

| | | External collaboration script | |
|--------------------------------------|-----------------|-------------------------------|----------------------|
| | | Low structured | High structured |
| Internal collaboration scripts | Low structured | N = 26 (13 dyads) | N = 22 (11 dyads) |
| | High structured | N = 26 (13 dyads) | N = 24 (12 dyads) |

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 content knowledge, and collaboration as well as computer experiences. Most importantly, in this first session learners were asked to answer the test assessing their internal scripts. 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 evaluate a fictitious discourse between two students about a science topic. This discourse included “good” and “bad” arguments and argumentative sequences in the sense of the models proposed by Toulmin (1958) and Leitão (2000). I.e., some utterances contained complete arguments, whereas others did not, and sometimes, argumentative sequences had the “argument – counterargument – integrative argument”-structure proposed by Leitão (2000), whereas in other cases, they had not. The students’ task then was to individually identify these “good” and “bad” arguments or argumentative sequences and specify why they were good or bad. On the basis of their answers, students received a test score ranging from 0 to 20. The median score of 3 was used as the criterion according to which learners were classified as holding either a low or a high structured internal script resulting in 48 learners classified as holding a low structured and 50 learners as holding a high structured internal script

For the actual collaboration phase two weeks later, homogenous dyads were established with respect to the degree of structuredness of the learners’ individual scripts and gender, i.e. that there were only dyads consisting of two girls or two boys both holding either a low or a high structured internal script. Each dyad 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 several questionnaires to assess the domain-specific content knowledge and domain-specific knowledge on argumentation that was acquired during collaboration (see below). Completing these questionnaires required about 40 minutes.

Setting and learning environment

Dyads worked on a German version of the WISE project “The Deformed Frogs Mystery” (see figure 1). In this project, learners were introduced to the phenomenon that many frogs with massive deformities on legs and eyes had been found in the late 90’s. However, among biologists it is not yet clear what the underlying mechanism for these deformities is. Therefore, the project provides learners with two competing hypotheses. The *Parasite Hypothesis* states that a small parasite called “trematode” burrows into the tadpole near where the legs will develop, and the *Environmental-Chemical Hypothesis* implies that a hormone-like substance in the water of the dumps frogs live in causes legs and eyes to develop

strangely. In order to discuss the pro's and con's of these two hypotheses, the web-based learning environment contains different kinds of background information, e.g. journal articles, maps about the distribution of the deformities, or photographs of the deformed frogs. Discussion should then focus on evaluating the two hypotheses on the basis of this background information. 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?". The two learning partners of each dyad worked together in front of one computer screen and could talk face-to-face. There were always between three and five dyads located in the same room, but they were separated from each other to achieve rather controlled experimental conditions. A teacher was not present.

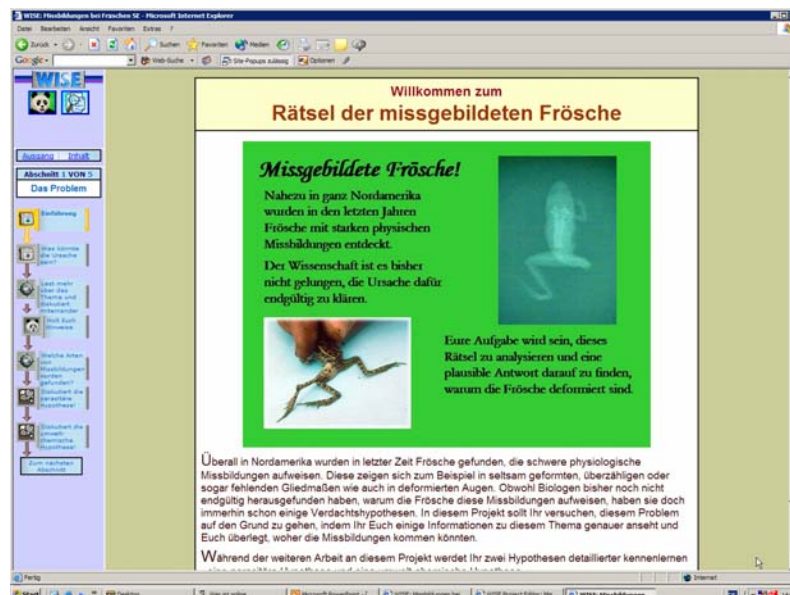


Figure 1: Welcome screen of "The Deformed Frogs Mystery" project.

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, all learners were asked to discuss the two hypotheses on the basis of the information they had just viewed and to type their arguments. However, the two 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 beyond being asked to discuss the two hypotheses on the basis of the information of the particular unit.

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). The first time learners had to discuss the two hypotheses, learning partner A was assigned to defend the parasite hypothesis. In order to do that, he or she was asked to give an argument containing of data, a claim and a reason. To achieve that, the learner was supposed to type each component (data, claim, reason) in a separate text field including adequate cues (e.g., “It was found that...” for data). Next, his or her learning partner was asked to type a counterargument into the respective text boxes, again containing the three argument components and the respective cues. Finally, both learners were asked to formulate an integrative argument, which again had to consist of data, a claim, and a reason. After that, for the environmental-chemical hypothesis, roles were switched. During the course of collaboration, which learner had to advocate which hypothesis was varied. Moreover, 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 anymore, 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. Pea (2004) strongly suggests that scaffolds should be faded out as learners internalize more and more of the target activities. A recent study by McNeill, Lizotte, Krajcik and Marx (2004) has demonstrated that fading might even contribute to higher learning gains than leaving instructions unfaded over time.

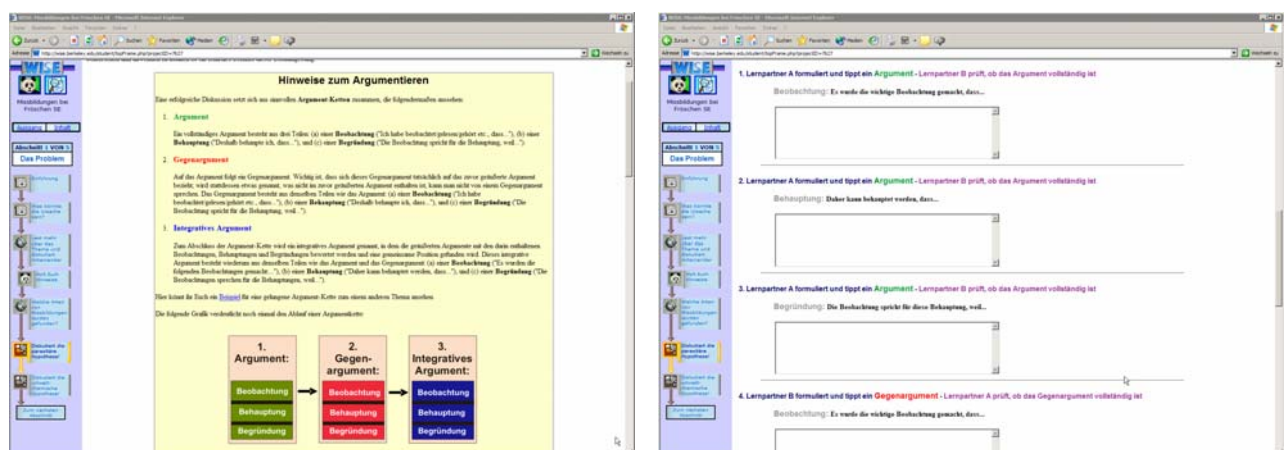


Figure 2: Screenshots of the high structured external collaboration script (left screen: introductory text; right screen: pre-structured text boxes to be filled in by the participants).

Instruments and dependent measures

Dependent measures were the individual students' performance in subsequent knowledge tests. One knowledge test aimed to assess the learners' domain-general knowledge on argumentation, and the other one was designed to measure different dimensions of domain-specific content knowledge.

Domain-general knowledge test about argumentation

In this test, learners were supposed to name the three components of a complete argument as well as the three components of an argumentative sequence. Moreover, they were asked to give examples for a complete argument and a complete argumentative sequence concerning the topic "smoking cigarettes". Learners received points for each correctly named component of a single argument and an argumentative sequence as well as for each of these components that was included in their examples. That way, 12 points could be reached in this test. Reliability of this scale was .72 (Cronbach's Alpha).

Domain-specific content knowledge test

The domain-specific knowledge test contained five open-ended questions. In the first four questions, learners were asked to reproduce the mechanisms that according to the contents of the learning environment might cause the frog deformities (parasite and environmental-chemical). Learners received one point for a partial correct reproduction of a mechanisms (e.g., "The parasite burrows into the tadpole"), two points for a completely correct explanation of a mechanism, and additionally one point for citing relevant data and one more point for making meaningful connections between data and mechanisms, i.e. specifying why a particular set of data counted as evidence for or against one of the mechanisms. The resulting subscale was termed *knowledge about mechanisms*. After reliability check, one item was deleted yielding a 5-items-scale. 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. Learners received credits according to the following scheme: one point was given for uttering that experiments should be conducted, one point for mentioning specific variables that should be examined, one point for mentioning that variables should be systematically varied, and one point for proposing to evaluate the effects of a variation of variables. The resulting scale was termed *knowledge about scientific methods*. However, we also computed an overall test score for domain-specific content knowledge, in which we added all items of the domain-specific

content knowledge test, establishing one *overall domain-specific content knowledge measure*. The same content-specific knowledge test was also used to assess the learners' prior knowledge. However, 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 (Cronbach's Alpha for knowledge about mechanisms) and .66 (Cronbach's Alpha for knowledge about scientific methods).

Statistical analyses

Concerning both domain-specific content knowledge and domain-general knowledge on argumentation, 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. For determining the effects of internal and external scripts on domain-specific content knowledge, the each specific content-specific prior knowledge measures were included as a covariate (except for knowledge about mechanisms because of its low reliability), although learners in the four conditions did not differ significantly concerning their content-specific prior knowledge ($F(1,95) < 1.06$; *n.s.*). As a covariate for domain-general knowledge on argumentation, the actual point score in the test for assessing their internal scripts was used. For all analyses, the alpha-level was set to 5 %.

Results

Learning prerequisites

Before testing our hypotheses, we controlled for differences in the pretest measures. Concerning the domain-specific prior knowledge measures, we found no statistical significant differences between the four experimental conditions ($F(1,94) < 1.06$; *n.s.*).

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. The low structured internal/high structured external condition reached somewhat lower scores, followed by high structured internal/low structured external and low structured internal/low structured external. An ANCOVA with the actual point score in the initial internal script test as a covariate revealed a significant main effect for the external collaboration script ($F(1,93) = 12.96$; $p < .01$) indicating that the high structured external script led learners to acquire more

argumentation-specific knowledge than the low structured external script. Neither the main effect for the internal script nor the interaction between the two factors reached statistical significance ($F(1,93) < 1.15$; *n.s.*). Results are presented in Fig. 3.

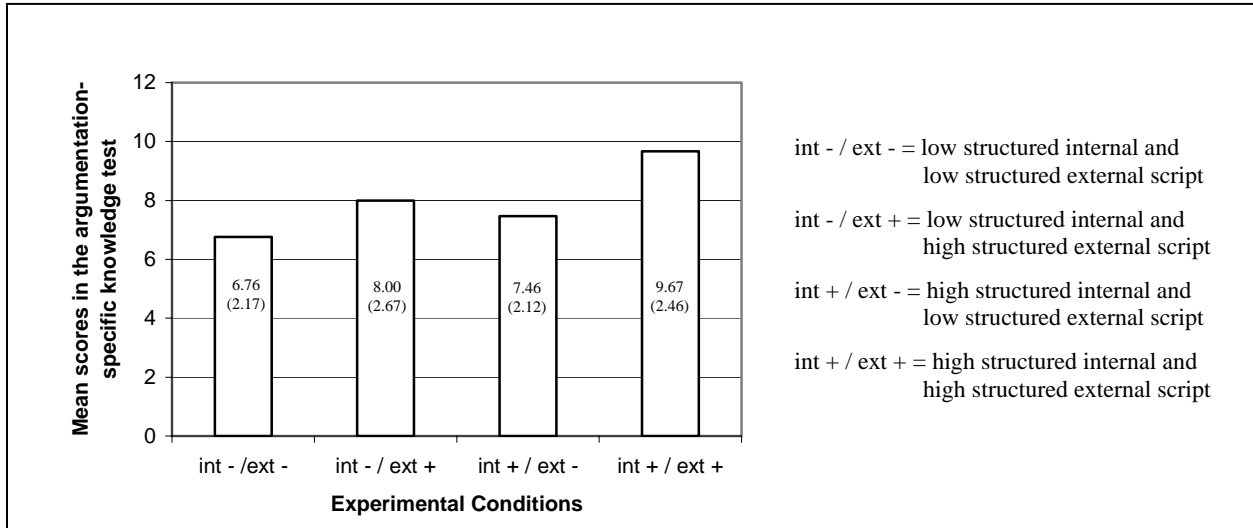


Figure 3: Mean scores (standard deviations in brackets) in the test on domain-general knowledge on argumentation across the four experimental conditions.

Domain-specific content knowledge

Table 2 presents the mean scores and standard deviations in the three content-specific knowledge measures for the four experimental conditions (both for pre- and post-tests).

Table 2: 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 | M | M | M | M | M | M | M |
| | (SD) | (SD) | (SD) | (SD) | (SD) | (SD) | (SD) | (SD) |
| Domain-specific content 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) |

On the *overall measure of domain-specific content knowledge*, learners holding high structured internal scripts received higher scores than learners with low structured internal scripts. There were only marginal differences between learners having collaborated on the basis of the high structured and the low structured external script. An ANCOVA (with the overall domain-specific content knowledge as dependent variable and the overall prior knowledge as control variable) revealed a significant main effect for the internal script ($F(1,93) = 10.33; p < .05$).

The same pattern of results could be observed for *knowledge about mechanisms*. Again, learners holding high structured internal collaboration scripts reached higher scores than learners with low structured internal scripts. Again, there were no differences between learners who had collaborated by aid of the high structured external script and those who followed the instructions of the low structured external script. Consequently, an ANOVA yielded a significant main 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 who collaborated on the basis of the high structured external script reached lower scores, especially when they held low structured internal scripts. An ANCOVA revealed a marginally significant main effect for the external script ($F(1,93) = 3.18; p = .08$) indicating that learners having worked with the low structured external script reached higher scores than learners having been supported by the high structured external script. Post hoc comparisons revealed that learners holding high structured internal scripts who had collaborated on the basis of the low structured external script were significantly better than learners with low structured internal scripts who had learned with the high structured external script ($t(46) = -2.23; p < .05$).

Discussion

Overall, our results support quite clearly our initial assumption that argumentative knowledge construction is guided by both externally provided instruction and the learners' internal scripts. However, the very structure of these scripts has an impact on what kind of knowledge in fact is acquired. In order to investigate the question how internal and external scripts play

together concerning the acquisition of domain-general knowledge on argumentation and domain-specific content knowledge in web-based collaborative inquiry learning, we set up two competing hypotheses, an interactive effects hypothesis and an additive effects hypothesis. The results we found for the acquisition of *domain-general knowledge on argumentation* clearly support the additivity hypothesis: As predicted, the high structured external collaboration script helped all learners, independently of their internal collaboration scripts. Moreover, the supportive effect of the high structured external script was similar for both learners with high and low structured internal scripts since there was no interaction between external and internal scripts. Therefore, in order to reach the objective to get learners to acquire domain-general knowledge on argumentation, we recommend to provide them with high structured external scripts, which specify in a detailed way how to proceed in collaborative argumentative knowledge construction. Hence, with respect to our main research question, we can say that a web-based collaborative inquiry learning environment can be improved by implementing a high structured external collaboration script, at least considering the acquisition of domain-general knowledge on argumentation, and it can even achieve that all learners regardless of their internal scripts can benefit from it.

However, in contrast to our expectations, the high structured external collaboration script failed to facilitate the acquisition of domain-specific content knowledge. Rather, it appeared that the learners' internal scripts are more influential than external scripts with respect to content-specific knowledge construction. For *overall domain-specific content knowledge* as well as for *knowledge about mechanisms*, we found that learners with high structured internal scripts learned more than individuals holding low structured internal scripts, regardless of the structure of the external collaboration script. It seems that since the learners' internal scripts have developed over long periods of time (see Schank & Abelson, 1977), they are more easily accessible (Perkins, 1993) than any freshly induced strategy, so that learners can use their own strategy effortlessly just like a very familiar tool. It is plausible that students will rather rely on strategies they have developed for years and which have been proven functional for them than to adopt an externally induced and probably new strategy as long as they have the opportunity to do so. Since neither the high nor the low structured external script included any hints concerning *what specific contents* to discuss, learners had a good deal of freedom, thereby having the opportunity to rely more on their internal scripts concerning content-specific aspects of the learning environment. For the high structured external collaboration script to boost the learners' acquisition of domain-specific content knowledge, maybe more content-specific scaffolds like content-related questions rather than

the provision of a formal argumentation script might be helpful. However, in the study by Weinberger, et al. (2004), it appeared that content-specific cues were not able to improve conceptual learning, maybe because they triggered rather automatized than thoughtful reactions. However, stronger effects of the high structured external script used in this study might be observable in studies taking longer time spans into account since it might take time to get learners to internalize the argumentation-specific script instructions, which help them to engage in deep elaborations of the learning material.

In the beginning of this paper, we also had argued that collaboration scripts are complex entities that might have very specific effects on specific learning outcomes and also have negative side-effects, i.e. that benefits concerning some knowledge dimensions can go at the expense of others, even though this might not have been intended when designing the collaboration script (Weinberger, et al., 2004). Our results provide justification for this view, since we found that individuals tended to acquire more *knowledge about scientific methods* when they did *not* receive further support by the high structured external collaboration script. This result might be attributed to the fact that the high structured external script set constraints for activities, which could have contributed to the acquisition of *knowledge about scientific methods*, which was not the case for activities that contributed to an acquisition of *knowledge about mechanisms*. In fact, the high structured external script was more directed towards discussing the two hypotheses and related evidence than towards thinking about what research methods might be able to determine what causes the frog deformities. Thus, our results prove that external collaboration scripts can be tailored to specific outcomes. Designers of collaboration scripts should aim at inducing activities, which contribute to the desired learning outcomes without at the same time restricting further activities that might also be fruitful with respect to these learning outcomes.

In sum, our results are in favour of the *additive effects hypothesis* and provide counter-evidence to the *interactive effects hypothesis*. The high structured external script supported both learners with high and low structured internal scripts on acquiring domain-general knowledge on argumentation and simultaneously did not impede learning of domain-specific content. However, generalizability of the reported findings might be restricted since learners reached on average rather low scores in the pretest, which assessed their internal scripts. Yet, taking into account the results of international studies like PISA, it could not be expected that students would reach very high scores in this test. We speculate that individuals having been classified as holding high structured internal scripts in this study still did not have enough argumentative skills to fully play them out in a rather unstructured learning environment. It

might be that if learners' internal collaboration scripts were structured even higher than were the internal scripts of the learners assigned to this condition in this study, the interactive effects hypothesis might receive stronger support. Subsequent research is needed to address this issue.

With respect to the design of inquiry learning environments to be used in real classroom settings, our results demonstrate that the benefits of such environments can be augmented by adding additional micro-structuring facilities to them. Collaboration scripts can be designed to improve the learners' abilities to argue with hypotheses and evidence that are provided in inquiry learning environments without impeding their content-related learning. Yet, it must be clear that different learners may require different forms of such instructional support in order to reach comparable learning gains. There might be conditions, under which learners with high structured internal scripts can benefit more from a rather open learning environment, whereas in other settings, they might require more external structuring. This points to the need for developing instructional designs that are flexibly adaptable to different types of learners.

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