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Scripting a distance-learning university course: Do students benefit from net-based scripted collaboration?

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Abstract This study reports findings from an experimental field study of scripted collaboration for net-based learning in the context of a one-semester university course on operating systems. In scripted collaboration, activities of learners are coordinated and guided according to particular rules, implemented via respective tools in the learning environment. Forty-two distributed groups of three students collaborated on five successive assignments employing the virtual learning environment CURE. Three collaborative tasks—brainstorming, clustering, and essay writing—were implemented as scripts with dedicated tools guiding the net-based collaborative process. Half of the groups collaborated via scripted task versions, and, as a control, half of the groups performed the tasks in a non-scripted manner. No general advantage of scripting was found concerning acquisition of knowledge; nor was overscripting observed. Collaborative scripting appears to be neither generally advantageous nor disadvantageous, but highly contingent on the particular content and task under consideration. Results suggest that scripting might be slightly more supportive in more complex tasks such as essay writing, in contrast to undemanding tasks such as brainstorming.

Keywords Computer-supported collaborative learning · Net-based learning · Scripted collaboration

Introduction

The notion of scripting in collaborative learning arguably originated in the work of O'Donnell and Dansereau (1992; King 2007; O'Donnell and King 1999). There is now accumulating evidence that scripting can serve as a viable means to improve computer-

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supported collaborative learning (Fischer et al. 2007a, b; Stahl et al. 2006; Stegmann et al. 2007; Weinberger et al. 2005), particularly in distributed learning situations when learners communicate and collaborate via the Internet (Dillenbourg and Jerman 2007; Jucks et al. 2003; Oehl and Pfister 2010; Pfister 2005; Pfister et al. 2003; Pfister and Oehl 2009; Schooneboom 2008); for contradicting evidence, however, see Rummel et al. (2009). In essence, scripting means to impose some kind of structure and a set of rules on the learning process in order to foster systematic and efficient communication, coordination, and collaboration among the members of a learning group (Kobbe et al. 2007). A particular implementation of scripting is then called a script. It is assumed that distributed learning groups will perform better, that is, acquire more knowledge and achieve a deeper understanding when supported by appropriate scripts. In the context of net-based collaborative learning, scripting usually implies that the learning environment and user interface provide the tools and features that are required to support scripted collaboration, pointing out that conceptual structure and technical implementation are usually tightly integrated (Haake and Pfister 2007; Hoppe et al. 2007; Kobbe et al. 2007; Wessner and Pfister 2007).

To the best of our knowledge, research on scripting collaborative learning has been conducted, for the most part, relying on laboratory experiments (Bromme et al. 2005; Fischer et al. 2007a, b). Laboratory studies have focused on short learning episodes; real learning, however, commonly extends over several weeks or months, such as a semester in university courses. If authentic courses were examined, the focus was almost exclusively on case studies (Martinez et al. 2006; Rourke and Kanuka 2007). Also, very few studies exist which investigate the effects of net-based collaboration over an extended period of time (Cakir et al. 2009; De Wever et al. 2007). This paper contributes to the research on scripting in authentic and extended distributed learning situations as are encountered in real courses at distance-learning universities.

Three issues are addressed. First, we compare performance on collaborative variants of tasks such as brainstorming and essay writing between scripted and non-scripted versions across a one-semester course. Second, we examine if learning outcome is improved as measured by a conventional knowledge test as a consequence of employing scripted collaboration. Third, we examine if learning outcomes are positively related to performance on collaborative tasks. Altogether, findings are expected to shed light on the feasibility and usefulness of scripted collaboration in real university courses.

The structure of scripts

Dimensions of scripting

Several characteristic features of collaborative scripts can be distinguished (Fischer et al. 2007a, b; Kobbe et al. 2007; Kollar et al. 2006). Here, we focus on *granularity* and *coerciveness*. Concerning granularity, some scripts control elementary processes of communication, for example, who is allowed to contribute, or what kind of contribution is permissible. These granular rules refer to the *micro-level* of collaboration and aim to support critical features of basic communication and coordination processes (Dillenbourg and Jerman 2007; Oehl and Pfister 2010; Pfister 2005). Other scripts focus on the *macro-level* of a learning process (Dillenbourg and Hong 2008; Oehl and Pfister 2010; Tchounikine 2008). Macro-level scripts commonly partition the learning episode into a small set of successive phases which are associated with particular tasks, such as first reading a text paragraph, then exchanging comments among learners, then constructing an artifact together in a collaborative workspace, and eventually integrating individual proposals into a common report (O'Donnell and Dansereau 1992; Rummel and Spada 2005). Macro-level scripts may also assign specific roles to individual members of the group (Kobbe et al. 2007; Schellens et al. 2007), such as summarizer or critique, and may also scaffold the learning process by providing specific cues related to the substance matter under discussion (Weinberger et al. 2007).

Another important dimension is the degree of *coercion* exerted by the script. Low coercion means that participants are largely free to follow the rules of the script, which are supposed to recommend but not to enforce particular activities. Under high coercion, however, participants are forced to comply with the scripting rules and the sequential structure of tasks, especially, if the scripting procedure is hardwired into the learning environment, leaving learners with few degrees of freedom to behave differently than required by the script (Pfister and Mühlpfordt 2002). There is some concern that a high level of coercion may lead to *overscripting* (Dillenbourg 2002), resulting in a possible decline in learning performance and motivation, because the enforced script might interfere with the learners' cognitive representation and style (Dillenbourg and Jerman 2007). The risk of overscripting is especially high when internal and external scripts do not correspond (Carmien et al. 2007). Some authors argue that it might be more advantageous if learners are able to depart from the script or to adapt the script for their own purposes (Dillenbourg and Traum 2006; Stahl 2006). Overscripting might be more serious in extended courses. Thus, it is somewhat unclear whether it will prove to be more beneficial to provide scripts as optional affordances for interaction and learning, or as enforced rules to guide the process (Hesse 2007; Stahl 2006; Suthers 2006).

Atomic and composite scripts

Haake and Pfister (2007; Tchounikine 2008) have emphasized that complex scripts should be decomposed into more elementary components, and, vice versa, that composite scripts can be generated by flexible aggregation of atomic scripts. A script supporting a complex collaborative task, such as discussing and summarizing a difficult text (King 2007), can be considered as a hierarchy of tasks and subtasks, each associated with its specific scripting rules. We distinguish between *atomic* scripts controlling the learners' activities and interactions at the micro-level of a particular task, and *composite* scripts structuring the sequence of collaborative tasks at the macro-level. A composite script, controlling macro-level activities, is then defined by a series of atomic scripts (or, recursively, by further composite scripts), which constitute subtasks of a comprehensive learning task and control activities on the micro-level.

Take as an example the process of trying to understand a complex theory, which is presented as a long textual description. The first task might be for each learner to read the text and make notes individually. The second task might be for all learners to discuss the single paragraphs successively, and to achieve a shared understanding of key concepts. The third task might be to collaboratively construct a joint summary text. The overall script, then, consists of three interdependent tasks—reading, discussing, and writing, each of which consists of specific activities, such as making notes, explaining concepts to others and questioning their statements—and producing a common text. These would lead to one three-task composite script, controlling the macro-level phases, and three atomic scripts, controlling the micro-level of activities related to the execution of each single task.

Scripting a distance-learning course

In this study, we examine the use of a composite script in a computer science course on operating systems. Students in this course are supposed to learn basic concepts, theories, and algorithms needed for operating system design and implementation. The traditional instructional design of such a course includes lecture units, individual assignments, a course newsgroup, direct consultation, and the final exam. Seven lecture units are provided as learning material on specific course topics for individual knowledge acquisition to students in a written form at two-week intervals. Every course unit is accompanied by an individual assignment consisting of exercises, the correction of the submitted solutions, and a sample solution. A newsgroup supports discussion among students. Students may individually contact instructors via phone or email. Finally, a thirty-minute graded oral exam is used to assess students.

A major problem for students in this domain is to understand how different requirements, concepts, and solutions are interrelated in the design of an operating system. In the traditional course design, such interdependencies are mentioned in the course units, but are not supported by specific assignments. However, in the oral exam, such knowledge and competencies are required to reach a satisfying grade.

In order to help students develop a deeper understanding and to practice problem—solving and argumentation skills, a new type of collaborative assignment was created. A three-phase composite script was constructed to help distributed students develop the solution in the group. In the first phase, brainstorming is used to activate appropriate concepts from the previous course units; here, students may benefit from other students' ideas and perspectives. In the second phase, a clustering technique is used to construct structural relationships among concepts. In the third phase, essay writing is used to train argumentative skills in textual form.

From an instructional perspective, the above tasks can be considered suitable for the acquisition of theoretical concepts, abstract relationships, and an integrative deeper understanding of a complex domain. There is a particular didactical sequence concerning the cognitive processes involved: from simple and intuitive, such as brainstorming, to difficult and effortful, such as writing an essay (Reigeluth 1999). We will briefly elaborate on the three collaborative tasks used in the study.

Brainstorming

Brainstorming is supposed to help students to activate their preexisting knowledge about a domain, as well as to support the recollection of newly learned material. Learners may be stimulated by perceiving ideas from co-learners, and learners running out of ideas may be inspired by reading the contributions of others. Combining the ideas of all students in a group should lead to a more comprehensive awareness of the concepts involved. An atomic script regulating the brainstorming activity should help distributed students to coordinate their activities, for example, how to begin and end brainstorming, how and where to contribute, and how to avoid the spontaneous criticism of others.

Previous research indicates that brainstorming in groups does not necessarily lead to increased creativity (Ziegler et al. 2000). However, in educational contexts, the goal is not to generate creative ideas, but to activate relevant knowledge. Some evidence suggests that collaborative brainstorming, particularly in virtual groups, might be useful when the acquisition of new knowledge is emphasized, and when some guidance is provided (Isaksen and Gaulin 2005; Michinov 2005; Paulus and Paulus 1997). We assume that when the goal is the acquisition of new concepts in a largely novel domain, scripted brainstorming will be helpful to provide structural guidance.

Clustering

Clustering was used as a natural continuation of the brainstorming task. Clustering requires students to assign concepts to predefined categories, forming clusters of related concepts. Whereas the brainstorming task is mainly concerned with the activation of concepts, clustering motivates students to think about similarities and relationships. An atomic script was constructed that aims at facilitating clustering activity in a distributed group: Each student can at the same time (1) create or delete clusters, (2) assign a concept to a cluster, (3) remove a concept from a cluster, or (4) create a concept. The script enables parallel work while ensuring that students can communicate, and, thus, alleviating the process of reaching consensus.

The clustering technique might be considered as a variant of constructive knowledge structuring (Jonassen et al. 1993). Though not primarily based on a graphical representation, the process of clustering is closely related to the technique of concept mapping (Novak 1998). Concept mapping has been shown to be potentially beneficial for learning (Wallace et al. 1998), and there is evidence that it is well suited for net-based problem-solving groups to obtain a shared understanding (Stoyanova and Kommers 2002).

Essay writing

As the final task, a collaborative essay writing task was devised in order to make students elaborate on their previous brainstorming and clustering outcomes. Joint writing within a team is required in many jobs, and the ability to write concise and comprehensible documents is an important skill for computer science students, as it is for virtually any academic profession (Kittleson and Southerland 2004; Prain and Hand 1996). Usually, essay writing has been used to assess performance, not as a means for learning. However, there is some evidence that scripted co-authoring can be a highly valuable tool for knowledge construction and reflective thinking, if sufficient guidance and support is provided (O’Donnell and Dansereau 1992; Pargman 2003).

Scripted versus non-scripted collaboration

A scripted version of each collaborative task was constructed, together with a non-scripted control version. Basically, the non-scripted version relies on a simple textual instruction which students can follow as closely as they like. The scripted version, as will be outlined in more detail below, provides dedicated tools which trigger particular collaborative activities. Table 1 contrasts the main features of the scripted and the non-scripted versions.

Research questions

As an overarching objective, we are interested in the applicability of scripting in a real distance-learning university course during an entire semester. In particular, we first examine if differences can be found in performing the scripted and the non-scripted versions of three collaborative tasks. We assume that scripting will be beneficial, eliciting richer and more correct solutions, as compared to the non-scripted condition. Second, we examine if

Table 1 Main characteristics of scripted and non-scripted collaborative tasks

	Scripted	Non-scripted
Instruction	step-by-step	full instruction at start
Coordination	regulated by system (implemented tools)	by participants
Sequencing	system-controlled turn-taking	by participants
Role assignment	by system	by participants
coerciveness	high	low
side activities	allowed	allowed
distribution of information	automated	by participants

learning outcomes are better under scripted collaboration. We hypothesize that scripted collaboration has an advantageous impact on knowledge acquisition. Third, we investigate the relationship between performance on collaborative tasks and individual knowledge acquisition. In particular, we assume that improved collaborative performance, as possibly instigated by scripting, will lead to improved individual learning outcomes.

Method

Design

Participants worked in learning groups of three. Each group was randomly assigned to the scripting or the control condition, yielding 21 groups in each condition. Each group successively worked on five assignments with a two-week interval between assignments. For each assignment, the scripts for the three collaborative tasks, brainstorming, clustering, and essay writing, were processed in that order. Scripting condition was thus realized as an experimental between-subjects factor, whereas assignment and task constitute fully crossed repeated measurement factors. Learning groups constitute a random factor, with individual students nested within groups.

Participants

From a total of 300 students enrolled in the course, 126 participated voluntarily in the study; note that this constitutes a self-selected sample. Participants indicated their availability in terms of time slots, and could suggest which co-learners they wanted to have in their group. Only a few students explicitly preferred particular group members, and we accommodated those wishes, implying a moderate amount of self-selection. Otherwise, groups were formed randomly.

During the study, a few groups became dysfunctional because of dropouts. For those four groups that became too small, the group was closed and new groups were established from the remaining participants; those groups were considered regular new groups.

The course setting

The study took place during a one-semester distance-learning course on operating systems at the FernUniversität Hagen (Distance Teaching University), which is a 10 ECTS masterlevel course implying approximately a 300 h workload. Every two weeks, students receive a course unit including 50–60 pages of material for self-study. Secondly, they receive assignments which have to be submitted within two weeks, and which will be graded. Students who want to take a final oral exam are not required to obtain credits for these assignments.

We sent a message to the courses' newsgroup advertising the option of voluntarily participating in special collaborative assignments. Students could get 50% of the total points for all assignments of the course just by participating in the collaborative assignments. In addition, the message emphasized that these assignments would improve their argumentation and collaboration skills, which would be beneficial for taking an oral exam. These collaborative assignments will be examined in this study.

The collaborative learning environment

The learning environment used in this study is called CURE, a Web-based shared workspace system supporting collaborative work and collaborative learning (Haake et al. 2004a, b). CURE uses the room metaphor (Greenberg and Roseman 2003), and the metaphor of virtual keys to model shared workspaces. The core concepts of CURE are the following (Fig. 1):

Rooms represent shared workspaces used by a group of users. Rooms may form a hierarchy, that is, a room may contain sub-rooms, which may, in turn, be used to create workspaces for subgroups. Rooms offer various communication channels such as chat and threaded discussions.

Each room may contain *pages*. A page represents a shared artifact of some type. CURE supports two types of pages: Content pages are editable by end users through editing in a simple wiki syntax, whereas binary pages contain binary files which can be displayed or edited by external tools.

A group of users is associated with a room by using *virtual keys*. A virtual key belongs to a room and defines access permissions and interaction possibilities of its owner to this room. All owners of keys to a room are considered the room's user group. Different roles can be assigned to users by giving them keys with different interaction rights (Haake et al. 2004a, b).

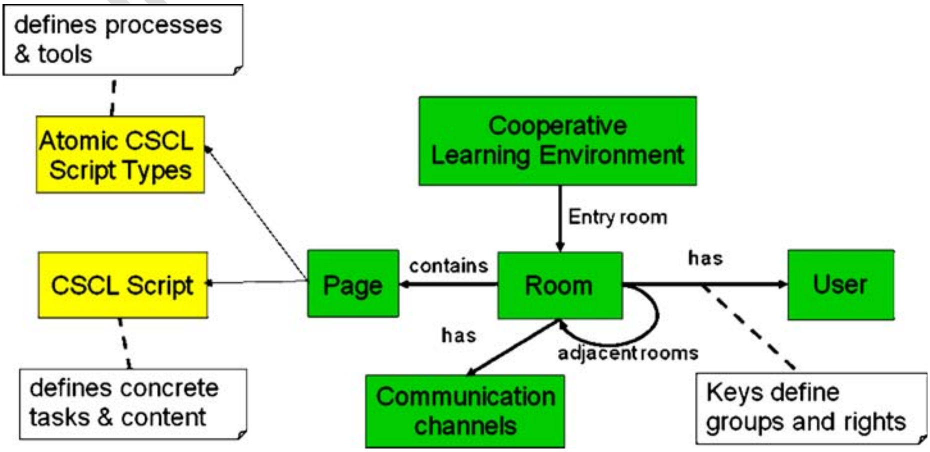

Fig. 1 The architecture of the collaborative environment CURE

Users access rooms in CURE through a Web browser. Figure 2 shows a typical room as displayed in a Web browser. The top row provides the room title and buttons for interaction with the room, such as opening a threaded discussion. The second section shows the currently visited page with its title, buttons for interaction (e.g., to edit the page), and the content of the page. The third section presents the navigation options. The last section shows the room's chat tool.

Implementation and procedure

Control condition In the non-scripted control condition, the instructions pertaining to the script were presented textually in a CURE page in the group's room. The three members of a learning group were allocated to a CURE room which contained for each assignment a sub-room presenting a page with the task description and textual instructions describing the composite script with its three tasks. Each assignment room contained pages on which the group had to submit their results from the brainstorming, clustering, and essay writing task, respectively. Finally, each room contained the multiple-choice test pages, which were accessible only for the respective group member. Students were basically free how to proceed in fulfilling the task; they could use the communication and collaboration features of their CURE room, and nothing could prevent them from deviating from the instructions.

Scripting condition To implement scripts, we extended the CURE system with two new types of pages: CSCL-Script pages define the particular task and content of a script, while atomic CSCL-Script-Type pages define the processes and the tools to be used.

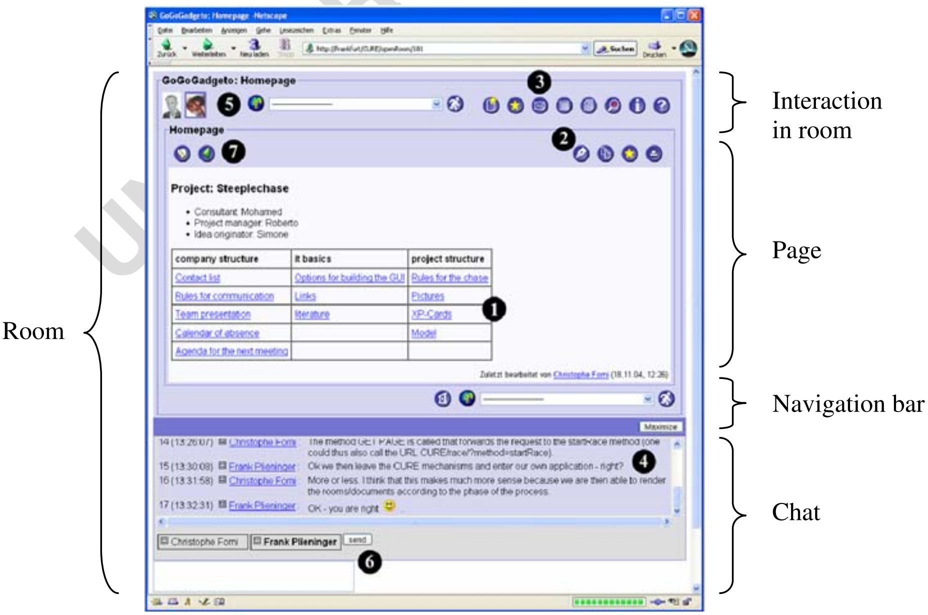

Fig. 2 The CURE room interface. (1 content of current page, 2 edit page button, 3 access room's threaded discussion, 4 room's chat, 5 presence awareness, 6 chat participants and box for sending chat messages, 7 access to version history of the page)

During script execution, each group member is assigned a role by the CURE server and sees the appropriate user interface of the currently active step. Only operations permitted in this state for this role are presented to the user (Fig. 3). More details on the specification and implementation of scripts in CURE can be found in Haake and Pfister (2007).

For each assignment, students submitted the results of each phase in their CURE room. Each result was represented as a single CURE page. Thus, we have three CURE pages (brainstorming results, clustering results, and essay text results) per assignment and per group. In addition, after each assignment, each group member worked individually on a multiple-choice knowledge test, represented as another CURE page. Students were informed that the test results were just for measuring the impact of the collaborative tasks as a learning device, and would not be used for grading.

Students entered the script by navigating to the room in CURE. Upon entering the room, each student saw a welcome page which presented a summary of the assignment and a button to start the script. CURE then commenced execution of the atomic script defining the first task. Each student was assigned a role, and the respective user interface was generated. The interface showed (1) which task of the overall script is currently active, (2) the list of students currently logged in, (3) the user-interface elements representing the information and actions available to that role in the current state, (4) a chat window keeping a log of the discussion, and (5) a button for switching to the next task. If one group member would finish a task, the script would switch to the next task. A chat could be used in parallel to work on the tasks to coordinate group activities.

In the *brainstorming script*, participants saw (1) a text input field for capturing a new idea, and (2) a display of all ideas generated so far by all group members. Thus, students could concurrently create as many ideas as they wanted, and, when running out of ideas, look at other's ideas and create new ideas based on what they saw. They could use the room's chat for discussion, or for when to switch to the next phase.

In the *clustering script*, students saw the list of concepts from the brainstorming task, and three predefined cluster titles with the list of currently associated concepts. Initially, the

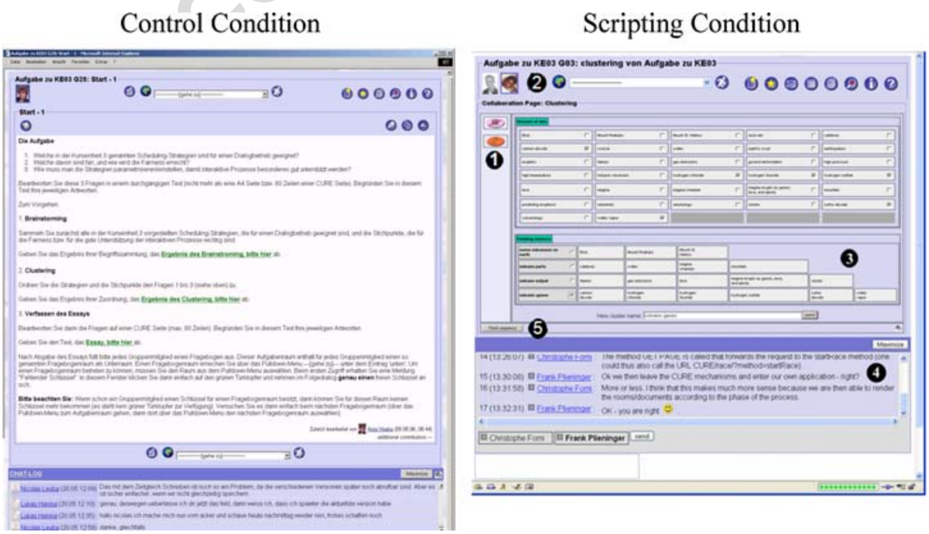

Fig. 3 Control condition and scripting condition interfaces in CURE

three clusters were empty. By selecting and deselecting concepts in the list, the student could assign and reassign concepts. Whenever selecting or deselecting a concept in the list, it was shown to all students of the group. Students were informed that one concept could be a member of several clusters. CURE ensured consistency by sequencing student's selecting and deselecting actions. Again, students could use the room's chat to discuss the task, and when to switch to the next phase.

In the *essay writing task*, students saw the results of the clustering task as initial input for the essay writing task. One student was assigned the role of "author." This student could write and create a first version of the text. The other students were assigned the role of "commenter." Upon completion of the author's initial text, indicated by the author pressing a "send to commenters" button, the commenters would receive copies of the text, which they could now change. Upon completion, the commented version would be sent to the author for revising the original version of the text. The tool would show the original version with changes by the commenters highlighted. By pressing the "next round of authoring" button, the author would submit the revised version of the first round of co-authoring, and the system would then switch roles, that is, the first commenter would become author, the second commenter would become first commenter, and the author would become second commenter. Only after executing three rounds, could the current author decide to either terminate the script or to continue with another round.

Students could always use CURE's awareness features such as presence awareness and the change reports to stay informed about each other's presence and activities. The script automatically sent email notifications to offline users whenever their role changed to prevent group members from waiting too long for activities to be performed by an absent group member.

Measurements

Brainstorming For each assignment topic, a normative reference list of correct concepts was created by three experts in the field (one professor and two postdoc researchers). The number of correct concepts listed in each submitted brainstorming result page was counted; synonyms and repetitions of a concept were discarded. This count of correct concepts served as a dependent variable measuring the group's joint performance in the brainstorming task.

Clustering For each assignment topic, three category labels were provided defining three topical clusters. For each concept, three experts determined the correct cluster allocation. For each clustering page, the number of correct allocations was counted. This count served as a dependent variable measuring the group's joint clustering performance.

Essay correctness In the essay writing task, students were supposed to write a one- page essay about the assignment's topic. As before, three experts generated a reference essay which was assumed to provide an optimal set of correct arguments. For each essay page, the number of correct arguments included was counted; this count served as a performance measure of the group concerning joint essay production.

Essay comprehensibility This measure addresses an essay's clarity and comprehensibility in terms of structure and formulation, irrespective of the number of correct arguments. Two raters evaluated the essay's comprehensibility on a five-point rating scale (from 1 = not comprehensible at all, to 5 = highly comprehensible). If raters disagreed, the essay was discussed until agreement was reached.

Essay coherence This measure addresses how well a potential reader can follow the essay's line of reasoning, that is, if arguments are well connected and whether arguments and claims have been backed by facts and warrants. Two raters evaluated coherence on a five-point rating scale (from 1 = not coherent at all, to 5 = highly coherent). If raters disagreed, the essay was discussed until agreement was reached.

Knowledge test For each assignment, a multiple-choice test of thirty questions covering the respective course unit was administered. The test was judged as face valid by three experts, and calibrated with students from the previous class who just passed the oral exam. The number of correct items served as a measure of the amount of knowledge acquired by each individual student. Note that the knowledge test score is an individual measure, whereas the previous variables are group-level attributes.

Results

First, we examine if there are differences in performance of the collaborative tasks (brainstorming, clustering, and essay writing) depending on whether or not these tasks are scripted. As outlined above, we expect improved performance under scripting compared to the control condition.

Secondly, we test if scripting per se improves learning outcomes as measured by the multiple-choice knowledge test following each assignment. We assume that a scripted version of brainstorming, clustering, and essay writing should lead to greater knowledge gains.

Third, we examine if learning outcomes can be predicted from performance on the three collaborative tasks, irrespective of their being scripted or not. Even if scripting does not make a difference, it is expected that the learning outcome is positively related to collaborative task performance.

Note that all scores pertaining to the collaborative tasks are group-level data, whereas learning outcomes are individual student data. Thus, analyses of collaborative task performance are based on groups as units of observation. For better comparison, all variables have been normalized to range from 0 (worst) to 100 (best) by dividing the actual score by the maximum score attainable in each task.

Collaborative task performance

For the *brainstorming* task, the number of correct concepts generated by a group was used as the dependent variable. A 2 (scripting condition) × 5 (assignment) analysis of variance, with repeated measurement on the assignment factor, yields a significant main effect of assignment ($F(4,147)=17.26$, $p<.001$, $\eta_p^2=0.32$). No other significant main effects or interactions are found. Assignments three and five yield less correct concepts during brainstorming (Table 2, Fig. 4a).

For the *clustering* task, the number of concepts correctly assigned to the predefined cluster super-categories was used as the dependent variable. A 2 (scripting condition) × 5 (assignment) analysis of variance with repeated measurement on the assignment factor yielded a significant main effect of assignment ($F(4,147)=18.10$, $p<.001$, $\eta_p^2=0.33$). As with the brainstorming task, no other significant main effects or interactions are found. As can be seen in Table 2 (Fig. 4a), tasks two and three are somewhat more difficult than the other tasks.

For the *essay* task, the number of correct statements included served as the dependent variable in a 2 (scripting condition) × 5 (assignment) analysis of variance with repeated

Table 2 Means of task performance across assignments scripting and control condition (scores are normalized to a range from 0 = worst to 100 = best)

Task	Assignment 1	2	3	4	5	*M*
Brainstorming						
scripting	40	38	31	42	31	36.4
control	43	44	28	47	31	38.6
Clustering						
scripting	36	26	20	38	33	30.6
control	38	28	22	37	40	33.0
Essay correctness						
scripting	53	66	57	44	60	56.0
control	55	56	54	46	62	54.6
Essay comprehensibilty						
scripting	96	87	81	91	98	90.6
control	91	78	81	86	100	87.2
Essay coherence						
scripting	96	79	79	87	81	84.4
control	94	71	70	83	88	81.2
Multiple-choice test						
scripting	63	79	71	78	72	72.6
control	66	83	73	76	76	74.8
M(scripting)	64.0	62.5	56.5	63.3	62.5	
M(control)	64.5	60.0	54.7	62.5	66.2	

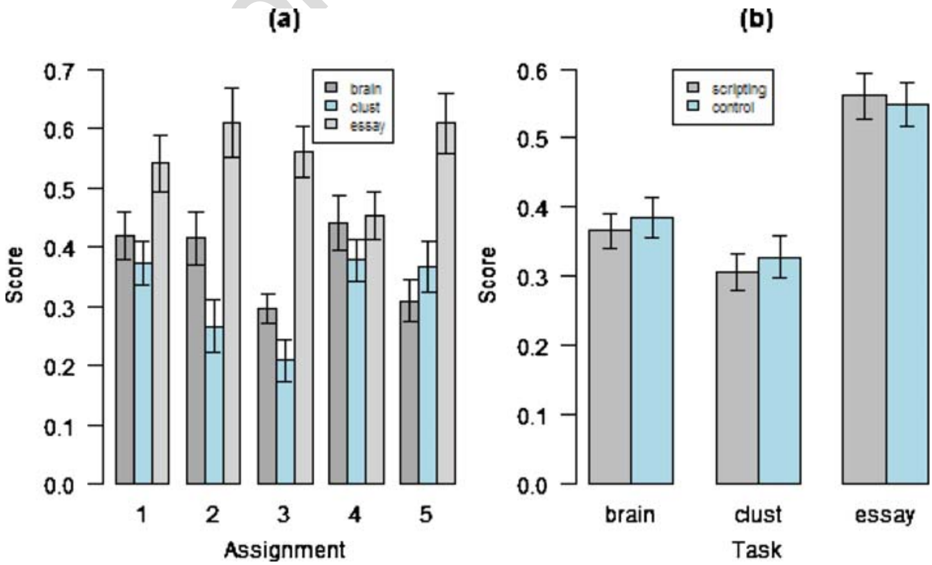

Fig. 4 Mean performance scores of collaborative tasks as a function of (**a**) assignment and task, and (**b**) of task and scripting condition (*error bars* indicate 95% confidence intervals)

measurement on the assignment factor. Again, only the main effect of assignment turned out to be significant ($F(4,147)=10.23$, $p<.001$, $\eta_p^2=0.22$). With respect to the essay task, assignments one and three seem to be somewhat more difficult than the other assignments (Table 2, Fig. 4a).

For the essay task, two further variables were generated by rating the essays according to comprehensibility and coherence. Essay *comprehensibility* was rated by two raters on a rating scale from one (not at all comprehensible) to five (fully comprehensible). The comprehensibility rating served as the dependent variable in a 2 (scripting condition) × 5 (assignment) analysis of variance with repeated measurement on the assignment factor. As before, the only significant effect turned out to be the assignment factor ($F(4,147)=11.96$, $p<.001$, $\eta_p^2=0.25$). As can be seen in Table 2 (Fig. 4a), assignments two and three led to slightly less comprehensible essays than do the other assignments.

Essay *coherence* was rated by two raters on a rating scale from one (not at all comprehensible) to five (fully comprehensible). The essay coherence rating served as the dependent variable in a 2 (scripting condition) × 5 (assignment) analysis of variance with repeated measurement on the assignment factor. Again, the only significant effect was the assignment factor ($F(4,147)=11.52$, $p<.001$, $\eta_p^2=0.24$). Table 2 and Fig. 4a show that assignments two and three led to somewhat less coherent essays than the other assignments.

A multivariate analysis of variance taking all five dependent task variables, analyzed separately above, as a joint multivariate vector, yields equivalent results with a significant main effect of assignment only, according to a likelihood-ratio test ($\chi^2(4)=11.52$, $p=.021$).

Because brainstorming, clustering, and essay correctness are comparable with respect to the kind of performance measured, that is, number of correct concepts or statements generated, we can compare performance across these collaborative tasks by considering the three tasks as a repeated measurement factor. A mixed-effects model analysis with learning group, assignment, and task included as random effects, with scripting condition as fixed effect, and the normalized scores on the three tasks as the dependent variable, yielded a significant main effect of collaborative task ($F(2,68)=209.56$, $p<.001$, $\eta_p^2=0.86$; see Fig. 4b), a main effect of assignment ($F(4,136)=6.74$, $p<.001$, $\eta_p^2=0.17$), and a significant interaction between task and assignment ($F(8,272)=27.04$, $p<.001$, $\eta_p^2=0.44$). Scripting condition did not yield a significant effect.

In sum, no difference could be detected between the scripting and the control condition with respect to performance on collaborative tasks. Guiding students through collaborative tasks such as brainstorming, clustering, and essay writing, supported by scripting tools implemented in the learning environment, does not improve performance on the collaborative tasks; note, however, that neither does it deteriorate performance, and overscripting turns out to be no issue here. Performance rather turns out to be highly contingent on the particular assignment to be worked on, with different collaborative tasks being differentially suitable for specific assignment topics.

The five measures of collaborative performance are correlated to some degree (Table 3). Hence, in addition to analyzing each measure separately, we tried to identify underlying components to capture the common mechanisms across the different tasks. A principal component analysis was conducted on the five performance variables. The first principal component accounts for 45.4% variance, and the second principal component for 22% variance; further components with eigenvalues less than one are ignored. As can be seen in Table 4, all five measures show loadings above 0.40 on the first component, indicating that it represents a general performance component. The second component, in contrast, yields a bipolar pattern of loadings, with brainstorming and clustering showing negative, and essay comprehensibility and coherence showing positive loadings. We

Table 3 Correlations among performance measures of collaborative tasks

Measure	1	2	3	4	5
1. Brainstorming	–				
2. Clustering	.57*	–			
3. Essay Correctness	.32*	.27*	–		
4. Essay Comprehensibility	.09	.38*	.29*	–	
5. Essay Coherence	.19*	.22*	.39*	.45*	–

* p<.01.

tentatively interpret this second component as indicating the extent of deeper understanding. Essay comprehensibility and coherence are likely to be related to a deeper qualitative understanding of the respective topic, whereas brainstorming and clustering may be related to a more superficial aspect of knowledge and memory of technical terms.

A 2 (scripting condition) × 5 (assignment) analysis of variance with the component scores of the first principal component (general performance) as the dependent variable, yields a significant main effect of assignment ($F(4,151)=14.98$, $p<.001$, $\eta_p^2=0.28$). More interestingly, taking the second principal component as the dependent variable, we find again a main effect of assignment ($F(4,151)=7.32$, $p<.001$, $\eta_p^2=0.16$), but additionally the scripting condition effect turns out to be significant ($F(1,37)=5.83$, $p=.021$, $\eta_p^2=0.14$). Students in the scripting condition score higher on the second principal component ($M=0.173$, $SD=0.908$) than students in the control condition ($M=-0.167$, $SD=1.150$). This finding suggests that scripting may have a beneficial effect concerning the construction of a more coherent and elaborate understanding of the subject matter. Note that this finding pertains to the group level, that is, to the joint product of a collaborative group effort.

Learning outcomes as a function of scripting condition

Learning outcome was measured individually via a 30-item multiple-choice test. We first test for the effect of scripting condition on test performance at the group level, that is, using the group average of the individual members' multiple-choice test scores as the dependent variable. A 2 (scripting condition) × 5 (assignment) analysis of variance with repeated measurements on the assignment factor yields a significant main effect of assignment ($F(4,143)=50.15$, $p<.001$, $\eta_p^2=0.57$), a marginally significant effect of scripting condition ($F(1,35)=3.16$, $p=.084$, $\eta_p^2=0.08$), as well as a marginally significant interaction ($F(4,143)=$

Table 4 Principle components of scripting performance

	PC1	PC2	PC3	PC4	PC5
Loadings:					
brainstorming	0.427	−0.616			0.582
clustering	0.490	−0.413	−0.410		−0.640
essay correctness	0.446		0.692	0.541	
essay comprehensibility	0.432	0.448	−0.553		0.451
essay coherence	0.438	0.479		−0.719	
% variance	45.4	22.0	15.2	10.9	6.5

2.24, p=.067, η_p^2=0.05). The marginal effects involving the scripting condition suggest, surprisingly, that in the control condition, average performance is somewhat better than in the scripting condition, though this may reverse under some assignments, as indicated by the interaction (Fig. 5).

Learning outcomes as a function of task performance

A multilevel analysis was performed with the individual multiple-choice test scores as the dependent variable. The learning groups (m=42) and the assignments (j=5) can be defined as completely crossed random factors, and subjects (n=120) as a random factor nested within groups. The variables measuring collaborative task performance, that is, brainstorming, clustering, essay correctness, essay comprehensibility, and essay coherence, constitute group-level predictors or level-2 attributes (Hox 2002). Employing a random intercept model, it turned out that scripting condition is not significantly related to learning outcome. However, essay correctness as well as essay coherence turned out to be significant predictors of individual test outcomes. Essay correctness was positively related with test score (b=0.081, p=.0296), indicating that individual learners tend to perform better on the test if the collaboratively generated essay includes a greater number of correct concepts. Essay coherence, however, was negatively related with test score (b=−0.096, p=.004), indicating that members of learning groups that collaboratively generate more coherent essays will score slightly lower on the multiple-choice test. One might speculate that the coherence of a joint product such as an essay written collaboratively is easier to achieve if collaborators are less knowledgeable, or, that in order to obtain joint coherence, collaborators have to neglect some of their individual surplus knowledge.

Assignment difficulty

Throughout, test performance as well as performance on the collaborative tasks was found to be highly contingent on the particular assignment (Figs. 4 and 5). A plausible cause

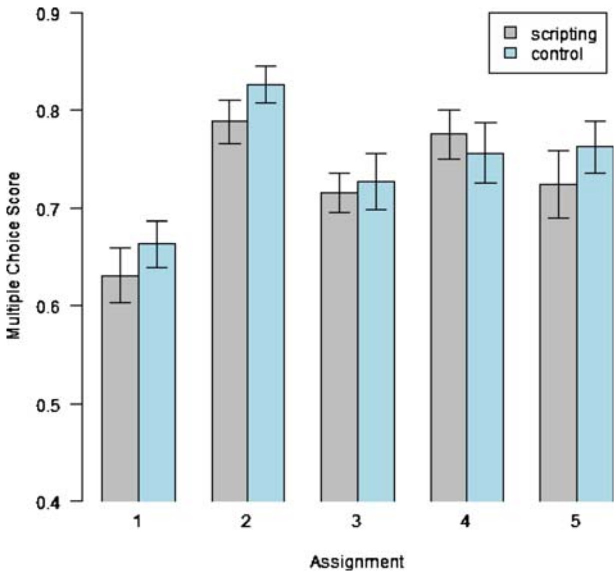

Fig. 5 Mean scores of multiple-choice-test as a function of assignment and scripting condition (*error bars* indicate 95% confidence intervals)

might be that assignments differed in complexity or difficulty. Thus, we asked six independent experts (professors of computer science) to rank the five assignments according to difficulty. Agreement among these experts turned out to be fairly low (Kendall's coefficient of concordance=0.306), as was the correlation with average test scores (Kendall's rank correlation=0.20). According to expert ratings, the most difficult assignment was assignment five, and the easiest assignment was assignment four. Yet, no consistent pattern emerges concerning the relationship between assignment difficulty and performance. The easiest assignment four is the only assignment showing higher test scores for the scripting condition. There is also a tendency that differences between experimental conditions are larger for those assignments rated as more difficult. However, considering the low agreement among raters, we refrain from further speculation about the role of assignment difficulty in scripted collaboration.

Discussion

Do students benefit from scripted collaboration in a real long-term university course? Generally, it turned out that students have no difficulty adapting to the rules and requirements of scripted collaborative tasks. There are virtually no dropouts during the semester, and students continuously worked together in their learning groups yielding practically no missing data on task variables and multiple-choice tests across all assignments. We conclude that, contrary to the often expressed concern of overscripting (Dillenbourg 2002), scripted collaboration, as operationalized in this study, does not impair collaborative learning in net-based groups.

However, we found no general difference between the scripted and the control condition concerning performance on the collaborative tasks. That is, students performed brainstorming, clustering, and essay writing tasks equally well in both conditions. A substantial difference was only found between assignments. Because the five assignments touched five fairly different content domains of the subject matter taught during the semester (that is, different aspects of operating systems), this effect might demonstrate possible differences in complexity or difficulty. However, based on expert difficulty ratings, no consistent pattern could be identified to clarify the cause of assignment variation. Note that because the temporal order of assignments is necessarily confounded with content, no conclusions can be made about a change in performance over time.

However, a principal component analysis of the five collaborative task scores (brainstorming, clustering, essay correctness, essay comprehensibility, and essay coherence) yields a somewhat more detailed picture. Two meaningful principal components were identified, a general performance component and a second component which we interpret as signifying deeper understanding, with high loadings on essay comprehensibility and coherence. Scores on this second component are significantly higher in the scripted condition compared with the control condition. This effect is not tremendously large, but suggests that scripting does foster students' understanding of the subject matter in a way that enables them to produce more comprehensible and more coherent summaries of the topic under consideration. Despite the fact that collaborative task performance is, for the most part, determined by the requirements and idiosyncrasies of the particular assignments, and, additionally, influenced by a general performance component, scripting shows a detectable difference concerning one particular aspect of collaborative performance, namely, to express one's understanding in a comprehensible and coherent way.

Looking at performance on the individual multiple-choice test scores, scripting did not show a substantial effect. At the aggregated group level, scripting yielded a marginal effect on average group performance. Surprisingly, group test scores are slightly higher in the control condition, suggesting that scripted collaboration might even be disadvantageous under some assignments.

Concerning the impact of collaborative task performance on multiple-choice test scores, a significant relationship was found with essay correctness and essay coherence. Members of groups whose collaboratively produced essay tended to include more correct concepts, also tended to display better individual performance on the multiple-choice test. Possibly, a transfer of knowledge from the joint essay to students' individual knowledge took place here. Surprisingly, essay coherence turned out to be negatively related with test scores, that is, members of groups whose essay was rated as more coherent display lower scores on the multiple-choice test. We can only speculate about this relationship, a conjecture being that more individual knowledge might possibly be hindering the group from producing a coherent joint artifact.

It should be emphasized that scripted collaboration of net-based groups in the context of a one-semester university course constitutes only one of many sources of the overall learning process. One may conclude that scripting, in contrast to non-scripted collaboration, tends to be slightly more beneficial for the more exacting task of essay writing, probably requiring a deeper understanding of relationships and conceptual meaning. Multiple-choice tests, on the other hand, primarily tap basic facts and definitions. Presumably, the effect of scripting might show up more clearly when more demanding types of tests are administered.

However, the most prominent finding is the general and strong effect of assignments. Due to the constraints of a real university course, it was not possible to systematically vary assignments with respect to characteristics such as difficulty, complexity, or previous knowledge of students about the assigned topics. Also, there is a basic confounding with time, because students most likely become more experienced and proficient in handling the collaborative tools as well as in collaborating per se. Future research needs to examine the particular characteristics of knowledge domains which are amenable to scripting support.

As a main shortcoming of this study, we used collaborative tasks as a means to promote learning, which then was assessed via multiple-choice tests. Knowledge measurement via multiple-choice tests has been rightly criticized for not being able to assess understanding beyond mere recall of superficial facts, let alone assessing deeper understanding, or the ability to transfer and apply newly learned knowledge (Carver 2006). The performance in the collaborative tasks, especially in essay writing, might, indeed, be a more suitable indicator of learning outcome. In the future, assessment methods should clearly focus on the intended goals of collaborative learning, which is primarily about conceptual understanding, and the ability to meaningfully apply knowledge in solving authentic problems. Methods such as peer assessment, supported by appropriate net-based tools, might turn out to become a more suitable approach (van Gennip et al. 2009; Yu et al. 2005).

It remains an open question what kind of scripting is appropriate in terms of granularity and in terms of coercion for extended courses. Hesse (2007) distinguishes two strategies to ascertain if collaboration is, in fact, beneficial for learning. One strategy referred to as the scripting approach assumes that the designer of a collaborative learning process knows the proper rules and guidelines, that is, the correct script; consequently, learners are forced to follow the script. The second strategy, referred to by Hesse (2007) as the awareness approach, rather tries to supply a rich collection of awareness features, informing learners about other participants' activities and knowledge, about task features, or about the collaboration history. However, it is up to the learners to make use of this offer of awareness features, and, thus, to self-regulate their learning process (Buder and Bodemer 2008). Kreijns et al. (2003) argue, however, that simply providing people with opportunities and devices to collaborate does not automatically trigger interactions that will ultimately lead to better learning (see also Pfister 2005).

The two conditions examined in this study can be paralleled to these two strategies. In the control condition, students were simply instructed and asked to proceed according to the collaborative task. In the scripting condition, particular tools enforced to a large degree that students actually comply with the rules defined by the script. Our findings suggest that the danger of too much enforcement, that is, of overscripting, might be less severe than assumed. Students do not generally perform worse in the control condition.

In this study, the selection of collaborative tasks as well as the particular implementation of tools to support and structure the tasks has been somewhat arbitrary, largely guided by pragmatic considerations and constraints of the ongoing course. Strijbos et al. (2004) have pointed out that one of the major problems of current research in the field of computer-supported collaborative learning is the lack of design principles for CSCL settings. This issue is especially acute in applied settings, when a multitude of needs and constraints has to be taken into account. A flexible environment (Dillenbourg and Tchounikine 2007; Haake and Pfister 2007) which can be adapted during the learning process, depending on aspects such as assignment difficulty, or learning progress, might be a next step toward increasing the probability of successful net-based collaborative learning.

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. Hox 2002 was cited here in the body but not present in reference list. Please check.

Q2. Reference Fischer et al. 2007 was changed to Fischer et al. 2007a, b, as well as in body citation. Please check.

Q3. Reference Haake et al. 2004 was changed to Haake et al. 2004a, b as well as in body citation. Please check.

Q4. Reference Oehl and Pfister in press was changed to Oehl and Pfister 2010 as well as in body citation. Please check if appropriate.