Computer-Supported Collaborative Learning (2007) 2:225–246
DOI 10.1007/s11412-007-9016-2

Scripting by assigning roles: Does it improve knowledge construction in asynchronous discussion groups?

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Received: 9 June 2006 / Accepted: 10 July 2007 /
Published online: 11 September 2007

Abstract This article describes the impact of learning in asynchronous discussion groups on students' levels of knowledge construction. A design-based approach enabled the comparison of two successive cohorts of students (N=223 and N=286) participating in discussion groups for one semester. Multilevel analyses were applied to uncover the influence of student, group, and task variables on the one hand, and the specific impact of a particular form of scripting – namely the assignment of roles to group members – on the other. Results indicate that a large part of the overall variability in students' level of knowledge construction can be attributed to the discussion assignment. More intensive and active individual participation in the discussion groups and adopting a positive attitude towards the learning environment also positively relates to a higher level of student knowledge construction. Task characteristics – differences between the consecutive discussion themes – appeared to significantly affect levels of knowledge construction, although further analysis revealed that these differences largely disappeared after correcting for task complexity. Finally, comparisons between both cohorts revealed that the introduction of student roles led to significantly higher levels of knowledge construction. An effect size of 0.5 was detected.

Keywords Asynchronous discussion groups · Computer-supported collaborative learning · Higher education · Online learning · Scripting

Introduction

Although it has been argued that computer-supported collaborative learning (CSCL) environments foster collaborative knowledge construction (Clark et al. 2003), the major question now is: Under what circumstances, in what particular learning environments, with

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what type of students, and in view of what kind of learning tasks does CSCL have a positive impact (Jacobson 2001)? In this article, we focus particularly on variables that can be manipulated to influence student interactions in a direct way. More specifically, we script student discourse in asynchronous discussion groups. This aim corresponds to the suggestion of Dillenbourg (2002), who claims that the application of scripts for collaborative learning can be a technique to affect collaborative learning directly. Collaboration scripts can specify, sequence, and assign collaborative learning activities in online learning environments (Kollar et al. 2003). More specifically, a script can be defined as a detailed and more explicit didactic contract between the teacher and the group of students regarding their mode of collaboration (Brousseau 1998; Dillenbourg and Jermann 2003). In CSCL environments, collaboration scripts are considered as powerful means to improve processes and outcomes of collaborative learning (Kollar et al. 2003). The concept of a "script," however, encompasses a very broad range of methods, techniques, and approaches depending on the communication mode (synchronous versus asynchronous) that is used and the time span (from 1 h to a complete semester) they fill (Dillenbourg 2002). Collaboration scripts can vary in the degrees of freedom they give learners to structure the collaboration (Kollar et al. 2006) and different group sizes are used. Also, the objectives of using structuring tools can be quite different. Therefore, although research already exists with regard to the use of structuring tools in computer-mediated environments, these studies are hardly sufficient to cover the whole range of possibilities. In this respect it is difficult to talk about the overall efficacy of CSCL scripts.

In this article, we analyze the impact of a specific type of collaboration script – namely, assigning and rotating roles among group members – on the process of social negotiation in asynchronous discussion groups. Roles are seen as important factors in determining the quality of knowledge construction in a community (Aviv et al. 2003). They compel students to focus on their responsibilities in the discussion group and on the content of their contributions. Moreover, as roles increase student awareness of collaboration, affect the perceived level of group efficiency, and elicit more task content statements (Strijbos et al. 2004), we might expect students to collaborate better, resulting in higher levels of knowledge construction. Although a number of studies have already concentrated on introducing roles in online discussion groups, these studies aimed at examining the effect of roles on, for example, student participation rates, their interaction patterns, or the group efficiency (Hara et al. 2000; Strijbos et al. 2004; Zhu 1996). The value of the present study is that roles are introduced with the specific aim of enhancing knowledge construction through social negotiation. Studies that concentrated on the impact of knowledge construction (e.g. Weinberger 2003; Kollar et al. 2006) did not research the impact of the introduction of roles (in this case seen as very general scripts or *macro scripts*) on the *knowledge construction through social negotiation* in *long asynchronous* discussions. In this respect, our study meets the need for empirical studies regarding the facilitation of groups who learn together online for a long period. As was stated by Weinberger (2003), further studies such as this are needed to examine the effects of scripts for long-term collaboration.

In addition, research on collaboration scripts for face-to-face and for computer-mediated learning has largely neglected the importance of the individual and his or her characteristics. As previous research had indicated, one critical learning characteristic is students' domain-specific prior knowledge (Dochy et al. 1999). Research needs to examine what specific other collaboration characteristics individuals bring to a collaborative learning situation. In our study, multi-level analyses were used to study the impact of both individual and group characteristics and processes.

Theoretical background

With regard to the study of learning processes in CSCL environments, three general intertwined key elements can be distinguished in the literature: the individual learning processes of students engaged in CSCL, the task put forward in the online learning environment, and the collaborative or group dimension in the CSCL setting.

Concerning students' *individual learning processes*, the basic assumption is that 'learning' can be seen as an information processing activity. This is in line with cognitivist principles and presumes that learners actively engage in cognitive processing in order to construct mental models. In this way, new information is integrated into existing cognitive structures. Because of the importance of individual student experiences and their existing cognitive structures, students' individual features are considered to be of importance in CSCL research. In addition to the impact of individual student features, students' processing activities are also triggered by the *task* put forward in the online learning environment. In this respect, a second substructure in CSCL research points to the impact of the assignment put forward and discussed in the CSCL setting. The assignments in the discussion groups are assumed to prompt the cognitive processes of the students. In CSCL, the task is put forward in a collaborative environment. Therefore, the third substructure in CSCL research refers to the importance of the *group*. Working in a collaborative environment invokes collaborative learning, which requires the learner to organize his or her output so that it becomes relevant input for the other learners. The collaborative exchange at the input and output level is considered to produce a richer base for further cognitive processing at the individual level. The asynchronous nature of the discussion environment forces the learner to communicate the output in an explicit way. Student output mirrors the cognitive processing activities, allowing learners in a collaborative setting to profit from the processing effort of other group members. As the output of other learners is organized, students are expected to experience lower levels of cognitive load when using this output as input for their own individual cognitive processing. Their subsequent output is expected to be of better quality, thus reflecting a higher level of knowledge construction.

Research indicates that the efficacy of collaborative learning depends on the complex interaction between these three components: the individual students, the group they are participating in, and the assignment they are collaborating on. In order to understand the entire story, studies on CSCL need to consider variables at these different levels (Kollar et al. 2006). Therefore, the present study takes into account features of individual students, as well as group and task characteristics. Regarding the *individual learners*, the present study focuses on the following student characteristics: attitude towards the CSCL learning environment (Muirhead 2000; Lockhorst 2004), gender (Hakkarainen and Palonen 2003), and learning styles (Simons 2000). Moreover, as it can be hypothesized that the more students express their line of thought, the more the construction of mental models is facilitated, student engagement in the discussion (i.e., the amount of individual contribution) is also regarded as relevant (Schellens et al. 2005). In relation to *group characteristics*, this study concentrates on the intensity of the group interaction (i.e., the total number of contributions in the discussion group) in the CSCL environment (Dillenbourg et al. 1995; Schellens et al. 2005). Finally, with regard to *task characteristics*, the complexity of the assignment (Carey and Kacmar 1997) and the amount of imposed structure in the discussion (Dillenbourg 2002; Weinberger et al. 2005a) are considered to influence the nature of the cognitive activities, resulting in varying levels of knowledge construction. The latter feature – the amount of imposed structure on the discussion – is the central element in the present study. More specifically, we focus on the impact of scripting by assigning roles to students.

The focus on scripting stems from the finding that there is no straight line between collaboration, as such, and learning (Dillenbourg 2002). According to the theoretical framework, learners construct knowledge by active participation in discussing and sharing knowledge with their peers when working in small groups on a specific assignment. Unfortunately, numerous studies indicate that the desired effects often fail to emerge. For instance, research indicates that not all group members are actively engaged in the discussions (e.g., Ellis 2001; Hara et al. 2000; Graham et al. 1999; Salomon and Globerson 1989) or that the content of the group discussions remains superficial (e.g., Coleman 1995; Schellens and Valcke 2005; Vonderwell 2003). These deficits can result from features of the individual students or of the group they belong to, but can also be due to the unique character of the task. Whatever the reason might be, it is a fact that communication in the interactive construction of knowledge is not straightforward and uncomplicated (Ewing and Miller 2002). Scripting is considered to hold the possibility of enhancing the communication processes in CSCL environments and can be regarded as a compromise between the freedom of collaborative learning and the constraints usually induced by instructional design (Dillenbourg and Jermann 2007). Scripting is situated at the convergence of the instructional engineering approach, which dominated learning technologies for two decades, and the socio-constructivist stream (Dillenbourg and Jermann 2007).

Scripts can be considered as instruction strategies to enhance cognitive processing. A distinction can be made between content-oriented and communication-oriented scripts. The *content-oriented scripts* are about provoking or stimulating specific cognitive activities and can be regarded as 'direct scripts,' which means that they have an immediate effect on the ongoing cognitive processes. Within these scripts, two levels can be discerned. On the first level, help with the construction of declarative and procedural knowledge is noted. On the second level, content-oriented scripts induce metacognitive activities. The *communication-oriented scripts* aspire to stimulate the collaboration processes. They aim at fulfilling the necessary conditions for effective collaborative learning within a virtual learning environment. Within these communication-oriented scripts, two cornerstones can be distinguished. On the one hand, these scripts facilitate and stimulate interaction between the participants, which is believed to influence the cognitive processes indirectly. On the other hand, even within these communication-oriented scripts a content dimension related to the specific assignment is needed.

By giving a script to students, internal cognitive processes inside the student are evoked. The expected effect on the internal cognitive processes depends on the kind of (external) scripts given. The processes evoked by assigning roles and the way these processes are triggered go back to the problem-solving tradition and metacognitive theories.

Flavell (1985, p. 104) describes metacognition as follows: "It has usually been broadly and rather loosely defined as knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise." It is called metacognition because its core meaning is 'cognition about cognition.' Metacognitive skills are believed to play an important role in many types of cognitive activities, including problem solving and various forms of self-instruction and self-control in face-to-face interaction, but also in CSCL environments (Baker and Lund 1997; Chalmers and Nason 2003; Hurme and Järvelä 2001; Inaba 2006). In the literature on problem solving, the work of Wallas (1921) – who designed an early model for the resolution of problems – is important with regard to scripting. The model contained four steps: preparation, incubation, illumination, and verification. Inspired by this model, Polya (1957) developed a model that can be called an heuristic. An heuristic is a general approach to solve problems based on a number of defined principles or rules and which automatically leads to a solution. Bransford and Stein (1984) added a new first step to this model and talked about the IDEAL heuristic, which includes the following steps: Identify the problem, Define and represent the problem, Explore possible strategies, Act on the strategies, and Look back and evaluate the effects of your activities. More recently, the work of Garrison (1992) inspired this research with regard to scripting online learning. Garrison (1992) identified five stages in the problem solving process. According to his theory, 'problem solvers' move through the following stages: identifying a problem, defining it more clearly, exploring the problem and possible solutions, evaluating their applicability, and integrating this understanding with existing knowledge.

The roles in the present study can be seen as a way to stimulate metacognition and problem solving behavior. They compel students to focus on their responsibilities in the discussion group, on the content and the nature of their contributions, and on how these will add to the ongoing discussion in order to find an answer to the authentic problem presented in the assignment.

Research setting

Blended learning environment

The research was conducted in a naturalistic, real-world setting. The asynchronous discussion groups of approximately 10 students per group were a formal component of a 7-credit first year university course Instructional Sciences, which is part of the academic bachelor's curriculum Pedagogical Sciences at Ghent University. This course introduces students to a large variety of complex theories and conceptual frameworks related to learning and instruction. The discussion groups were organized parallel to the weekly face-to-face sessions in order to promote students' incorporation of the learning content. After a trial session of 3 weeks, students participated in four successive discussion themes of 3 weeks each. Each year, the discussion sessions started in October and ended in January, which means that, for both cohorts, the discussion lasted for one semester.

Discussion themes and tasks

Students worked together in the discussion groups by applying the theoretical concepts of the course to solve problems, which were presented in the online environment. These problems were, in line with constructivist principles, based on real-life authentic situations. For a more detailed description of the kind of discussion assignments, see the research of Schellens et al. (2005).

Task complexity was determined and controlled for, as it was a key variable in the research design for each task in the discussion groups. More specifically, three independent coders were asked to rate the complexity of the assignments on the following evaluative dimensions: the extent of the assignment, the presence or absence of necessary or additional information, the availability of the conceptual base, and the language of the given information. The degree of complexity of the tasks showed a strong upward trend. In the initial discussion tasks, students only had to deal with a limited number of questions. Moreover, the assignments were supported with all the necessary information (clustered on the same web page), documented with the conceptual base, and a solution procedure was suggested in the learning environment. The third and fourth task were more comprehensive (information on different websites) and complex, the conceptual base was not completely available or clear, additional information had to be looked up using different sources, and the solution procedure was not made completely available. A lot of information was given in English (a foreign language for these students) and supplementary questions had to be answered.

Two cohorts of students in design-based research

In addition to the real-world setting, the research was conducted in two consecutive steps: the design of the course and its redesign. These successive research stages fit in with the concept of design-based research. Design-based research is useful to produce theories on learning and teaching; the methodology is interventionist, it takes place in naturalistic contexts, and it is iterative (Cobb et al. 2003). Design-based research expects that researchers systematically adjust various aspects of the environment so that each adjustment can serve as a type of experimentation that allows the researchers to test and generate theory in naturalistic contexts (Brown 1992). This approach of progressive refinement in design involves putting a first version of a design into the world to see how it works. Then the design is revised based on experience until the bugs are worked out (Collins et al. 2004). With regard to the present study, the choice of this type of research made it possible to test and refine the educational design of the asynchronous discussion groups during two consecutive academic years. More specifically, the initial design of the asynchronous discussion groups was readjusted for a second cohort of students based on the results of the first research year (Schellens et al. 2005). In comparison with the first cohort, the objectives of the online discussions (i.e., acquiring insight in and applying the theoretical concepts discussed in the face-to-face lectures); the content, authentic nature, complexity, and duration of the discussion assignments; the group composition; the learning materials; and the provided support were better maintained. The main feature of the redesign was the scripting of the asynchronous discussions by assigning roles to students in order to refine the practice of online discussions on the one hand, and to address theoretical questions and issues with regard to the application of scripts on the other. In this respect, the present study meets the twofold goal of design-based research; namely, improving practice and producing theory (Collins et al. 2004).

Scripting by role assignment

The two cohorts of students correspond to two research conditions. In the first cohort or condition (year 1), the interaction between the students was not scripted. In the second cohort or condition (year 2), the group interaction was scripted by assigning roles. Except for the scripting approach, the learning environment was primarily the same for both successive cohorts. The course was taught by the same instructor and the same course reader and learning material was used. In both cohorts, the same tutor followed the ongoing discussions but did not give concrete content feedback. The nature of the discussion assignments was also the same for all discussion groups in the research, regardless of the cohort; the same learning goal, context, inquiry expectations, time requirements, and deliverables were put forward.

As to the role assignment, four different roles were distinguished: "moderator," "theoretician," "summariser," and "source searcher." The "moderator" was asked to monitor the discussions closely, to interject praise, offer advice, answer questions, and pose critical questions. This student stimulated active group participation. The "theoretician" had to ensure that all appropriate theories were considered when tackling the task and had to indicate which aspects, relevant theoretical knowledge, or information was lacking. The "summarizer" summarized the contributions and initial solutions of the students. This student had to indicate the different points of view and had to make provisional conclusions. Moreover, summarizers should post a final summary and conclusion at the end of the discussion. The 'source searcher' looked for additional sources and further information in order to stimulate students to go beyond the scope of the course reader. The selection of the four roles is based on examples in the literature, where facilitators, resource persons, summarizers, starters, wrappers, discussion moderators, topic leaders, and topic reviewers are distinguished (Cohen 1994; Hara et al. 2000; Shotsberger 1997; Tagg 1994). Further, the particular selection and interpretation of the roles builds on the specific aim of the asynchronous discussion groups, that is to foster dynamic and structured debate with respect to the authentic assignments or problems on the basis of the course manual and relevant external sources in order to get a grip on the different theoretical concepts introduced in the course. Therefore, the roles were particularly chosen in order to support both communicative as well as cognitive processes. As was argued by Kollar et al. (2006), collaboration scripts for computer-mediated learning typically focus on facilitating communicative and coordinative processes. By focusing on communication and coordination, the primary targets of the script instructions are the interactions between the group members rather than their cognitive processes. Collaboration scripts however can be developed to facilitate both communication and coordination as well as individual knowledge construction. In that way collaboration scripts may be able to support both individual and group processes simultaneously (Kollar et al. 2006).

The roles were randomly assigned to 4 students in each group. At the start of every new discussion, the roles were assigned to 4 other students within the same group. This is in line with the collaboration script proposed and tested by O'Donnell and Dansereau (1992). A typology functionality was included in the discussion environment. The typology and the different types, in this case the different roles, were defined and added to the forum. If students with a role wanted to post a message to the forum, they first had to pick a type of the typology concerned, in this case this means choosing between summarizer, source searcher, moderator, and theoretician from a drop-down menu. When their message was contributed to the forum, the role this student performed appeared next to their message (Fig. 1).

Taking into account the specification framework for computer-supported collaboration scripts (Kobbe et al. 2007), it can be concluded that in the script cohort, role assignment is applied as a task distribution mechanism, while traversion and rotation are used as sequencing mechanisms. Students traverse four successive discussion themes, while roles are rotated among group members with every new theme. As to the group formation mechanism, asynchronous discussion groups of approximately 10 students were chosen.

Participants

Two cohorts of students (N=223 and N=286) participated in the discussion groups during two consecutive academic years. The learning environment was primarily the same for both successive cohorts except for the scripting. The course was taught by the same instructor and the same course reader and learning material was used. In both cohorts, the same tutor followed the ongoing discussions but did not give concrete content feedback. Both cohorts consisted of freshman students enrolled for the course Instructional Sciences. For the first

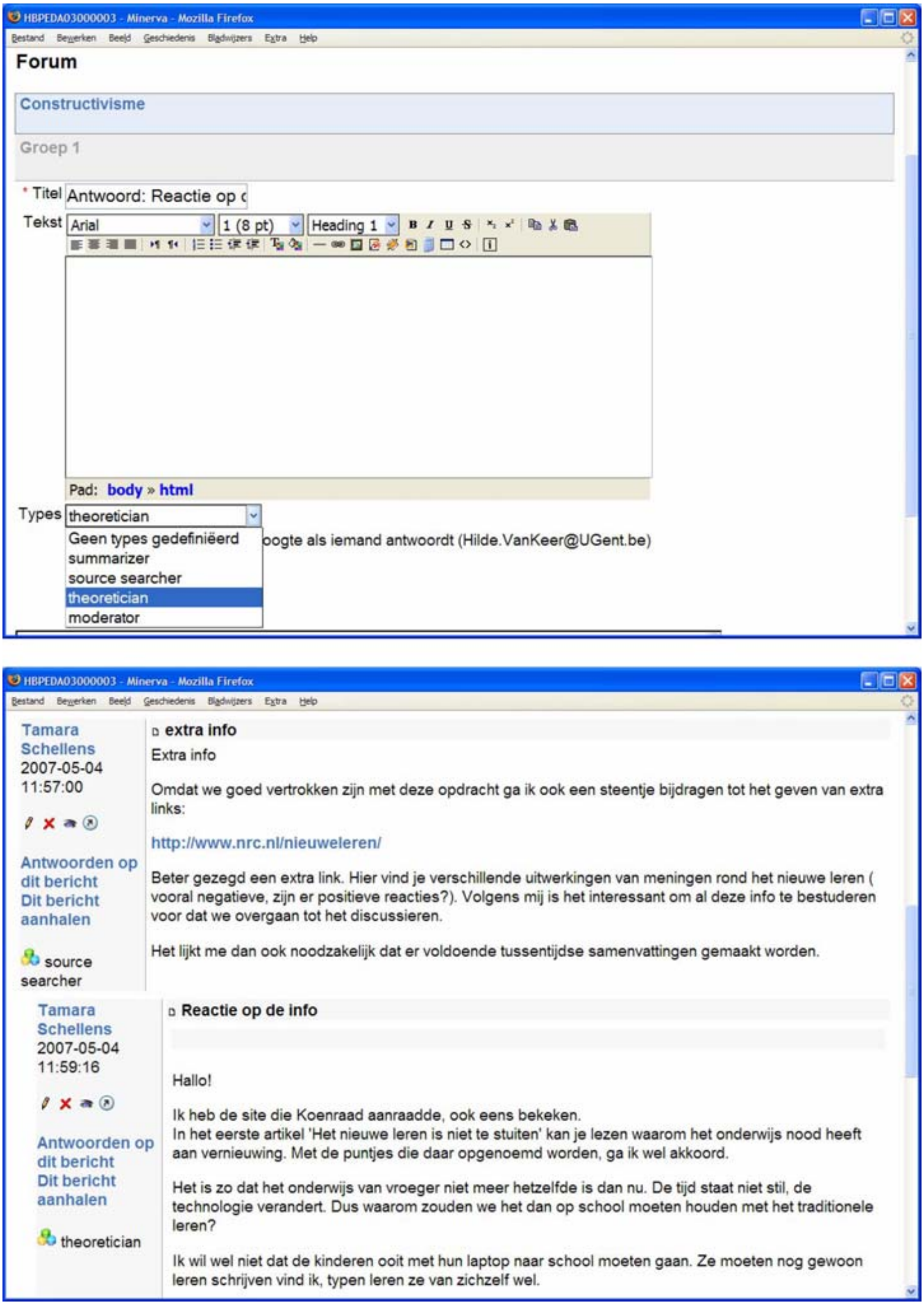

Fig. 1 Screenshot of the forum

cohort, the largest portion of the students (88%) just finished secondary education; 12% already possessed a diploma from higher education. With regard to the second cohort, 83% of the students just finished secondary education, while 17% already had preliminary training. Only the students who just finished secondary education participated in our research. Students did not differ in their prior educational level, nor did they differ in regard to their attitudes and experiences towards working with computers. In both cohorts, male students were the minority (approximately 10%). Therefore, the research samples were not considered to differ in any way.

Research questions and hypotheses

In the context of the present study, we agree with the statement of Dennen and Paulus (2005) that assessing process-based outcomes can be just as important as assessing product-based ones. In the case of online discussions, it becomes necessary to find out what is actually occurring when students talk together. In this respect, the focus of the assessment can not only be on the quantity or the quality of the messages, but also on the evidence of learning through a process of constructing new knowledge (Dennen and Paulus 2005). Therefore, both student exam scores and the achieved level of knowledge construction in the discussions were studied.

The following research questions were formulated:

– What is the impact on student levels of knowledge construction and final exam scores of scripting the interaction in asynchronous discussion groups by assigning roles?
– What is the differential impact on student levels of knowledge construction and final exam scores of being assigned a specific role?

Based on our theoretical framework, it can be hypothesized that students who are part of the script cohort will reach higher levels of knowledge construction and achieve a higher score for their final test. In addition, a differential impact of the different roles can be expected.

Content analysis

The fact that CSCL necessarily makes the learning visible provides the methodological basis for empirical research. Researchers of collaborative learning are not restricted to indirect evidence of learning (such as pre-test and post-test differences) because they can analyze and interpret the making of meaning as it unfolds in the data at the group level and in individual trajectories of utterances (Stahl 2003). The asynchronous nature of the discussion environment forces the learner to communicate the output in an explicit way. All the written communication in the CSCL environment is therefore considered relevant. More specifically, the students' output mirrors their cognitive processing.

In this study, we build on the work of Gunawardena et al. (1997) to analyze the transcripts of the written communication and to identify students' levels of knowledge construction as reflected in their contributions to the discussion. A typology is proposed to evaluate knowledge construction through social negotiation. More specifically, 5 different phases are distinguished in the negotiation process during learning. Every phase corresponds to a level of knowledge construction, and in the long run every one should reach the highest phases.

- Level 1. Sharing/comparing information: In this phase, typical cognitive processes reflect observation, corroboration, clarification, and definition.
- Level 2. Identifying dissonance/inconsistency: In this phase, cognitive processes focus on identifying and stating, asking and clarifying, restating and supporting information.
- Level 3. Negotiating what is to be agreed (and where conflicts exist)/co-construction: These type of messages are about proposing new co-constructions that encompass the negotiated resolution of the differences.
- Level 4. Testing tentative constructions: The newly constructed structures are tested, and matched to personal understanding and other resources (such as literature).
- Level 5. Statement/application of newly-constructed knowledge: This is related to final revisions and sharing the new ideas that have been constructed by the group.

Rourke and Anderson (2004) and Rourke et al. (2001) describe the difficulty of inferring the presence of an underlying construct, such as knowledge construction, from what is observable in computer conferencing transcripts. Therefore, providing a more comprehensive picture of the context of the discourse is also a key to generating lines of research that will result in useful prescriptive knowledge, such as instructional design theory. Using additional data collection methods beyond just collecting archives of a class discussion can help provide this contextual information. In particular, surveys or interviews can help triangulate discussion-based findings. Student surveys can be used to see how attitudes affect one's participation and perception of whether or not learning resulted from a particular activity (Dennen and Paulus 2005).

To meet this demand, a survey was administered at the beginning and at the end of the course. This survey helped to gather data about student characteristics, such as age, gender, and prior training or experiences in higher education. In addition, a special section was added to measure students' attitude towards the CSCL learning environment. This attitude questionnaire was a self-developed instrument and confronts students with the major characteristics of the online environment by asking them to rate their appreciation of the different features of the discussion groups on a four-point Likert scale. The internal consistency of this instrument was satisfying (Cronbach's α=0.72). Furthermore, the approaches and study skills inventory for students (ASSIST) (Entwistle et al. 2000) was used to gather information about students' learning styles. This inventory more specifically distinguishes a *deep*, *strategic*, and *surface apathetic* approach to studying. In the present study, a short version of the ASSIST (18 items) was used. This short version correlates highly with the full version and can therefore be considered as equivalent. Respondents are asked to indicate on a five-point Likert scale to what extent they disagree or agree with the statements. Each of the three approaches to studying is measured by six test items. Cronbach's alphas for the short version are 0.76 for the deep approach, 0.78 for the strategic approach, and 0.72 for the surface approach. The internal consistency was also tested in the context of the present study. Cronbach's alpha coefficients were 0.76 for the deep approach, 0.78 for the strategic approach, and 0.70 for the surface approach.

Unit of analysis and coding of the messages

The identification of a unit of analysis in content analysis has to be reliable, and must exhaustively and exclusively encompass the sought-after construct (Rourke et al. 2001). In the present study, the complete message was chosen as the unit of analysis. This choice presents some advantages: first of all, it is objectively identifiable, which means that multiple coders can agree consistently on the total number of units; secondly, it produces a manageable, controllable set of cases. (In the case of the present study, we recorded a total of 1,428 units of analysis for the non-script cohort and 1,933 units of analysis for the script cohort.) The third advantage is the fact that we are dealing with a unit that has parameters determined by the author of the message.

Each unit of analysis was coded according to the scheme of Gunawardena et al. (1997) by three independent research assistants. We tried to establish inter-rater reliability using the following method: The researchers received training in the use of the package and had plenty of time to exercise with the tool. Training was provided to all coders and included: (a) full explanations of the conceptual framework and coding process; (b) copies of coding rules and guidelines; (c) examples and non-examples; (d) practice with sample data. Group discussion helped researchers get acquainted with the particularities of the coding scheme and to reach mutual agreement about the coding category to be selected. Quality control of the coding implied the calculation of the inter-rater reliability. A common method to determine inter-rater reliability is to calculate the percent agreement statistic (Holsti 1969). Quite high percent agreement measures were found. In order to steer clear of mistakes, we included an extra stage in the coding process in which we asked the coders to code the first 5 discussions individually, and afterwards discuss the results with the other two coders. In that way, the quality of the coding could even be improved. We did this for both cohorts. The remaining discussions were done separately and inter-rater reliability was calculated for the second time after they finished all codings. Initial values for the non-script cohort were 0.81, and after negotiation between the coders a percent agreement of 0.87 was found. For the second cohort, the initial value was 0.85 and the after-negotiation percent agreement was 0.91. To determine whether or not it was always the same research assistant who changed her code, percent agreement was also calculated for each individual research assistant. This represents the agreement between a coder's first and second code attribution to a unit of analysis. Intra-rater reliability was larger than 0.70.

Data analysis

In the present study, we considered the methodological problems that have often shown up in this kind of research: a heavy reliance on on-time observation of groups and the tension between individual-level versus group-level analyses (Flanagin et al. 2004).

So far, over-time group research has been scarce (Scott 1999) although its importance has been repeatedly stressed (e.g., Cragan and Wright 1990; Frey 1994; Poole et al. 1999). Application of over-time analysis, as well as development of process theories, provide the potential to expand inference beyond simple correlation techniques and to examine the effects of time lags on causal influences among variables (Monge 1990). Interaction in the discussion groups can change and evolve over time. Therefore, conducting observations over a relatively long period is necessary if we want to pinpoint the reasons for the change and capture the development in group processes (Flanagin et al. 2004). In this respect, in the present study, students' traversion through four discussion themes was studied.

As to the tension between individual-level versus group-level analyses, the critical position of appropriate statistical analysis techniques has only recently been raised in CSCL research. Despite the existing strengths of individual- and group-level analyses, group-level analysis ignores how individual characteristics interact to affect group-level constructs, whereas individual-level analysis violates the statistical assumptions of independence of residual error terms when individuals are nested in groups (Poole et al. 1999). Moreover, focusing on only one level at a time is problematic as potential cross-level interactions influencing the outcome variable (Hox and Kreft 1994) are ignored.

In the present study, the students are divided in a number of groups and the individual observations can not be seen as completely independent because of what individuals share in the group setting (Hox 1994; Stevens 1996). In this respect, Hox and Maas (2002, p. 2) claim that "even if the analysis includes only variables at the lowest level, standard multivariate models are not appropriate. The hierarchical structure of the data creates problems, because the standard assumption of independent and identically distributed observations is generally not valid". Due to the violation of the assumption of independence, conventional modelling can result in underestimation of standard errors and thus in incorrect conclusions about statistical significance (De Wever et al. 2007). Taking into account the hierarchical data structure of the present study in which individuals are nested in groups, and because of the joint modelling of variables at different levels, we took a multilevel modelling perspective on analyzing the data. This modelling approach enables us to discern variations at both the group and the individual levels, as well as the relationship between them. More specifically, the software MlwiN (Rasbash et al. 1999) for multilevel analysis was used to analyze the data. More specifically, the iterative generalized least squares estimation procedure was applied.

As multilevel models are very useful for over-time analysis, a three-level model was built to study students' levels of knowledge construction in the successive discussion themes, treating the repeated observations of individuals as the first level since the multiple observations of an individual are nested within the person. Level 2 focuses on individual-level variables (e.g., gender, learning style) and level 3 focuses on group-level variables (e.g., group size, interaction activity). With regard to the study of students' final exam scores, a two-level model was built with students (level 1) nested within groups (level 2). The impact of all variables regarding the characteristics of individual students, and group and task features described in the theoretical base, was tested in the analysis. However, because in multilevel models parsimonious models are preferred, only significant predictors ameliorating the model were retained.

Results

Descriptive results

Tables 1 and 2 provide an overall picture of the performance of both the script and non-script cohort with regard to students' attained level of knowledge construction and final examination scores. More specifically, Table 1 presents the distribution of students' messages reflecting the different levels of knowledge construction based on Gunawardena et al. (1997). In both cohorts, high proportions of contributions are primarily perceived in level 1 (*sharing and comparing information*) and level 3 (*negotiating what is to be agreed/co-construction*). With respect to the presence of these levels of knowledge construction in students' communication, both cohorts are found similar. Differences between the script and non-script cohort are mainly found in the presence of level 4 (*testing tentative constructions*), and especially in the occurrence of level 2 (*identifying dissonance/inconsistency*) and level 5 (*statement/application of newly-constructed knowledge*). In the non-script cohort, level 5 communication was almost non-existent. In the script cohort, students more often reached this highest level of knowledge construction, which was at the expense of contributions in level 2.

Table 1 Proportions of messages coded for each level of knowledge construction (Gunawardena et al. 1997) for both cohorts per discussion theme

	Theme 1 (%)	Theme 2 (%)	Theme 3 (%)	Theme 4 (%)	All themes (%)
Non-script cohort					
Level 1	42.7	47.7	60.8	56.8	51.7
Level 2	17.3	13.3	13	11.4	13.7
Level 3	39	36.7	24.6	30.6	33.1
Level 4	0.6	2.0	1.4	0.6	1.2
Level 5	0.3	0.3	0.3	0.6	0.4
Script cohort					
Level 1	40.8	59	58.8	56.9	52.9
Level 2	10.1	6.6	4.5	3.2	6.1
Level 3	35.3	27.0	29.5	29.8	29.8
Level 4	6.6	2.3	0.6	2.1	2.8
Level 5	7.1	5.1	6.7	8.0	6.5

For both the script and non-script cohort, Table 2 reports students' mean level of knowledge construction and final exam scores. As can be seen in Table 2, the script cohort outperforms the non-script cohort in final examination score, as well as in the attained levels of knowledge construction during the four different discussion themes. To test whether these differences are statistically significant, multilevel analyses were performed.

Impact on students' knowledge construction

To test the hypotheses with regard to the impact on student knowledge construction, students' "mean level of knowledge construction" per discussion theme was used as a dependent variable. A two-step procedure was followed. The first step in the analysis consisted of the estimation of a three-level unconditional model, which partitioned the variance of the dependent variable into between-groups, between-students, and between-discussion themes components. The second step involved entering explanatory variables at group and student level, based on the theoretical framework. Continuous independent variables were grand mean centered to facilitate the interpretation of the intercept.

Initially, all predictors were included in the model as fixed effects. Afterwards, the assumption of a fixed linear trend was verified by allowing the coefficients to vary at random.

Table 3 presents the model estimates for the three-level analyses of students' level of knowledge construction. The results for the fully unconditional three-level null model

Table 2 Mean level of knowledge construction and final exam score for both cohorts

	Non-script cohort	Script cohort
Level of knowledge construction—theme 1	M=1.83 (SD=0.47)	M=2.21 (SD=0.74)
Level of knowledge construction—theme 2	M=1.83 (SD=0.54)	M=1.87 (SD=0.74)
Level of knowledge construction—theme 3	M=1.58 (SD=0.48)	M=1.83 (SD=0.73)
Level of knowledge construction—theme 4	M=1.68 (SD=0.43)	M=1.90 (SD=0.72)
Level of knowledge construction—all themes	M=1.73 (SD=0.48)	M=1.95 (SD=0.73)
Final exam score	M=9.50 (SD=3.03)	M=10.50 (SD=2.25)

Table 3 Summary of the model estimates for the three-level analyses of students' mean level of knowledge construction

Parameter	Model		
	Model 0	Model 1	Model 2
Fixed			
Intercept	1.842 (0.053)***	1.089 (0.257)***	1.290 (0.225)***
Theme 2		−0.243 (0.071)**	−0.261 (0.060)***
Theme 3		−0.329 (0.071)***	−0.336 (0.061)***
Theme 4		−0.261 (0.071)***	−0.265 (0.061)***
Number of contributions		0.056 (0.010)***	0.049 (0.009)***
Attitude towards learning environment		0.015 (0.007)*	0.011 (0.006)
Script cohort		0.268 (0.084)**	
Moderator			−0.032 (0.140)
Theoretician			0.029 (0.136)
Source searcher			−0.484 (0.147)**
Summarizer			1.507 (0.130)***
No role assignment in script cohort			0.195 (0.092)*
Random			
σ^2_{v0}	0.034 (0.016)*	0.016 (0.010)	0.021 (0.010)*
$\sigma^2_{\mu0}$	0.015 (0.015)	0.002 (0.013)	0.002 (0.009)
$\sigma^2_{\varepsilon0}$	0.383 (0.025)***	0.342 (0.024)***	0.249 (0.017)***

Per cell: regression coefficient and standard error

*$p<0.05$; **$p<0.01$; ***$p<0.001$

(model 0) shows an intercept of 1.842, which represents the overall mean of the level of knowledge construction according to the 5-level coding scheme of Gunawardena and colleagues (1997). As can be inferred from model 0, the overall variability in the mean level of knowledge construction per discussion theme can be attributed for the most part (88.66%) to discussion theme-level factors (differences between the assignments); 7.87% to group-level factors (differences between the groups); and 3.47% to differences between students within the groups. These results imply that the differences in level of knowledge construction between students are smaller than the differences between the groups and between the consecutive assignments. The variances at the theme- and group-level are significantly different from zero. No significant variance was found on the student-level.

To understand the changes in level of knowledge construction from discussion assignment 1 to assignment 4, the variable '*measurement occasion*' was added to the fixed part of the model. Three dummies were created with theme 2, 3, and 4 contrasted against the first discussion assignment. For all discussion assignments, a significant decrease in students' mean level of knowledge construction is observed as compared to the first assignment. By including the explanatory variable '*task complexity*' in the model, however, the significant differences between the themes are no longer observed. Taking into account that the degree of complexity of the discussion assignments showed an upward trend, it can be concluded that the increasing complexity of the themes is at the base of the significant decrease in levels of knowledge construction. This corroborates the fact that characteristics of the assignment are of key importance to fostering knowledge construction.

With regard to student characteristics, model 1 indicates that the '*number of contributions*' students post to the discussion (χ^2=32.338, df=1, p=0.000) and students' '*attitude towards the learning environment*' (χ^2=5.300, df=1, p=0.021) have a significant positive effect on students' mean level of knowledge construction per discussion theme. No significant effects were found for students with a strategic (χ^2=0.031, *df*=1, *p*=0.860) or a deep learning style (χ^2=1.669, *df*=1, *p*=0.196) as compared to students with a surface approach.

The key research variable in the present study is the implementation of roles. In this respect, the variable '*cohort*' was added to the fixed part of the model, represented by one dummy '*script cohort*' contrasted against the reference category '*non-script cohort*' (model 1). Students who were part of the script cohort acquired a significantly higher level of knowledge construction compared to the students in the non-script cohort (χ^2=9.501, *df*=1, *p*=0.002).

Taking into account that different roles ("moderator", "theoretician", "source searcher", and "summarizer") were assigned, in a following analysis step '*role type*' was included in the model. In this model (model 2), students from the non-script cohort were compared with the different roles assigned in the script cohort. Five dummies were created – one for each of the four roles and one with no roles – with roles contrasted against the reference group (students in the non-script cohort).

No significant effects were found for the role of theoretician (χ^2=0.044, *df*=1, *p*=0.833) and moderator (χ^2=0.053, *df*=1, *p*=0.818). These students did not differ significantly in their levels of knowledge construction as compared to students in the non-script cohort. A significantly negative effect was found for students being assigned the role of source searcher (χ^2=10.874, *df*=1, *p*=0.001). Those students obtained a significantly lower level of knowledge construction. As compared to students in the non-script cohort, only students who performed the role of summarizer reached a significantly higher mean level of knowledge construction (χ^2=133.403, *df*=1, *p*=0.000) with a large effect size of 1.6 standard deviation.

The analysis also revealed that there was a significant effect of being part of a scripted discussion group without having to perform a role (χ^2=4.501, *df*=1, *p*=0.034).

In short, it can be concluded that both student and task characteristics influence students' level of knowledge construction. At the student level, the amount of messages and a positive attitude towards the learning environment are important. At the task level, the complexity of the task should be taken into account. An overall significant impact, with an effect size of 0.5 standard deviation, was found for the script cohort, which implies that assigning roles has a positive effect on individual students' levels of knowledge construction.

Impact on students' final exam scores

To test the hypotheses regarding the impact on students' final exam scores, a similar two-step procedure was followed. Table 4 presents the model estimates for the two-level analyses of students' final exam scores.

The first step consisted of the estimation of a two-level null-model. The intercept of 10.04 in this model represents the overall mean of the final exam scores of all students in the discussion groups. Only 6.76% of the overall variability in the final exam scores can be attributed to group-level factors or between-group differences; 93.24% of the variance is due to differences between individual students within the discussion groups.

The second step was to include explanatory variables in the analysis. Only significant predictors ameliorating the model were retained. The "*number of contributions*", "*appreciation of the learning environment*", and student "*learning styles*" were successively added to the model as student-level explanatory variables.

Table 4 Summary of the model estimates for the three-level analyses of students' final exam scores

Parameter	Model	
	Model 0	Model 1
Fixed		
Intercept	10.043 (0.206)***	4.673 (1.208)***
Number of contributions		0.231 (0.044)***
Attitude towards learning environment		0.074 (0.031)*
Strategic learning style		0.960 (0.385)*
Deep learning style		1.296 (0.418)**
Script cohort		1.404 (0.417)**
Random		
$\sigma^2_{\mu 0}$	0.472 (0.233)*	0.434 (0.228)
$\sigma^2_{\varepsilon 0}$	6.507 (0.382)***	5.640 (0.380)***

Per cell: regression coefficient and standard error

*$p<0.05$; **$p<0.01$; ***$p<0.001$

The variable *number of contributions* per theme appears to be a positive and significant predictor ($\chi^2=27.783$, $df=1$, $p=0.000$) of final scores. The same goes for students' *attitude towards the learning environment* ($\chi^2=5.706$, $df=1$, $p=0.017$) and *learning style*. Students with a strategic ($\chi^2=6.203$, $df=1$, $p=0.013$) or a deep learning style ($\chi^2=9.632$, $df=1$, $p=0.002$) attain significantly higher final exam scores.

After including the student-level explanatory variables, the group-level variable *cohort* was included in the model. A significant positive effect was found for students in the script cohort ($\chi^2=11.362$, $df=1$, $p=0.001$). Students who were part of this cohort achieved significantly higher scores for their final exam.

In summary, it can be concluded that with regard to the results for students' final exam scores, comparable results as for the levels of knowledge construction were found. The number of individual messages per theme is an important predictor and also the influence of students' appreciation of the learning environment is substantial. Students with a positive attitude towards the learning environment attain higher scores. Further, students' learning style is a strong predictor as well: students with a strategic or deep learning style obtain higher scores as compared to students with a surface approach. Finally, it is also clear that students who were part of the script cohort attain higher scores on their final exam.

Discussion

From the perspective of this research, the question of how to organize the computer-supported learning environment in a way that it promotes knowledge construction and effective learning remains important. Computer-supported collaboration scripts can facilitate specific processes and outcomes of argumentative knowledge construction of students in higher education (Weinberger et al. 2005b). Scripting, and more particularly, the use of roles, was introduced in our research as a way to meet this demand. It is also assumed that learners and their surroundings make up a learning system in which learning is or can be guided by different system components, namely the individual learner, the other group members, the computer environment, the task, and the imposed script (Kollar et al.

2006). The different components were taken into account in the present study. However, the main focus was on the impact of role assignment on the ongoing learning process.

The results for both cohorts indicate that a large part of the variability in levels of knowledge construction can be attributed to the different discussion assignments. As to the impact of task characteristics, task complexity seemed to play an important role. When tasks are too straightforward, students are not motivated or triggered to solve the problem. On the other hand, when task are too complex, they stop discussing or discuss only a subpart of the assignment. Harper et al. (2000) mention in this respect that while complexity may be necessary to provide authentic learning environments, too much complexity can make learners feel insecure and lose track of learning objectives. Therefore, the learning challenge should be balanced to keep up with the learner's abilities (Quin 1997). The significant decrease in students' level of knowledge construction from the first to the following discussion assignments more specifically indicates that the increasing complexity of the successive tasks was difficult for the freshman students to cope with. After taking task complexity into account, no significant differences in students' attained level of knowledge construction could be found between the consecutive discussion themes. This finding indicates that, when working with separate assignments where each discussion theme is related to new knowledge elements, students have to start from scratch in each new discussion.

As to the impact of student characteristics, the results indicate that more intensive and active participation in the discussion groups is positively related to students' achieved level of knowledge construction and the score on their final exam. These results corroborate the findings of previous research (Schellens et al. 2005), which stated that engagement should be fostered in students' learning activities since engaged students participate more often, which leads to the desired outcomes. Assumptions that the implementation of scripts, and more particularly the assignment of roles in discussion groups, may stimulate this intensive and active participation, could be fortified.

The key question in the present study focused on the impact of roles on students' levels of knowledge construction reflected in the discussions and on their results in the final exam. In general, the results largely support our hypotheses: students in the script cohort perform better as compared to students in the non-script cohort. It appears that scripts, in this case well-defined roles, can be used to help students during the collaborative knowledge construction process. In this respect, it appears that this way of scripting leads the other students to give more complete arguments (containing more theory, reasons for their opinions, etc.) and to react and elaborate more on other students' postings. This finding is in line with the research of Weinberger et al. (2005b), which indicated that computer-supported collaboration scripts can improve the argumentative discourse quality of students. Scripts can be integrated into a CSCL-environment and are proven to facilitate the discussion, which leads to better results. In contrast to the results of Weinberger et al. (2005b), the scripts in the present study not only improved the ongoing discussion processes, operationalized by the levels of knowledge construction according to the model of Gunawardena, but they also led to improved acquisition of domain-specific knowledge, operationalized by students' individual final exam scores. In this respect, the findings fit with the study of Mäkitalo et al. (2004), who pointed at the possibility of decreasing the uncertainty level by using roles and therefore stimulating more discourse, leading to better learning outcomes.

Contrasting our expectations, practicing a role did not increase one's level of knowledge construction during that specific role assignment. Only students engaged in the role of summarizer achieved significantly higher levels of knowledge construction compared to students in the non-script cohort. The positive effect of the summarizer can be attributed to the fact that this student is expected to post interim summaries during the discussions, which requires the identification of similarities or differences between the contributions, to develop a general overview, to consider all opinions, etc. These activities undoubtedly foster the attainment of higher levels of knowledge construction. Unexpectedly, a significantly negative effect was found for source searchers. These students obtained a significantly lower mean level of knowledge construction as compared to students who worked in groups without the role script. This effect is probably due the fact that we noticed that source searchers usually only mentioned interesting websites, articles, or books, but failed to explain the link within the ongoing discussion or to discuss the supplied external sources. It is clear that this kind of contribution to the discussion is limited to sharing and comparing information, which is only the first level of knowledge construction in Gunawardena's model (Gunawardena et al. 1997), leading to significantly lower levels of knowledge construction. Taking into account both the overall significant effect of the script cohort on the one hand and the non-significant effect of being engaged in the roles of moderator or theoretician on the other hand, the other group members appear to take advantage of the efforts of students with a particular role. In this way, the other group members benefit and achieve significantly higher levels of knowledge construction. It is possible that the design of the script – the description and specification of the different roles – was too strict and too guided towards executing the specific role. In this respect, Dillenbourg (2002) uses the concept of "overscripting." It is not unlikely that students who had to perform a role were merely giving support and were not able to use the response from other students for a deeper elaboration, thereby acquiring higher levels of knowledge construction themselves. In other words, these students did a good job of scaffolding, but were unable to use the information of the other students, probably because they stuck too close to their role. Therefore, future scripts might foster both the communicative as well as the content dimensions in order to encourage students with roles to learn as well. This is an important finding and points at the importance of clearly defining and explaining the roles to students with sufficient attention for all dimensions.

With regard to future research, the process of social construction of knowledge needs further investigation. We define learning as a process, demonstrated through conversation, in which learners reflect upon what they currently know and negotiate new meaning and knowledge creation with other students through conversation and argumentation (Dennen and Paulus 2005). Closely examining these processes is necessary to shed light on the impact of role assignment on the functioning of the complete discussion group. This hypothesis will be subject to further research. In this respect, attention should also go to the impact of roles, which are more focused on one's own personal cognition than on the management of the overall interaction. In addition, wanting students to perform a role and at the same time wanting them to benefit from it for that particular assignment might be too much to expect at one time for freshman students. Maybe the effects of being assigned a role plays out later in new discussion assignments. Further research is needed to address this issue.

We can conclude that roles create the potential for improving knowledge construction. In the second cohort, an overall positive effect of role assignment was detected. All students in this cohort outperformed the students in the cohort without role assignment. Nevertheless, the present study revealed that not all roles equally promote knowledge construction for the students that have to perform that specific role when compared to their fellow students. It appeared that students for some roles stuck too close to their description role and did not participate in the ongoing discussion or failed to link their role performance sufficiently to the discussion. These are also important findings and point at the importance of clearly defining and explaining the roles to the students.

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