Internal and external cooperation scripts in web-based collaborative inquiry learning

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INTERNAL AND EXTERNAL COOPERATION SCRIPTS IN WEB-BASED COLLABORATIVE INQUIRY LEARNING

Effects on the acquisition of domain-specific and general knowledge

Abstract. Cooperation scripts are a powerful means to improve collaborative learning. Scripts can be designed to support argumentative knowledge construction. However, not only externally induced cooperation scripts but also the learners' internal scripts on argumentative knowledge construction influence argumentative processes and what kind of knowledge is acquired during collaboration. In this study, 98 students (49 dyads) of two German secondary schools participated. We implemented two versions (high vs. low structured) of an external cooperation script directed towards supporting argumentative knowledge construction into a web-based collaborative inquiry learning environment. Further, we classified the learners' internal scripts as either high or low structured, thereby establishing a 2x2-factorial design. We investigated how external and internal scripts as well as their interaction influenced the acquisition of both domain-specific and general knowledge. Results suggest that learners' internal scripts are more important for acquiring domain-specific knowledge, whereas external scripts are more influential for the acquisition of general knowledge.

1. INTRODUCTION

In theory and research on computer-supported collaborative learning (CSCL) as well as in instructional psychology, cooperation scripts are considered a powerful means to improve processes and outcomes of collaborative learning (Kollar, Fischer & Hesse, 2003). For example, Weinberger, Reiserer, Ertl, Fischer and Mandl (in press) demonstrated that cooperation scripts embedded in different net-based learning environments were able to improve the learners' ability to apply theory-based knowledge to transfer problems as well as their recall rates of learned information. One main advantage of cooperation scripts is that they can be tailored to support a variety of activities like problem solving, learning from text or learning concrete procedures (for an overview see O'Donnell, 1999). One area in which instructional support in the nature of cooperation scripts especially is demanded is collaborative argumentative knowledge construction. Many studies have found that students often experience difficulties in engaging in argumentation (Kuhn, Shaw & Felton, 1997; Brem & Rips, 2000). Especially in the U.S. this problem was addressed by the development of several computer- or web-based inquiry learning environments (e.g., WISE, CoLAB, BGuILE) providing learners with the opportunity to deal with evidence for a specific problem, to plan and run experiments on science issues etc. (e.g., Schwartz, Lin, Brophy & Bransford, 1999; Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001). That way, learners are enabled to acquire knowledge both concerning domain-specific content like for example mechanisms that underlie scientific phenomena as well as about scientific methods of experimenting or hypothesis generation. However, in most of these environments there is considerable potential to improve the provided instructional support concerning argumentative knowledge construction.

2. WHAT IS ARGUMENTATIVE KNOWLEDGE CONSTRUCTION?

Research on argumentation and argumentative knowledge construction appears to be scattered. At least two different approaches to argumentative knowledge construction can be found. On the one hand, there is a structural perspective, which seeks to evaluate the quality of single arguments on the basis of the structural components it includes (Toulmin, 1958). On the other hand, there is a dynamic perspective on argumentation, dealing with how argumentation develops in discourse. In such a view, argumentative sequences like "argument – counterargument – reply" become important for collaborative knowledge construction (Leitão, 2000). Since learners engage in elaborating content while generating longer argumentative sequences, this is also supposed to result in an acquisition of more domain-specific content knowledge. 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.

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.

3. SCRIPTS FOR ARGUMENTATIVE KNOWLEDGE CONSTRUCTION IN INQUIRY LEARNING

As mentioned above, one promising way to facilitate students' argumentative knowledge construction is to provide learners with cooperation scripts (O'Donnell & Dansereau, 1992), which specify the processes according to which collaboration should proceed. Such cooperation 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 cooperation script depends on what the actual outcome of collaboration is supposed to be. Of course, the cooperation 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 reach these objectives. Yet, if wrong placed, these constraints might restrain learners to engage in activities that also might be beneficial with respect to the intended learning outcomes. Thus, it 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 cooperation script.

Despite the rather positive effects of cooperation 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. 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' internal scripts might also lead to different profiles of what individuals learn during collaborative argumentative knowledge construction.

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 effect of their interrelation concerning the acquisition of different types of domain-specific content knowledge as well as argumentation-specific knowledge (as an instance of domain-general knowledge) during collaborative learning in a web-based collaborative inquiry learning environment.

4. GOALS OF THE STUDY

The main objective of this study is to analyse 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 argumentation, we developed two versions of an external cooperation script (low vs. high structured) and implemented them into a curriculum project of the computer-based inquiry learning environment WISE (*W*eb-based *I*nquiry *S*cience *E*nvironment; Slotta & Linn, 2000). It was then our aim to investigate how these externally provided cooperation scripts and the learners' internal scripts on argumentative knowledge construction interact with respect to both the acquisition of different forms of domain-specific content knowledge as well as domain-general knowledge about argumentation in inquiry learning environments. 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 cooperation 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 content- and argumentation-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 cooperation script will support argumentative knowledge construction of all learners, independently from the nature of their internal scripts on argumentative knowledge construction, because even the contents of a high structured internal script will play out only when additional instructional support is provided.

5. METHOD

5.1. Participants

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

5.2. Design

An experimental 2x2-factorial design was established with the internal cooperation script (high vs. low structured) and the external cooperation script (high vs. low structured) as independent variables. Dyads were homogeneous with respect to the learners' internal scripts and gender and were randomly assigned to one of the two external script-conditions. Learners were identified as holding a high or a low structured internal script by assessing their performance in a test, in which they were asked to 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. Reliability of the used scale was sufficient. The design of the study can be viewed in table 1.

Table 1. Design of the empirical study.

		External cooperation script	
		Low structured	High structured
Internal scripts on argumentative knowledge construction	Low structured	N = 26 (13 dyads)	N = 22 (11 dyads)
	High structured	N = 26 (13 dyads)	N = 24 (12 dyads)

5.3. 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.

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 only dyads existed consisting of two girls or two boys both holding either a low or a high structured internal script. 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 external cooperation script and the other the high structured one (see below). Dyads were randomly assigned to one of these two conditions. The collaboration phase 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.

5.4. Setting and learning environment

Dyads worked on a German version of the WISE project "The Deformed Frogs Mystery". 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 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.

5.5. External cooperation script

The two versions of the external cooperation script were implemented in the "Deformed Frogs" project. At the end of each information 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 were simply asked to discuss the two hypotheses on the basis of the information of the particular unit. In the *high structured* 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 warrant. To achieve that, the learner was supposed to type each component (data, claim, warrant) 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 in a counterargument, again containing the three argument components and the respective cues. Finally, both learners should try to formulate an integrative argument, which again had to consist of data, a claim, and a warrant. 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 continually faded out to avoid the problem of "over-scripting" (Dillenbourg, 2002). Moreover, 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.

5.5. Instruments and dependent measures

Dependent measures were the individual students' performance in the subsequent knowledge tests. One knowledge test aimed to assess the learners' *domain-specific content knowledge*, whereas the second test assessed their domain-general knowledge on argumentation. In order to give a more detailed measure of the content-specific knowledge acquired, we split up the content-specific knowledge test into two subscales. The first subscale (*knowledge about mechanisms*) measured knowledge that was related to the two proposed mechanisms (parasite vs. environmental-chemical substance) as well as to evidence connected with them, whereas the second subscale (*knowledge about scientific methods*) assessed the learners' knowledge concerning how to proceed to determine the reason for the deformities. Reliabilities for the subscales were sufficient. The same content-specific knowledge test was also used to assess the learners' prior knowledge. There, reliabilities of the used scales were sufficient for the overall measure as well as for knowledge about scientific methods, but not for knowledge about mechanisms. Therefore, the pretest measure of knowledge about scientific methods was not included in our analyses.

For the *domain-general knowledge about argumentation* test, only one scale was computed. In this test, learners were supposed to name the three components of a complete argument as well as the three components of a argumentative sequence. Moreover, they were asked to give examples for a complete argument and a complete argumentative sequence. 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. Reliability of this scale was sufficient.

5.6. 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 the 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 internal scripts-test was used. For all analyses, the alpha-level was set to 5 %.

6. RESULTS

6.1. 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.*).

6.2. Domain-specific content knowledge

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*. Yet, the differences between the four conditions were even more distinct than in the overall domain-specific content knowledge test. 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 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 slightly 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 t-tests revealed that learners holding high structured internal scripts who had collaborated on the basis of the low structured external script were significantly better than both conditions that included the high structured external script.

6.3. 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. However, in this measure, the second successful group was the low structured internal/high structured external condition, 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 cooperation 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.*)

7. CONCLUSIONS

We argued that for inquiry learning environments to be effective, additional instructional support should be provided that helps learners to engage in effective argumentative knowledge construction (see Reiser et al., 2001). Engaging in argumentative knowledge construction, in turn, should lead to the acquisition of more overall domain-specific content knowledge, but what content would be learnt would be influenced by the different script types. On the one hand, instructional (external) scripts prescribe nature and sequence of specific activities like “giving an argument consisting of data, claim, and warrant” and distribute roles among the learning partners (Kollar et al., 2003). However, we argued that collaborative argumentative knowledge construction is not only guided by the instructions provided in an externally provided cooperation script but also by the learners’ internal scripts on argumentative knowledge construction. We therefore investigated how these two script types interact with regard to their effects on the acquisition of different aspects of domain-specific content knowledge as well as domain-general knowledge on argumentation.

In order to investigate this question, we set up two competing hypotheses, an interactive effects hypothesis and an additive effects hypothesis. Overall, the results we found largely support the additive effects hypothesis. 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 learners holding low structured internal scripts, regardless of the structure of the external cooperation script. Thus, it can be said that the learners’ internal scripts on argumentative knowledge construction were more influential than the externally provided cooperation script with respect to the acquisition of domain-specific content knowledge. One possible explanation for the fact that internal scripts played a more important role than external scripts is that since the learners' internal scripts have developed over long periods of time (see Schank & Abelson, 1977), learners can use them effortlessly just like a very familiar tool. Thus, 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 a strategy that is new to them as long as they have the opportunity to do so. For the high structured external cooperation script to boost the learners' acquisition of domain-specific content knowledge, maybe more content-specific scaffolds like content-related questions might be helpful. However, maybe stronger effects of the high structured external script used in this study might be observable in longitudinal studies since it might take time to get learners to internalize the argumentation-specific script instructions, which might help them to engage in deep elaborations of the learning material.

However, for *knowledge about scientific methods*, we found that individuals learned more when they did *not* receive further support by the high structured external cooperation 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 the instructions provided in an external cooperation script can be tailored to specific outcomes. However, designers of cooperation scripts should be careful to induce activities, which contribute to the desired learning outcomes and not restrict further activities that might also be fruitful with respect to these learning outcomes.

Similarly, the results for *domain-general knowledge on argumentation* provided support for the additive effects hypothesis. There was a strong effect of the external script on the acquisition of domain-general knowledge on argumentation indicating that learning with the high structured external script was superior to learning with the low structured version of the externally induced cooperation script. This result provides strong support for the additive effects hypothesis: The high structured external cooperation script helped all learners, independently of their internal scripts on argumentative knowledge construction. 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 let learners 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.

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, since learners reached on average rather low scores in the pretest, which assessed their internal scripts, 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 scripts on argumentative knowledge construction 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.

8. CONSEQUENCES

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 structure of these scripts has an impact on what kind of knowledge in fact is acquired. Therefore, cooperation scripts must be designed carefully to assure that the activities they induce match with the desired learning outcomes. The likelihood of students' engagement in activities that do not contribute to these learning objectives should be restricted by structuring the external cooperation script accordingly. Yet, further research should aim to investigate the interplay of internal and external scripts also in other domains. For more in-depth analyses, however, process analyses are necessary which we have just begun. By looking at process data from transcripts of the oral discussions within each dyad and at logfile data, we hope to understand more clearly how different scripts play together in inquiry learning environments.

On a theoretical level, a distributed cognition perspective (e.g., Perkins, 1993) might be a valuable frame of reference for describing the impact of internal and external effects on learning. This perspective states that learners and their (social, artifactual, and also instructional) surround can form a learning system, in which the executive function is distributed over several system components, namely the individual learner, his or her learning partner, the computer-environment and the imposed external script. Then, it is an important question how to orchestrate the system components (or more specifically the different scripts) in a way that they promote effective learning.

On a practical level, our results demonstrate that the benefits of inquiry learning environments can be augmented by adding additional micro-structuring facilities to them. 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 equal learning gains. There might be conditions, in 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 of developing "flexibly adaptive instructional designs", as Schwartz et al. (1999) put it.

AFFILIATIONS

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