Collaborative Argumentation and Cognitive Processing - An Empirical Study in a Computer-Supported Collaborative Learning Environment

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Abstract: It has been assumed that deep cognitive processing is associated with better understanding. Better understanding of the content is supposed to improve the quality of argumentation in the discussions. Although plausible, empirical tests of these assumptions are sparse. Therefore, the goals of this study are to examine these assumptions and to provide analyses of cognitive processes during collaboration. A one-factorial design with forty-eight (48) participants was used to investigate the relation between the formal quality of single arguments (low vs. high) during online discussions of groups of three, cognitive processes, and knowledge acquisition. The formal quality of single arguments was fostered by means of a computer-supported collaboration script. Empirical evidence was found that the quality of argumentative knowledge construction during discussion is positively related to deep cognitive processing and that the scripted construction of single arguments had a positive effect on the individual acquisition of knowledge on argumentation.

Collaborative Argumentation in Asynchronous Online Discussions

Several studies in the field of Computer-Supported Collaborative Learning aim to foster the quality of argumentation in discussions of learners in order to enhance individual knowledge acquisition (e.g., Andriessen et al., 2003; Jermann & Dillenbourg, 2003; Kollar et al., 2005; Kuhn & Goh, 2005). These approaches assume that explicit, high-quality argumentation is related to better cognitive processing and thus, to knowledge acquisition of the individual learner (e.g., Baker, 2003; Kuhn et al., 1997). Although plausible, empirical evidence for this set of interconnected claims is very rare. Therefore, this contribution aims to investigate the relations between the quality of argumentation in online discussions, cognitive processing, and knowledge acquisition.

Asynchronous online discussions have been considered as an appropriate context for learners to engage in high-quality argumentation and deep cognitive processing (Kuhn & Goh, 2005; Marttunen & Laurinen, 2001). However, learners rarely use this advantage of asynchronous communication (e.g., Marttunen et al., in press). An instructional approach aiming to support the processes of argumentative knowledge construction is based on computer-supported collaboration scripts. Collaboration scripts specify and sequence learning activities and assign roles to different learners (Kollar et al., 2006). Thereby they can facilitate specific discourse activities such as the construction of arguments. In this paper we examine the assumptions of argumentative knowledge construction about the relations between the quality of argumentation, the depth of cognitive processing, and knowledge acquisition. We therefore assess both the individual cognitive processes and the quality of argumentation in online discussion, which is fostered (and thereby experimentally manipulated) by means of an argumentative computer-supported collaboration script.

Argumentative Knowledge Construction

By "argumentative knowledge construction" we refer to the joint construction and the individual acquisition of knowledge through collaborative argumentation (cf. Andriessen et al., 2003). Argumentative dialogue that may foster argumentative knowledge construction is likely to occur in collaborative learning when two or more individuals try to find a solution for an authentic problem (e.g., de Grave et al., 2001). Some studies report substantial relations between argumentative structures in learners' discourse and individual knowledge acquisition (Baker, 2003; Chinn et al., 2000; Kuhn et al., 1997; Leitão, 2000).

The *construction of single arguments* can be described against the background of Toulmin's (1958) model of argumentation. In a simplified version of Toulmin's model, arguments may comprise the components claim, grounds, and qualifications. The *claim* is an expression of the position that is advanced in the argument. Under the term *grounds* we subsume the elements *data*, *warrant*, and *backing* from Toulmin's model. A *datum* is constituted by factual information that favors the acceptance of the claim. A *warrant* is a rule of inference that justifies the transition from the datum to the claim and reveals the relevance of the data for the claim, such as theoretical laws or definitions. A *backing* is factual information such as statistics or expert opinions that provides a rationale for a warrant. Like the supporting elements of Toulmin's model, also Toulmin's qualifier and its associated rebuttal can be conflated. We suggest the heading *qualifications* for these elements. The so-called *qualifier* marks limited certainty of the claim and is usually constituted by a modal adverb such as "perhaps" or "probably". The qualifier is directly dependent on the so-called *rebuttal* that specifies states of affairs that would weaken or invalidate the claim. According to our simplified model, a completely explicit argument would comprise a claim supported by grounds and limited by qualifications. Hence, the formal quality of single arguments can be described on the basis of this simplified model.

The explicit formulation of grounds such as data and warrant (Baker, 2003) and the explicit consideration of alternative viewpoints (Spiro & Jehng, 1990) are regarded as being related to deep cognitive processes that foster knowledge construction. In addition, the participation includes active reception of arguments, too. The confrontation with new ideas or different positions might challenge the own position. Completely explicit arguments could facilitate the evaluation of grounds and qualifications, while bare claims may rather hinder deep cognitive processing. Hence, deep cognitive processing could be related to both by the production and the reception of high-quality arguments. A crucial type of cognitive processing with regard to knowledge construction is *cognitive elaboration* (McNamara et al., 1996). Cognitive elaboration is the enrichment of learning material using additional information taken from or inferred in combination with prior knowledge. Hence, arguments of high formal quality with respect to argumentative knowledge construction should be associated with deeper cognitive elaboration. There is ample evidence that deep cognitive elaboration of the learning material is causally related to knowledge acquisition (e.g., Stein & Bransford, 1979). In problem-oriented learning environments, argumentative knowledge construction is supposed to foster, in the first place, the ability to use theoretical concepts and their interrelations to analyze and solve complex problems (Bransford et al., 1989), i.e., application-oriented, domain-specific knowledge. Additionally, there is empirical evidence that participation in high-quality argumentative discussions may foster the acquisition of knowledge on argumentation (cf. Kuhn, 1991). This comprises knowledge of the components of arguments described above and on how to construct arguments that consist of the components claim, grounds and qualifications (i.e., knowledge on the construction of single arguments). For these kinds of knowledge acquisition to occur it is regarded as crucial that the argumentation in the discourse among the learners is of high-quality. It has been demonstrated that computer-supported collaboration scripts can facilitate specific processes such as the ones that are assumed to be related to knowledge acquisition in argumentative knowledge construction (e.g., Weinberger et al., 2005a).

Effects of Computer-Supported Collaboration Scripts on Argumentative Knowledge Construction

The approach of *computer-supported collaboration scripts* to support online discussions took its inspiration from scripted cooperation (see O'Donnell, 1999, for an overview). Collaboration scripts are instructional plans that specify and sequence individual and collaborative learning activities that are associated with deeper cognitive processing and thereby facilitate knowledge acquisition. The various activities may also be assigned to different learners who then take different roles (Palincsar & Brown, 1984; for an overview see Kollar et al., 2006). Computer-supported asynchronous online discussions provide two important opportunities for the application of collaboration scripts. First, in asynchronous settings they provide learners with the opportunity to perform the activities required by the script at their individual pace. Second, in computer supported collaborative learning scripts can easily be implemented in the graphical user-interface of the collaboration tool (e.g. Baker & Lund, 1997; Hron et al., 1997). Learners do not need to split their attention between what they discuss (e.g. a case analysis) and the instructions about which activities they are supposed to perform (e.g. to construct arguments containing grounds). Therefore, computer-supported collaboration scripts are typically implemented as prompts (e.g. Weinberger, 2003), buttons (e.g. Hron et al., 1997), or input text fields (Kollar et al., 2005).

Weinberger et al. (2005b) designed a computer-supported collaboration script for argumentative knowledge construction in problem-based learning in a higher education setting. It was designed to improve the quality of single arguments in online discussions by providing a set of text windows and related prompts for the different components of a completely explicit argument, i.e., an argument consisting of a claim, grounds and qualifications. In an empirical study, Weinberger et al. (2005b) found evidence that the script fostered both the quality of argumentation in online discussions and the individual acquisition of knowledge about argumentation. The individual acquisition of domain-specific knowledge (on Weiner's attribution theory in this case) was not affected. The authors explained this pattern of findings by learners' limited cognitive resources: The time to acquire both knowledge on argumentation and domain-specific knowledge was restricted to 80 minutes in this experimental study. This required the learners to allocate a considerable part of their cognitive capacity to the construction of knowledge on argumentation and accordingly left little resources for enhanced domain-specific knowledge acquisition. Thus, the study showed that argumentative computer-supported collaboration scripts are feasible means to foster the quality of argumentation in online discussions as well as the acquisition of knowledge on argumentation, while at the same time it did not appear to impede domain-specific knowledge acquisition. Hence, this setting seems suitable to examine to what extent the quality of argumentation is positively related to deep cognitive processing. The study presented here can be regarded as a follow up to the study by Weinberger et al. (2005). This paper aims to examine the relation between high quality argumentative discussions and the depth of cognitive processing more closely.

Research Questions

The following research questions were examined:

(1) To what extent does the scripted construction of single arguments affect the quality of argumentation and the depth of cognitive elaboration during argumentative knowledge construction? In line with the study of Weinberger et al. (2005b) we expect that the scripted construction of single arguments has a positive effect on the formal quality of single arguments. Moreover, we expect that learners supported by the scripted construction of single arguments engage in deeper cognitive elaboration than learners without support of the script.

(2) To what extent is the quality of argumentation related to the depth of cognitive elaboration? We expect a positive relation between the formal quality of the learning partners' argumentation and the depth of cognitive elaboration and that the effect of the scripted construction of single arguments on the depth of cognitive elaboration is mediated by the formal quality of the learning partners' argumentation. Furthermore, we expect a positive relation between the depth of cognitive elaboration and the formal quality of the learner's argumentation as well as that the effect of the scripted construction of single arguments on the quality of the learner's own argumentation is mediated by the depth of his or her cognitive elaboration.

(3) To what extent does scripted construction of arguments foster the acquisition of domain-specific knowledge and knowledge on argumentation? Since we did not change the conditions of the experimental setting in comparison to the study of Weinberger et al. (2005b), we expect that the scripted construction of single arguments should have a positive effect on the acquisition of knowledge on the construction of single arguments and no further effects on domain-specific knowledge acquisition.

Method

Participants, Design, Unit of Analysis, and Statistical Tests

Forty-eight (48) students of Educational Science at the University of Munich participated in this study during the winter term 2003/2004. The mean age of the participants was M = 22.77 (SD = 3.66) years. Participation was a requirement for receiving course credit in a mandatory introductory course for freshman because the experimental learning environment was part of the regular curriculum. The experimental session covered an important theory (Weiner's attribution theory; Weiner, 1985) and was a substitute for a three-hour lecture in the course. The learning outcomes of the experimental session, however, were not considered in grading. We manipulated the variable "scripted construction of single arguments" (with vs. without) by means of a computer-supported collaboration script for the construction of single arguments that will be described below. The participants were randomly assigned to groups of three. The groups were then randomly assigned to one of the two experimental conditions in this one-factorial design.

We decided to take the individual learners as the unit of analysis because individual knowledge acquisition is a main point of interest in this study and assumed to be a consequence of individual cognitive processes. However, learners in a group of three cannot be regarded as mutually independent, which can be considered as a violation of the random sample prerequisite of statistical procedures. Hence, we randomly selected one learner per group for this analysis, i.e. in the analysis each of the 16 groups is represented by one of its members.

Material and the Collaborative Learning Task

The content of the learning environment was Weiner's attribution theory (1985) and its application in education. In an educational context, this theory can be used to explain the learning motivation of people on the basis of the kinds of causes to which they themselves attribute success or failure. The students read a three-page description of this theory.

Three learning cases about practical contexts were used as a basis for online discussions in the collaborative learning phase. Each case was close to reality, complex and allowed learners to construct different arguments based on attribution theory. The group's task was to analyze the three cases and to come up with a joint solution for each case. The three students in each group were distributed over three laboratory rooms. An asynchronous, text-based discussion board was used for collaboration. This discussion board allowed the exchange of text messages that resembled emails. Learners could either start a new topic by posting a new message or reply to messages that had been posted before. Each message consisted of a subject line, author information, date, time, and the message body. While the learning environment set author information, date, and time automatically, the learners had to enter the subject line and the body of the message. Each of the three cases was discussed on a separate discussion board, and learners could switch between these boards at any time during the collaborative learning phase.

Implementation of the Scripted Construction of Single Arguments

The environment allowed for the graphical implementation of different types of computer-supported collaboration scripts. (1) The *control group* received no additional support in solving the three problem cases. (2) The *scripted construction of arguments* was implemented in the CSCL interface as a graphical structure of input text boxes that should help learners to construct single arguments (see Figure 3). The script, based on our simplified version of Toulmin's model (1958), differentiates between claim, grounds and qualifications. The learners were asked to fill in each text box of the interface to construct a completely explicit argument. After constructing the argument, they could add the argument to the message body by clicking on a command button ("add" button; see Figure 1). This triggered the event that the graphical structure was translated by the system into a pre-specified textual structure for the individual messages. Then, the learners could either construct a new argument with support from the graphical structure or submit the message. Non-argumentative parts of the message, such as questions, comments or expressions of emotion could be inserted directly into the message body, without using the argument construction script.

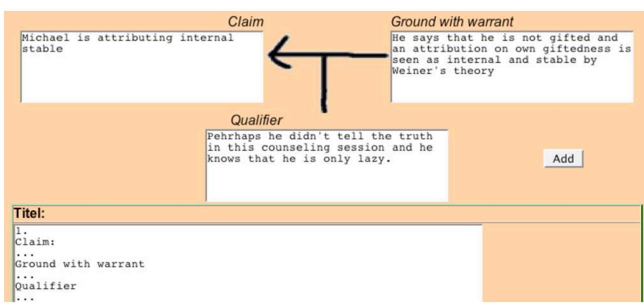

Figure 1. The interface of the script for the construction of arguments. This extension was placed between the description of the cases and the regular user interface. It comprises input text fields for claim, grounds and qualifications. With a click on the add-button, the argument was pasted to the input text field of the regular interface and the input text fields of the extension were cleared.

Procedure

First, the participants completed pretests that were designed to measure domain-specific prior knowledge and prior knowledge on argumentation. The data from these tests were used to control randomization. Subsequently, the participants had 20 minutes to read the three-page description of attribution theory individually. After that, the learners were introduced to the learning environment and to the think-aloud procedure. Then they collaborated for 80 minutes in groups of three, trying to develop solutions for the three cases and to reach agreement about them. In the final phase (about 45 minutes), the students took individual posttests on domain-specific knowledge and knowledge on argumentation. Time on task was held constant for the two conditions.

Data Sources and Variables

Quality of the construction of arguments. To assess the construction of arguments, the students' written online discussions during the collaborative learning phase were analyzed by means of a segmentation and coding procedure developed by Weinberger and Fischer (2006). Only the messages that referred to the case "Math" (about 1200 segments counted across all groups) were included in the analysis.

The discourse corpora were segmented by trained coders. The segmentation was based on propositional units, i.e. the criterion for segmentation was to separate units that include concepts from attribution theory that could be evaluated as true or false. E.g., the sentence "Michael is attributing internal and stable." was segmented into "Michael attributes internal" and "[Michael attributes] stable". With respect to the segmentation of the discourse corpora, the coders achieved an agreement of 84% during the training.

The segmented discussions were then analyzed for the construction of single arguments. With respect to the construction of arguments, the coders had to distinguish between (1) bare claims, (2) supported claims, (3) limited claims, and (4) supported and limited claims. Bare claims are neither explicitly supported by grounds, nor explicitly limited in their claimed validity by qualifications, e.g. "Michael attributes as internal". Supported claims are assertions for which grounds are provided. In the context of this study, learners could support their claims with grounds that were either observations from the case description (data) or definitions, laws and findings from research on attribution theory (warrants and backings), for example. Indicators for grounds that support claims are conjunctions such as "because", "due to the fact that" etc., yet learners do not always explicitly connect reasons to the corresponding claims. For instance, the claim "Michael attributes as internal" may be supported by the grounds "Michael ascribes his failure to lack of talent." and "Ascribing failure to lack of talent is an internal attribution". Limited claims are restricted in their claimed validity by qualifications, e.g. "[...] provided that Michael tells the truth". Supported and limited claims are both accompanied by grounds and restricted by qualifications. Five trained coders coded the online discussion. About 5% percent of the discourse data presented in this study were coded by all five coders. The interrater agreement computed on the basis of these overlapping codings of the construction of single arguments was sufficiently high (median of Cohen's $\kappa = .70$).

The *quality of the construction of arguments of the individual learner* is a compound variable that was defined as the amount of written arguments of one learner during the online discussions that were either supported by grounds or limited by qualifications, or both in the argumentation of the learner. The *quality of the construction of arguments of the learning partners* was determined in analogy to the previous variable, but only on the basis on the contributions of each learner's two partners, i.e. as the amount of arguments of the learning partners with grounds and/or qualifications.

Depth of cognitive elaboration. The participants were asked to think aloud during the whole collaboration phase. They were advised to articulate their thoughts without explaining or commenting on them. In each laboratory room, an experimenter was seated together with the participant in order to ensure that the think-aloud procedure was performed correctly. If necessary, the experimenter used one of the following sentences to advise the participant: "Please keep on speaking!", "Please do not comment your thoughts!", or "Please do not explain your thoughts!" The think-aloud protocols were recorded by the computer using a software that captures both the content of the computer screen and the audio signals from the laboratory room simultaneously. The think-aloud protocols were broken down into segments of ten seconds of duration. Trained coders classified each segment of the think-aloud protocols. "Cognitive elaboration" was coded when learners elaborated propositional units in which they applied concepts from attribution theory. Note that these propositional units were not provided in the learning material, but had to be inferred by the learner. Experts identified the propositional units that referred the case "Math", e.g., "Michael is attributing as internal", "The teacher is attributing as internal", or "The parents are attributing on missing ability". The median of the agreement between the coders concerning the categorization was sufficiently high (Cohen's $\kappa = .78$).

Following a line of argumentation introduced by Craik (2002), we operationalized the depth of cognitive elaboration as the duration of cognitive elaboration per proposition. According to Craik, the duration of cognitive processes can, under certain circumstances, be interpreted as an indicator of the depth of cognitive processing. The depth of cognitive elaboration depends on several attributes of learners, learning material, and the learning task. For example, learners with a high level of relevant prior knowledge process information faster than learners with a low level of knowledge. Different learning content (e.g., reading a novel vs. reading a manual) requires a different processing time. Memorization takes an amount of time different from problem solving. Therefore, there cannot be a general objective index of depth of cognitive elaboration. Conversely, however, this means that the duration of cognitive elaboration by similar learners with similar prior knowledge who process the same information with respect to the same task may allow for intersubjective comparisons of the depth of cognitive processing. Hence, all learners received the same learning material with the same task, and only freshmen were examined. The comparability of their prior knowledge was tested (see section "Randomization check").

Tests of domain-specific knowledge. Both the pretest and the posttest for the measurement of domain-specific knowledge consisted of the task to analyze a problem case from a practical context. The participants had to write an analysis based on Weiner's (1985) attribution theory individually on a sheet of paper and received no additional support. The case "Choosing a major" was used for the pretest and is about the influence of parents on their daughter's choice of her major subject at the university. In the case "Text analysis", which was used for the posttest, a student talks about the reasons of failing an exam in text analysis. Individual pretest and posttest were analyzed by means of a segmentation (see above for segmentation rules) and coding procedure developed by Weinberger (2003):

For the *pretest* experts identified propositional units in which theoretical concepts from attribution theory are used to describe case information concerning the case "Choosing a major". The number of these propositional units in the pretest was used as an indicator for domain-specific prior knowledge. Due to a floor effect (most participants did not apply concepts from attribution theory in the pretest), the reliability of the measurement was rather low (Guttmann split-half, $r = .42$).

For the *posttest*, experts identified propositional units in which theoretical concepts from attribution theory are used to describe case information concerning the case "Text analysis". The number of different propositional units that could be identified in a subject's analysis of the posttest case was used as a measure for his or her domain-specific knowledge. The reliability was sufficient (Guttman split-half, $r = .62$).

Tests of knowledge on the construction of arguments. In the *pretest*, prior knowledge on the construction of arguments was operationalized as the amount of arguments in the individual analysis of the problem case that were either supported or limited, or both, according to the segmentation and coding procedure that was described above for the analysis of the students' discussions.

In the *posttest* of knowledge on the construction of single arguments the participants were asked to recall components of single arguments (claim, grounds, and qualifications). For the successful recall of each of the three components they were credited one point. In addition, the participants were asked to formulate completely explicit arguments about "smoking" that contained all of the components of the simplified Toulmin model. These arguments were analyzed with respect to the components of a single arguments (claim, grounds, and qualifications). For each of the three types of components that were appropriately contained in the students' responses they were credited one point. Hence, the test scores could range from 0 to 6 points. Two trained coders rated the knowledge on argumentation tests (Cohen's $\kappa = .83$). The reliability coefficient was sufficiently high (Guttman split-half, $r = .88$).

Results

Randomization Check

In order to control potential effects of interfering variables and to ensure that randomization was successful, we compared a) the experimental conditions and b) unselected vs. selected individuals from the small groups with respect to domain-specific prior knowledge and prior knowledge on argumentation. These tests were conducted on a 20 percent alpha-level to reduce the probability of type-II-errors. Because of the floor effect of domain-specific prior knowledge, a Chi-square test was conducted with regard to this variable as well. Neither between the experimental groups nor between selected vs. unselected individuals significant differences were found.

RQ1: Effects of the Scripted Construction of Single Arguments on the Formal Quality of Single Arguments and the Depth of Cognitive Elaboration during Argumentative Knowledge Construction

The effects of the scripted construction of single arguments on the quality of the construction of single arguments and the depth of cognitive elaboration of the learning material were tested.In the scripted construction of single arguments condition learners produce more then twice the amount of supported claims (*M*=11.88, *SD*=7.08) than learners in the control group (*M*=5.38, *SD*=5.76), i.e. the script increases the *quality of construction of arguments* substantially ($t_{(14)}$ = -2.02, p < .05, d = 1.01, one-tailed). This finding replicates the findings of Weinberger et al. (2005) and supports our expectations. The scripted construction of single arguments also increased the *depth of cognitive elaboration(M=31.51, SD=16.68)* in comparison to no support by the script (*M*=62.67, *SD*=38.89). This effect was significant and large ($t_{(14)}$ = -2.05, p < .05, d = 1.04, one-tailed). This result is in line with our expectations and the assumptions concerning argumentative knowledge construction.

RQ2: Relation between the Formal Quality of Single Arguments and the Depth of Cognitive Elaboration

With regard to RQ2 we examined two relations: The first is the relation between the depth of their cognitive elaboration of the learning material and the quality of the learners' own single arguments in online discussion. The second is the relation between the quality of the single arguments of the learning partners and the depth of the learners' cognitive elaboration of the learning material.

As expected, the depth of the cognitive elaboration of the learning material is positively correlated with the quality of a learner's single arguments in the online discussion, i.e. the deeper the cognitive elaboration of the learning material, the higher the formal quality of single arguments of the learner. This correlation is large and significant (r = .64, N = 16, p < .05, one-tailed). A positive correlation that was not significant was found between the formal quality of the single arguments of the learning partners and the depth of the individual learners' cognitive elaboration (r = .44, N = 16, *n.s.*, one-tailed).

Additionally, we conducted two mediator analyses. If the variable examined actually mediates the effect of the scripted construction of single arguments, no effect on the residuals or an effect with a considerable smaller effect size (i.e. at least a one third lower than the effect on the criterion itself) should be found (cf. Baron & Kenny, 1986). We tested the depth of the learners' cognitive elaboration of the learning material as a predictor of the quality of their own single arguments in online discussion and the quality of the single arguments of the learning partners as a predictor of the depth of the learners' cognitive elaboration of the learning material. The first regression analysis predicts the formal quality of the learners' own single arguments on the basis of the depth of the learners' cognitive elaboration and explains a large proportion of its variance (F(1,14) = 6.72, p < .05, $R^2_{adj.}$ = .31). No effect of the script on the residual was found ($t_{(14)}$ = -1.61, *n.s.*, one-tailed). Hence, the effect of the script on the formal quality of the learners' own single arguments was mediated by the depth of the learners' cognitive elaboration. As indicated by the correlation reported above, in the second regression analysis the quality of the single arguments of the learning partners was not a significant predictor of the depth of the learners' cognitive elaboration (F(1,14) = 2.81, *n.s.*, $R^2_{adj.}$ = .12). The scripted construction of single arguments still had a significant and strong effect on the residual from this regression model ($t_{(14)}$ = -2.17, p < .05, d = 1.16, one-tailed). The effect size of the effect of the scripted construction of single arguments on the residuals of the depth of the learners' cognitive elaboration was 11.50% percent higher than the effect size of the effect of the scripted construction of single arguments on the depth of the learners' cognitive elaboration (d = 1.04; see RQ1). Hence, the formal quality of the single arguments of the learning partners cannot be considered as a mediator of the effect of the scripted construction of single arguments on the depth of cognitive elaboration in this context.

RQ3: Effects of the Scripted Construction of Single Arguments on the Acquisition of Domain-Specific Knowledge and Knowledge on the Construction of Arguments

Effects on the acquisition of domain-specific knowledge. Though learners in the scripted construction of arguments condition used theoretical concepts to describe case information in the individual posttest more often (see Table 1), this difference was not significant ($t_{(14)}$ = -0.76, *n.s.*, one-tailed). This finding replicates the findings of Weinberger et al. (2005b) and is in line with our expectations.

Effects on the acquisition of knowledge on the construction of single arguments. With respect to knowledge on the construction of arguments, learners in the scripted construction of single arguments condition scored about 30% higher than learners without support of the script in the posttest (see Table 1). The scripted construction of arguments fosters the acquisition of knowledge on the construction of arguments significantly and substantially ($t_{(14)}$ = -5.29, p < .05, d = 2.63, one-tailed, see Table 1). This finding again replicates the findings of Weinberger et al. (2005b) and is in accordance with our expectations.

Table 1: Individual outcomes of argumentative knowledge construction by experimental condition: means (m) and standard deviations (SD).

		Control group	Script for the construction of single arguments
Domain-specific knowledge acquisition		4.00	5.75
	SD	2.07	3.49
Acquisition of knowledge on construction of single arguments		3.50	5.50
	SD	0.76	0.76

Conclusions

With regard to RQ1, we could replicate the finding of Weinberger et al. (2005b) that the quality of argumentation can be fostered during collaboration by means of a computer-supported collaboration script. We found evidence that the scripted construction of arguments affects the depth of cognitive elaboration of the learning material.

With respect to RQ2, we found evidence that the depth of a learner's cognitive elaboration of the learning material is positively related to the quality of his or her argumentation. The mediator analysis showed that the depth of cognitive elaboration mediated the effect of the scripted construction of arguments on the quality of argumentation. With regard to the relation between the cognitive elaboration and the quality of the other learners' argumentation in the discussion the relation was less close compared to the relation between the depth of a learner's cognitive elaboration of the learning material and the quality of the learner's own argumentation. Therefore, this evidence is rather inconclusive. The mediator analysis indicated that the effect of the scripted construction of arguments on depth of cognitive elaboration might not be mediated by the quality of the *other learners' argumentation* in the discussion.

With respect to RQ3, we were able to replicate a second finding of Weinberger et al. (2005b): The computer-supported scripted construction of arguments fostered the acquisition of knowledge on argumentation without affecting the acquisition of domain-specific knowledge.

The findings of this study provide support for crucial assumptions about argumentative knowledge construction: We found empirical evidence for the claim that high quality collaborative argumentation is associated with deeper cognitive processing (as assumed, e.g., by Baker, 2003) as well as with the acquisition of knowledge of the individuals participating in a discussion. The simultaneous increase of the quality of argumentation and the depth of cognitive processing by the use of the collaboration script and the mediator analysis make it plausible that deep cognitive elaboration precedes high-quality arguments. However, one reason for deep cognitive elaboration may be the requirement to formulate high-quality arguments with grounds and qualifications. Hence, the writing of arguments and the depth of cognitive elaboration might interact reciprocally in a more complex way than we are able to test here. The findings with respect to the relation between the quality of arguments of the learning partners and the depth of cognitive elaboration were more inconclusive. They cannot be taken as evidence that the contributions of the learning partner do not affect the depth of cognitive elaboration. We can only speculate that high-quality argumentation as well as low-quality argumentation of learning partners can provoke deep cognitive processing. It might rather depend on the difference between the position of the individual learner and the position of his or her learning partners. If a claim with grounds and qualification is in line with the learner's position, he or she might tend to not engaging in deep cognitive elaboration, while a claim that challenges the own position, regardless whether a bare one or one supported by grounds, may provoke deep cognitive elaboration. Accordingly, learners might be in need of support during the reception of arguments. Although this study cannot provide conclusive evidence on this issue due to the small sample size, the experimental time constraints etc., it might stimulate more systematic empirical research on the relevance of the learning partner in computer-supported collaborative argumentation. Such research can take studies on the interaction of text characteristics and learner characteristics as starting point (McNamara et al., 1996).

However, some limitations of the study and thus the validity of its findings should be noted as well. To zoom in on the discursive and cognitive mechanisms involved in learning through argumentation, we chose to restrict our setting with respect to collaboration time and degrees of freedom in participation in an experimental laboratory setting. Some of the results could possibly be attributed to these restrictions. For example, it is an open question, what effects a collaboration script might have on the acquisition of domain-specific knowledge, when longer periods of time are considered. Under such conditions, individuals would be less strictly forced to decide how to allocate cognitive resources under time pressure. Moreover, once the argumentative knowledge has been acquired, more cognitive resources would be available for the acquisition of domain-specific knowledge (see Kollar et al., 2005). Furthermore, when the learners are able to perform the scripted activities by themselves, the external support need no longer be present in the interface and should be faded. It is still unclear, when and how fading of collaboration support should take place (see Pea, 2004). A further limitation concerning the generalizability of the findings applies. The study focused on specific aspects of argumentation, namely the construction of single arguments. The effects of scripts addressing more dialectic aspects (e.g., the sequencing of arguments, counterarguments, and integration were not examined in this paper. Therefore, the conclusions with regard to the relation of collaborative argumentation and cognitive processing might be limited to a specific (though important) subfield of argumentation.

Methodologically, this study contributed to advance the field in showing the potentials of using the think-aloud method in collaborative settings. The use of this method provided data to exemplarily test a hypothesis inherent in many approaches to collaborative learning: The hypothesis that specific collaborative activities are associated with the cognitive processing of the information by the participating individuals (e.g., King, 1999). Note that the main results of this study replicate findings of another study without the think-aloud procedure (Weinberger et al., 2005b). This can be taken as evidence that the method did not substantially interfere in a systematic way with the collaborative knowledge construction activities under investigation.

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