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Task-related and social regulation during online collaborative learning

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Abstract This study investigated how students collaborate in a CSCL environment and how this collaboration affects group performance. To answer these questions, the collaborative process of 101 groups of secondary education students when working on a historical inquiry task was analyzed. Our analyses show that group members devote most of their efforts to regulation of task-related activities. For example, by formulating plans or strategies or monitoring task progress. Group members also engaged in social activities often (e.g., disclosing personal information, joking). Less attention was paid to exchange of task-related information (e.g., asking task-related questions) and regulation of social activities (e.g., planning and monitoring the collaboration). Exploratory factor analysis was used to identify the interrelationships between the different collaborative activities. This analysis showed that collaborative activities can be grouped in four broad categories: discussion of information, regulation of task-related activities, regulation of social activities, and social activities. These activities were then used to predict group performance using multiple regression analysis. No effect of discussion of information and regulation of task-related activities on group performance were found. Regulation of social activities positively affected group performance, whereas social interaction negatively affected group performance. As in this study no inferences could be made about the causal relation between collaboration and performance, future research should attempt to focus on this relationship, for example by investigating more closely how different individual and group factors affect collaboration and group performance.

Keywords Computer-supported collaborative learning · Regulation · Group performance · Inquiry learning · Secondary education

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Introduction

Over the last decades educational research has shown that collaborative learning, be it face-to-face or through the computer, is an effective instructional method to increase student achievement (Lou et al. 2001). This finding is in line with socio-constructivist approaches to learning which emphasize that students should have the opportunity to construct knowledge themselves and with others (Jonassen 1999; Van Boxtel et al. 2000). A specific area of collaborative learning research, *computer-supported collaborative learning* (CSCL), aims to provide an environment to group members that supports and facilitates collaboration in order to enhance their learning processes (Kreijns et al. 2003). Usually this is done by offering tools that are designed to facilitate sharing of ideas and information and the co-construction of knowledge (e.g., using a representational tool, see Suthers et al. 2003). Research has shown that CSCL, like face-to-face collaborative learning, can have a positive impact on, for example, group performance and the quality of group discussions (Fjermestad 2004).

Research however, has also demonstrated that group members do not always collaborate effectively and efficiently in a CSCL environment. CSCL-groups are for example often less productive and effective than their face-to-face counterparts and they therefore need more time to complete their tasks (e.g., Baltes et al. 2002; Barkhi et al. 1999; Straus 1997). Furthermore, groups working in CSCL environments sometimes have difficulties with the social aspect of collaboration: they may find it difficult to engage in exploratory interactive argumentation (Clark et al. 2007) or conflicts may even arise between group members (Hobman et al. 2002). Finally, previous research has repeatedly demonstrated that group members sometimes experience coordination problems during online collaboration (Baker et al. 2001; Ellis et al. 1992; Erkens et al. 2005). These coordination problems may occur in the *content space* (i.e., efforts aimed at problem solving, such as exchange of information or discussion of answers and alternatives) or in the *relational space* (i.e., efforts to establish a positive group climate and to ensure effective and efficient collaboration) of collaboration (Barron 2003; Slof et al. 2010).

To gain more insight into how group members collaborate during CSCL and to understand how the collaborative process affects group performance, many researchers have developed instruments to study this process (e.g., Arvaja et al. 2007; Saab et al. 2005; Strijbos et al. 2007). In this study, we want to study the collaboration process as it takes place between group members working in a CSCL environment and more specifically examine what activities students perform during CSCL, what kind of regulation activities they perform (e.g., regulation of the collaboration) and how the different collaborative activities interrelate. Furthermore, because many collaborative learning studies focus on the interaction processes taking place between group members without explicitly considering how this process affects group performance (cf., Elbers and Streefland 2000; Kumpulainen et al. 2001; Yackel et al. 1991), we want to investigate the relationship between the collaborative processes on the one hand and group performance on the other hand.

The process of collaborating online

Since one of the aims of this article is to investigate the online collaborative process, it is important to describe the different activities students perform during online collaboration.

To successfully complete a group task group members have to engage in different types of activities (McGrath 1991). First, group members have to *perform task-related activities* that are aimed at solving the problem at hand. During collaborative learning, students work on a common goal, which often takes the form of a group product (Phelps and Damon

1989). This means they perform activities in the *content* space of collaboration (Barron 2003; Slof et al. 2010). This requires that they pool their information resources, exchange their ideas and opinions, and ask questions (Jehn and Shah 1997; King 1994). This mirrors the production function as described by McGrath (1991) in his Time, Interaction, and Performance theory, as well as the task conveyance activities identified by Dennis and Valacich's (1999) Theory of Media Synchronicity.

Collaboration also involves a social-relational aspect. Group members have to attend to the social and emotional element of collaboration to successfully complete a group task (Rourke et al. 1999). Students have to perform *social and communicative activities* that help to maintain a positive group climate (Kreijns et al. 2003). In this respect, McGrath referred to the group well-being and member support functions that group members have to perform during collaboration. Similarly, Massey et al. (2003) referred to the importance of social and relational communication during online collaboration. Behaviors such as offering positive comments and praising group members contribute to a sound social space and a positive group atmosphere (Kreijns 2004), which may increase group members' efforts to complete the group task (Jehn and Shah 1997; Rourke et al. 1999). Behaviors such as swearing or displaying negative emotions have, in contrast, been found to have a negative impact on group cohesion and the collaborative process (Kiesler and Sproull 1992; Wilson et al. 2006).

Grounding is another important social-communicative activity that group members have to perform in order to collaborate effectively online. Grounding is a necessary process for group members to establish shared understanding and a common frame of reference (Clark and Brennan 1991; Erkens et al. 2006; Van der Pol et al. 2006). To communicate and collaborate effectively, group members need to ensure they understand each other. Grounding can be seen as the strategies employed to create this understanding (Kirschner et al. 2008). One such strategy is tuning, defined as adapting to the collaboration partner(s). In a collaborative situation different perspectives and interpretations may, for example, exist between group members as a result of differing experiences and knowledge bases. During the grounding process, when one "tunes to the other group member " (e.g., adapts one's word use to that of the communication partner, see Niederhoffer and Pennebaker 2002), these differences are taken into account during the conversation and thus misunderstandings may be prevented. In other words, the listeners develop a framework in which they interpret the externalizations of others. This does not mean that they agree, but that they understand the origin of the statement. Another important grounding strategy to reach shared understanding is to ensure *joint attention* when needed. Joint attention exists when group members respond appropriately or engagedly to the proposals of a group member (Barron 2000). Appropriate or engaged responses are, for example, acceptations or starting a constructive discussion, while inappropriate responses are ignoring the other or outright rejections. Successful groups display higher levels of these engaged responses compared to unsuccessful groups (Barron 2003).

Merely performing task-related and social activities however, is not sufficient to ensure successful collaboration. It also requires considerable coordination and regulation of these activities (Erkens et al. 2005; Van der Meijden and Veenman 2005). Collaboration therefore also involves *coordination or regulation of task-related activities*. Metacognitive activities (Schraw and Moshman 1995; Zimmerman 2002) that regulate task performance (e.g., making plans, monitoring task progress, and evaluating plans or ideas) are considered important to successful performance during online collaboration (De Jong et al. 2005). For example, Massey et al. (2003) referred to the importance of project management during online collaboration. Furthermore, in a study on computer-supported collaborative writing, planning activities were related to the quality of written texts (Erkens et al. 2005). Finally, Jehn and Shah (1997) demonstrated task monitoring was related to performance on group tasks.

Not only task-related activities have to be coordinated, social activities have to be coordinated and regulated as well (Ellis 1997; Manlove et al. 2006). Collaboration requires *coordination or regulation of social activities*. During collaboration, group members are interdependent, and therefore they have to discuss collaboration strategies, monitor the collaboration process, and evaluate and reflect on the manner in which they collaborated. Hadwin et al. (2010) describe what they call socially-shared regulation. That is, regulatory processes that are aimed at regulating the collective activity. Studies by Yager et al. (1986) and Johnson et al. (1990) demonstrated the positive influence of regulating group processes. These studies showed that when group members discuss how their group is performing and how collaboration may be improved, group performance is increased.

In conclusion, online collaboration requires group members to engage in four different types of activities: task-related activities, social activities, regulation of task-related activities, and regulation of social activities. Researchers usually address only one or two of these activities when studying online collaboration. Van Drie et al. (2005) for example, focused mostly on task-related activities during collaboration on a historical inquiry task. Van der Meijden and Veenman (2005) focused on task-related activities and regulation of task-related activities when comparing online to face-to-face collaboration. The aim of this article is to show that to gain a complete picture of the nature of online collaboration, attention should be paid to all four activities. We will therefore examine which kinds of collaborative activities students perform during online collaboration. Furthermore, we want to investigate how the different collaborative activities interrelate during collaboration. Do students who are actively exchanging task-related information, for example, also actively regulate task-performance? Furthermore, we want to investigate the relationship between these four activities and group performance: which activities contribute to group performance? As we stated previously, this issue is seldom addressed by research.

Research questions

This article analyzes the data of three studies during which secondary education students worked together in a CSCL environment on an inquiry task for the subject of history. The collaborative process between the group members and their group performance will be examined to answer the following research questions:

1. Which kinds of collaborative activities (i.e., task-related, social, etc.) do students perform during online collaboration in CSCL environment?
2. How do the different collaborative activities interrelate during online collaboration?
3. What is the relationship between the use of the different collaborative activities during online collaboration and group performance?

Method

To answer the research questions above, the data of three studies were combined (Janssen et al. 2007a, b, 2010). During these studies, secondary education students worked on inquiry tasks for the subject of history. The participating students collaborated in a CSCL environment (described below). All their actions and communications in this learning environment were logged and analyzed to gain insight into the regulative processes taking place in the environment during the groups' online collaboration. Furthermore, the quality of the group products created by the groups for their inquiry tasks was analyzed to be able to examine the relationship between collaborative activities and group performance.

Inquiry tasks

During the three studies, three different inquiry tasks were used. The inquiry tasks were similar in nature. First, all three tasks were developed for the subject of history. The theme of the first task was 'Witchcraft and the persecution of witches', and the theme of the second and third task was 'Christianity during the Roman Empire'. Second, all three inquiry tasks can be characterized as open-ended, ill-structured tasks that focused on reading and comprehending and synthesizing historical sources. Third, these historical sources were used by the group members to write different types of texts. For study 1 for example, group members had to write answers to several historical questions based on the information given in the sources; while for studies 2 and 3 they had to write an essay. Finally, all three inquiry tasks lasted for eight, 50-minute lessons.

Participants

In total, 310 secondary education students participated in the three studies. All students, aged 15–18 years, were enrolled in the fifth year of the pre-university track. Students collaborated mostly in groups of three students, although some groups of two and four students were also formed. In total, the collaborative process and group performance of 101 groups were analyzed for the present study.

CSCL environment

During all three studies, students collaborated in a CSCL-environment named *Virtual Collaborative Research Institute* (VCRI). VCRI is a groupware program designed to support collaborative learning on inquiry tasks and research projects. The VCRI is developed for students ranging from primary to higher education. Students use VCRI to communicate with each other, access information sources, and co-author texts or essays. While working with VCRI, students share several tools. These tools are designed to support three different activities of the collaborative inquiry process: task-related or cognitive activities (e.g., writing an essay or constructing an argumentative map), meta-cognitive activities (e.g., planning and evaluating the inquiry process), and social activities (e.g., monitoring the collaborative process and supporting communication).

In VCRI students work on collaborative inquiry projects over longer periods of time. Students start by exploring the topic of the project, by reading, collecting, and summarizing information sources using the *Sources*-tool. Students can discuss with each other about the information found in the sources through the synchronous *Chat*-tool. Students can use the *Diagrammer* and *Debate*-tool to construct a diagram or map of the arguments found in the available information sources. Students use the *Cowriter*, a shared word processor, to collaborate on writing tasks (e.g., writing an essay or a report).

Procedure

The procedure was the same during the three studies. During the lessons, each student worked on a separate computer in a computer lab. Students were therefore often located in the same room during the lessons and could thus also talk face-to-face to each other. It should be noted however, that students mostly communicated electronically. The role of the teacher was similar in during the three studies: they were online to answer questions about the task during the lessons. In total, 13 teachers were involved in the studies (three teachers during study 1, and five during studies 2 and 3). The teachers were able to monitor the online discussions of their students when they logged into the VCRI environment. Teachers could also send messages in order to answer students' questions, or to warn students in case of misbehavior. Furthermore, teachers had access to the texts students were writing in the Cowriter. This way, teachers could monitor the progress of their groups. Although students could also consult the teachers face-to-face, most questions were asked online. Students were also allowed to work on the inquiry group task during free periods. Thus, they could work on the task in the school's media center when they had spare time in their timetable. After the eighth and final lesson the group members handed in their final version of the inquiry task to be graded by their teachers.

Coding of online collaboration

To answer the research questions, all communication between group members in the VCRI-environment was logged and analyzed. For this purpose a coding scheme was developed to classify all messages written by the group members during the three studies. In total, the scheme contains four scales: *task-related activities, regulation of task-related activities*, *social activities*, and *regulation of social activities*. Each scale contains two or more codes or so-called collaborative activities. Furthermore, the scheme included several additional categories (e.g., technical aspects) that did not belong to any of the four scales. In total, the scheme consisted of 19 categories (see Table 1).

The first scale referred to *performance of task-related activities* aimed at carrying out the task (Jehn and Shah 1997). This scale contained two categories pertaining to the discussion of relevant task-related information: exchanging and sharing task-related information (*TaskExch)* and asking task-related questions (*TaskQues*). The abbreviations of the codes are given between parentheses.

The second scale referred to *regulation and coordination of task-related activities*, containing four categories. Metacognitive activities that regulate task performance (e.g., making plans, monitoring task progress), are considered important to successful performance in electronic learning environments (Hadwin et al. 2010; Van der Meijden and Veenman 2005). First, planning (*MTaskPlan*) involved discussion of strategies necessary to complete the task, and delegation of task responsibilities. Second, monitoring (*MTaskMoni*) involved exchange of information that could be used to monitor task performance and progress, and assessing the amount of time available. Finally, evaluation involved appraisal and discussion of task performance and progress, which could be either positive (*MTaskEvl+*) or negative (*MTaskEvl-*).

Since group members also have to attend to the social, emotional, and communicative element of collaboration to successfully complete a group task (Kreijns et al. 2003; Rourke et al. 1999) the coding scheme also contained activities which are performed in the relational space (Barron 2003). Grounding activities in the relational space are aimed at establishing and maintaining a shared understanding (Kirschner et al. 2008; Slof et al. 2010), for example when students address conflicting points of view or acknowledge understanding of the partner's message. Furthermore, activities in the relational space are also aimed at establishing and maintaining feelings of trust and group cohesiveness (Phielix et al. 2010), for example by disclosing personal information, making positive remarks about

Table 1 Collaborative activities of the coding scheme

	Task-related activities (content space) Codes	Social activities (relational space) Codes
Performing	• Information exchange (*TaskExch*) • Asking questions (*TaskQues*)	• Greetings (*SociGree*) • Social support (*SociSupp*) • Social resistance (*SociResi*) • Shared understanding (*SociUnd+*) • Loss of shared understanding (*SociUnd-*)
Coordinating / regulating	• Planning the task (*MTaskPlan*) • Monitoring task progress (*MtaskMoni*) • Positive evaluations of task progress (*MtaskEvl+*) • Negative evaluations of task progress (*MtaskEvl-*)	• Planning the collaboration (*MsociPlan*) • Monitoring the group process (*MsociMoni*) • Positive evaluations of the group process (*MsociEvl+*) • Negative evaluations of the group process (*MsociEvl-*)
Other	• Neutral technical remarks (*TechNeut*) • Negative technical remarks (*TechNega*) • Positive technical remarks (*TechPosi*)	• Other / nonsense (*Other*)

group members, or greeting group members. *Performance of social activities* therefore constituted the third scale. This scale contained five categories. First, greetings (*SociGree*) contribute positively to group atmosphere (Rourke et al. 1999). Second, social support remarks (*SociSupp*) referred to comments that contributed positively to group atmosphere, such as exchanging positive comments, and disclosure of personal information. Third, social resistance remarks (*SociResi*) referred to behaviors that contributed negatively to group atmosphere, such as insults and displaying negative emotions. Fourth, shared understanding (*SociUnd+*) referred to confirmations and indications of agreement, which serve to reach and maintain joint understanding. Similarly, loss of shared understanding (*SociUnd-*) referred to denials, and expressions of incomprehension.

The fourth scale referred to *regulation and coordination of social activities*. Group members for example, need to discuss collaboration strategies or reflect on the manner in which they collaborated (Webb and Palincsar 1996). As with the task-related activities in the content space, it is also important that students coordinate and regulate the social activities taking place in the relational space (Manlove et al. 2006). During collaboration, group members should not only regulate their own learning process, but should also regulate the collective activity (Hadwin et al. 2010). This scale therefore contained four categories. First, planning (*MSociPlan*) involved discussion of collaboration strategies, such as helping each other, or proposals to work together on certain tasks. Second, monitoring (*MSociMoni*) referred to the social regulation aimed at monitoring the group processes. Finally, evaluation involved appraisal and discussion of group processes and collaboration, which could be positive (*MSociEvl+*) or negative (*MSociEvl-*).

Segmentation and coding procedure When communicating in the VCRI-environment, students often expressed multiple concepts or ideas within one message. It was therefore necessary to segment students' messages into smaller parts that were themselves meaningful before the start of the coding process. Therefore, the chat messages sometimes were segmented into smaller units (Strijbos et al. 2006). Segmentation and coding were done using the *Multiple Episode Protocol Analysis* (MEPA) computer program (Erkens 2005). Messages were segmented using a segmentation filter. A filter is a program, which can be used in MEPA for automatic data manipulation. Punctuation marks (e.g., full stop, exclamation mark, question mark, comma) and phrases connected through a conjunction (e.g., "and", "but", "or") are used to segment messages into dialogue acts (Erkens and Janssen 2008). Exception rules prevent the filter from segmenting messages into smaller units when this should not be done (e.g., "We should plan, write, and revise our text.") Using filters speeds up segmentation, and ensures segmentation rules are applied consistently. After the segmentation process, the segments were coded using the coding scheme.

Interrater reliability In all three studies, interrater reliability of the coding procedure was examined. For Study 1, two researchers independently coded 601 dialogue acts and reached a Cohen's Kappa of .86. The same two researchers coded 796 dialogue acts independently for Study 2 and reached a Kappa of .94. Finally, 1000 dialogue acts were coded by two researchers for Study 3; a Cohen's Kappa of .90 was found. It can be concluded that the procedure for coding online collaboration was sufficiently reliable.

Although the coding scheme focuses on *individual* students' collaborative activities, we aggregated individual frequencies to the level of the *group*. That is, we calculated for each group the frequency with which the activities in the coding scheme were used during their collaboration, by summing individual group members' frequency counts. We used the Average Deviation (AD) index to investigate whether aggregation to the group level was justified. The AD index can be used to calculate the extent to which group members tended to use collaborative activities to a similar extent (i.e., do group members, on average, exchange task-related information to a similar degree?). If this is the case, indicated by an AD index lower than .200, then aggregation to the group level is justified. In our dataset, the AD index ranged from .036 to .055, which indicates aggregation to the group level was justified.

Group performance

Since none of the inquiry tasks used in the three studies was alike, three different assessment forms were developed to measure group performance. For Study 1, this form contained 48 items (see Janssen et al. 2007b). The assessment items could be grouped into three main categories. *Use of sources* referred to the manner how well groups incorporated historical information in their group products. *Content and argumentation* addressed the manner in which students formulated their answers and supported their answers with arguments and evidence. *Text construction and language* referred to the adequacy of text construction and correct use of language. All items were answered on a 3-point scale, with 0 indicating poor quality and 2 excellent quality. Thus, in total 96 points could be earned.

For Study 2, a similar assessment form containing 36 items was developed (see Janssen et al. 2007a). The items of the form could be grouped into two main categories. *Conceptual content and argumentation* pertained to the elaborateness of historical concepts and ideas used in the essay and adequacy of the argumentation to support conclusions and ideas with arguments and evidence. *Quality of presentation* referred to structure of the written text and correctness of the language used. Some items were answered on a 3-point scale, whereas other items were answered on a 4-point scale. In total, 76 points could be earned.

The assessment procedure for Study 3 was somewhat different compared to the other two studies (see Janssen et al. 2010). To assess the quality of the essays for Study 3, each essay was segmented into a number of different, smaller topics. The quality of these topics was established by determining the *conceptual quality* of the topic (conceptual level of correctness of the arguments formulated within the topic) and the *grounds quality* of the topic (how well students used evidence of examples to support their claims). For each topic of the essay conceptual quality and grounds quality were assessed on a 4-point scale. As some groups covered more topics in their texts than other groups, we calculated the mean conceptual quality and the mean grounds quality of the topics covered in the essay for each group. These mean scores were summed to create an overall measure of group performance. This overall score could range from 0 to 6.

For the present article, it is necessary to be able to compare the group performance scores of the three studies. Therefore we divided the number of points earned by a group by the total amount of points they could earn. This proportion was used as a measure of group performance in the analyses carried out for this article. Thus, a group from Study 1 that received 62 points would get a group performance score of 62 : 96=0.65. Similarly, a group from Study 2 that received 62 points would get a performance score of 62 : 76=0.82. Finally, a group from Study 3 that received 5 points would get a performance score of 5 : 6=0.83.

For all three studies, the objectivity of the assessment procedure was examined. During all three studies, two researchers independently scored several essays to determine interrater reliability. For Study 1, percentage agreement ranged from 75.0% to 88.5% (Cohen's kappa ranged from .61 to .82), for Study 2 from 84.5% to 95.2% (Cohen's kappa ranged from .70 to .93), and for Study 3 from 89.4% to 92.2% (Cohen's kappa ranged from .85 to .88).

Results

Collaborative activities

During all three studies, group members communicated and collaborated intensively during all eight lessons. This resulted in extensive chat protocols. On average, groups sent a total of 923 messages (*SD*=547), with a minimum of 119 messages and a maximum of 3344 messages.

Table 2 displays an overview of the relative frequencies (percentages) of each collaborative activity. From this table it can be seen that some collaborative activities occurred relatively frequently, whereas other activities occurred relatively infrequently. During the inquiry task, groups are very busy regulating task performance. Mostly by planning the task (19.51%) and monitoring task progress (14.03%). Engaging in social activities occurs also frequently. Strikingly, over 20% of all messages are devoted to reaching and maintaining shared understanding (e.g., acknowledging the other, signaling acceptance, etc.). Additionally, almost 10% of the messages was coded as social support, meaning they were aimed at maintaining a positive group climate (e.g., joking, social talk). A significantly smaller proportion of the collaboration is devoted to asking task related questions (3.05%) and exchanging task-related information (8.37%). Regulating the group process appears to occur least frequently. About 9% of the messages exchanged is aimed at either planning the collaboration or monitoring the group process. Evaluating the group process occurs in less than 1% of the messages.

Relationship between collaborative activities

To gain more insight into the relationship between the different collaborative activities, the total group of activities was subjected to an exploratory factor analysis with varimax

Table 2 Mean percentages, standard deviations, minimum, and maximum of collaborative activities

	Percentage			
	M	*SD*	*Min.*	*Max.*
Information exchange (*TaskExch*)	8.37	6.09	0	34
Asking questions (*TaskQues*)	3.05	1.75	0	9
Planning the task (*MTaskPlan*)	19.51	5.08	7	33
Monitoring task progress (*MTaskMoni*)	14.03	3.39	6	24
Positive evaluations of task progress (*MTaskEvl+*)	1.83	0.81	0	4
Negative evaluations of task progress (*MTaskEvl-*)	2.09	0.95	0	5
Greetings (*SociGree*)	3.23	1.89	0	16
Social support (*SociSupp*)	9.56	5.08	1	35
Social resistance (*SociResi*)	2.51	2.12	0	11
Shared understanding (*SociUnd+*)	21.28	4.10	6	31
Loss of shared understanding (*SociUnd-*)	3.84	1.44	1	10
Planning the collaboration (*MSociPlan*)	3.30	2.44	0	10
Monitoring the group process (*MSociMoni*)	5.45	2.22	1	12
Positive evaluations of the group process (*MSociEvl+*)	0.17	0.25	0	2
Negative evaluations of the group process (*MSociEvl-*)	0.25	0.34	0	2

rotation. Based on examination of the scree-plot and the K1-rule (Hetzel 1996), four factors were extracted. These factors corresponded to four different ways of collaborating online. Together these factors accounted for 52.8% of the total variance. Table 3 shows the rotated factor matrix. A salience level of |.40| was used to interpret the meaning of the four factors.

Because exchanging task-related information, asking task-related questions, negatively evaluating task progress and performance, and loss of shared understanding (e.g., disagreements) all loaded significantly on the first factor, this factor was interpreted as *information discussion*. This factor accounted for 14.1% of the variance. Table 4 shows an example of this type of collaboration. During information discussion, students are sometimes critical of the information that is put forth by group members and sometimes question the correctness of proposed solutions. In the episode displayed in Table 4, this is evident from lines 7–15. The suggestion made by student 102 in line 7 is questioned by students 101 and 103 and this student is asked to explain the proposed solution.

Three collaborative activities loaded significantly on the second factor: planning task-related activities, monitoring task-related activities, and positively evaluating task-related activities (see Table 3). Because all these activities have to do with the regulation of the task, this factor was interpreted as *regulation of task-related activities*. This factor also accounted for 14.1% of the variance. In Table 5 an example of this type of collaborative activity is given. During this episode, the group members try to monitor task progress by keeping an eye on the deadline (line 3). Furthermore, they are evaluating the quality of their work (e.g., lines 7–8) and making plans for the next step in their inquiry process (e.g., line 5). This type of collaborative episode is representative for groups that are extensively regulating their task performance.

Factor three also consisted of three collaborative activities, as can be seen in Table 3: planning the collaborative process, monitoring the collaborative process, and negatively evaluating the collaborative process. This factor was therefore interpreted as *regulation of*

Table 3 Rotated factor matrix with loadings of activities on different factors

	Factors			
	1	2	3	4
Information exchange (*TaskExch*)	.78			
Asking questions (*TaskQues*)	.78			
Planning the task (*MTtaskPlan*)		.89		
Monitoring task progress (*MTaskMoni*)		.60		
Positive evaluations of task progress (*MTaskEvl+*)		.46		
Negative evaluations of task progress (*MTaskEvl-*)	.45			
Greetings (*SociGree*)				.53
Social support (*SociSupp*)				.65
Social resistance (*SociResi*)				.40
Shared understanding (*SociUnd+*)				.48
Loss of shared understanding (*SociUnd-*)	.67			
Planning the collaboration (*MSociPlan*)			.60	
Monitoring the group process (*MSociMoni*)			.66	
Positive evaluations of the group process (*MSociEvl+*)				.51
Negative evaluations of the group process (*MSociEvl-*)			.77	

social activities, because these three activities have to do with coordinating and regulating the group process. This factor accounted for 12.6% of the variance. Table 6 shows an example of a group involved in this type of interaction. This group is actively involved in monitoring the collaboration (lines 3–4), suggesting how to collaborate and plan the group process (lines 3 and 6), and evaluating the collaborative process (line 8).

Five activities loaded significantly on the fourth factor: greetings, social support (e.g., joking, social talk, disclosing personal information), social resistance (e.g., swearing, cursing), shared understanding (e.g., acknowledgment, acceptance), and positively evaluating the group process. Because most of these activities are not intended to regulate or coordinate the collaborative process, but are instead indications of social interaction, this factor was interpreted as *performing social activities*. This factor accounted for 12.0% for the variance. Table 7 shows an episode of a group in the process of performing a series of social activities. During this episode, two group members are greeting each other and discussing their activities during the weekend (lines 1–6). When student 311 urges them to start working on the inquiry, they tell him to shut up because they want to carry on their social conversation (lines 7–9).

Group performance

To investigate the relationship between collaborative activities and group performance, we summed the percentages of the all the codes that loaded significantly on a particular factor. For example, for the factor regulation of social activities, the codes MSociPlan, MSociMoni, and MSociEvl- were summed as a measure for the amount of social regulatory behavior by a group. These summed percentages were then used in a multiple regression analysis to analyze their effects on the group performance (see Table 8). We used the previously derived factor scores instead of the individual collaborative activities in the

Table 4 Example of a information discussion episode (translated from Dutch)

Line	Student	Message	Code
1	103	Good morning!	SociGree
2	101	We have to categorize the historical sources.	MTaskPlan
3	101	What categories are we going to use?	TaskQues
4	102	Rise of Christianity.	TaskExch
5	103	I have read a lot of sources about persecution of Christians by the Romans.	TaskExch.
6	101	Sounds good.	MTaskEvl +
7	102	Favorable developments for the Christians!	TaskExch
8	101	Favorable developments for the Christians?	TaskQues
9	103	What do you mean by that?	SociUnd-
10	102	I have read some sources about how the number of Christian converts grew over the years in the Roman Empire.	TaskExch
11	103	I see…	SociUnd+
12	101	I don't think such a category is really necessary.	MTaskEvl-
13	102	Why not?	SociUnd-
14	101	Well, the assignment says we should concentrate on explaining why Christians were persecuted by the Romans.	TaskExch
15	101	Your suggestion is not about explaining why Christians were persecuted.	MTaskEvl-

multiple regression analysis because using such a large number of predictor variables would require a much larger dataset and to also facilitate interpretation of the results of the analysis.

Before conducting this regression analysis however, we checked whether it was appropriate to aggregate the interaction variables to the group level across the three studies. This was done using multivariate analysis of variance (MANOVA), with study as a grouping factor. We tested whether the groups differed significantly across the three studies on the four interaction factor scores. Using Pilai's trace, there was no effect of study on the four interaction factor scores, $V=.11$, $F(8, 192)=1.35$, $p=.22$. Overall, this indicates that across the three studies, groups interacted similarly and that aggregation across the three studies was justified. It should be noted however, that using separate univariate ANOVAs

Table 5 Example of an episode of regulation of task-related activities (translated from Dutch)

Line	Student	Message	Code
1	218	Can you please take a look at our sub questions?	MTaskPlan
2	218	Let me know if you think they are okay.	MTaskMoni
3	218	We have to finish this by the end of this period.	MTaskMoni
4	219	Okay.	SociUnd+
5	216	When we are finished we can start writing the answers to the questions.	MTaskPlan
6	217	Yep.	SociUnd+
7	219	Kevin, I think the sub questions are excellent.	MTaskEvl+
8	216	Me too!	MTaskEvl+
9	218	Great, let's move on then!	MTaskPlan

Table 6 Example of an episode of regulation of social activities

Line	Student	Message	Code
1	606	What can I do now?	MTaskPlan
2	605	You can help me to write the conclusion of the essay	MSociPlan
3	606	Isn't Anne working on that?	MSociMoni
4	604	We are both working on it.	MSociMoni
5	604	But we haven't thought of a good conclusion yet	MTaskEvl-
6	606	Sure, I'll try to help you both.	MSociPlan
7	605	Great!	SociSupp
8	604	Guys, I think we are great team!	MSociEvl+
9	606	We're the best! ;-)	SociSupp

on the interaction factor score, a significant difference between studies was found for regulation of social activities, $F(2, 98)=3.23$, $p=.04$. Inspection of the mean scores for this variable show that during the third study, the groups seemed to regulate social activities more often than in the first and second study. Post-hoc tests did not detect significant differences between the three studies however, although a marginally significant difference was found between study 3 and study 2, $t=2.45$, $p=.07$.

The results displayed in Table 8 show the results of a multiple regression analysis using the four interaction factor scores to predict group performance. In total, the four interaction factor scores explain almost 50% of the variance in group performance scores ($R=.494$, $F(4, 96)=23.471$, $p=.000$). Furthermore, information discussion and regulation of task-related activities did not significantly predict group performance ($\beta=.123$, $p=.56$, and $\beta=-.036$, $p=.87$ respectively). In contrast, regulation of social activities was found to significantly predict group performance ($\beta=.358$, $p=.03$). This indicates that the more effort group members invest into regulating the process of collaboration, the better they perform as a group. Additionally, a significantly negative effect of performing social activities on group performance was found ($\beta=-.483$, $p=.03$). This indicates that the more groups are engaged in social activities, the worse they perform.

Table 7 Example of an episode of social activities (translated from Dutch)

Line	Student	Message	Code
1	312	Hi everyone!	SociGree
2	311	Hey Chris!	SociGree
3	312	How was your weekend?	SociSupp
4	311	Great! I went to the soccer match on Sunday.	SociSupp
5	311	How about you?	SociSupp
6	312	We went to the cinema.	SociSupp
7	313	Guys, shouldn't we start working?	MTaskMoni
8	311	Oh, shut up!	SociResi
9	312	You can start working, we want to chat! ;-)	SociResi
10	313	Whatever…!	SociResi

Table 8 Correlations between collaborative activities and group performance

	B	*SE B*	*β*
Information discussion	.002	.004	.123
Regulation of task-related activities	.000	.004	−.036
Regulation of social activities	.009	.004	.358*
Performing social activities	−.008	.004	−.483*

R^2 =.494, p=.000

*p<.05

Conclusions and discussion

Our analysis shows that the participating students were very busy regulating task performance. Especially planning the task and monitoring task progress were activities performed often by the students. This high level of regulatory behavior is not surprising given the complexity and size of the inquiry tasks used in the three studies. In all three studies, students worked on a complex inquiry task lasting for eight 50-minute lessons. To be able to complete this task, students needed to plan the task and monitor task progress carefully (Van der Meijden and Veenman 2005).

We also found that group members devoted large parts of the communication to social activities, of which a large part was reserved for reaching and maintaining shared understanding. This means that during the online collaboration, students were actively trying to shape the grounding process by tuning to the other group members, signaling agreement, or acknowledging understanding. Furthermore, social activities such as joking and comforting group members also occurred relatively frequently. This shows that the groups involved in the three studies paid considerable attention to creating a positive group climate and a sound social space (Kreijns et al. 2003). On the other hand, the high percentage of communication devoted to the grounding process also highlights the difficulties students sometimes face when communicating electronically (Walther 1992).

The other two main activities occurred less frequently. A relatively small part of the communication between group members was coded as exchange of task-related information or asking for task-related information. Moreover, an even smaller part of the communication was aimed at regulating the group process. This is surprising, because research has shown that task-related activities are important for group problem solving (Jehn and Shah 1997). Furthermore, several authors have speculated that regulation of the group process is also important for successful online collaboration (e.g., Manlove et al. 2006). Both activities did however not feature prominently in the collaborative process of the groups involved in this study.

Exploratory factor analysis of the coded data identified four broad categories of collaborative activities. These four categories are discussion of information, regulation of task-related activities, regulation of social activities, and social activities.

These four main categories were then used in a multiple regression analysis to predict group performance. Our analysis shows that discussing information did not predict group performance. This is surprising, because critical and exploratory discussions have been shown to be important for effective collaboration (Wegerif et al. 1999). This hypothesis is not confirmed by this study however.

We also found that regulation of task-related activities did not positively affect group performance. Again, the literature suggests that regulating the task is important for successful collaboration (De Jong et al. 2005), whereas this hypothesis cannot be confirmed by this study. Perhaps the large amount of task regulation displayed by the groups is an indication the inquiry tasks were too complex for them. During complex inquiry tasks, students' working memory may be overloaded, thereby negatively affecting their performance (Kirschner et al. 2006). The large amount of task regulation found in the protocols may be a sign that this was the case for some of the groups in our study.

In the introduction of this article we stated that group members do not only need to regulate their task-related activities, but that the group process should be regulated as well. This hypothesis was confirmed by the significantly positive effect of regulation of social activities on group performance. This indicates that when group members pay attention to the planning, monitoring, and evaluation of the collaboration, they perform better on their task. This is in line with previous research on face-to-face collaboration (e.g., Yager et al. 1986).

This finding also sheds more light on findings from recent research from a cognitive load perspective. From such a perspective, the inter-individual coordination that is required for successful coordination, can be considered extraneous cognitive load (Kirschner et al. 2009). That is, coordinating and regulating the collaborative process places an additional burden on students which may overload their working memory resulting in less than optimal learning performance. In this respect, these coordinating and regulating activities are sometimes referred to as transaction *costs* (Ciborra and Olson 1988). On the other hand, it might be argued that collaboration also facilitates processes that are germane to learning and performance (i.e., processes that facilitate group members' learning process such as giving detailed explanations or engaging in constructive argumentation). Furthermore, collaboration also allows students to pool their information resources, thereby decreasing the burden placed on their working memory. Whether collaboration will be effective and efficient therefore depends on the interplay between the benefits of collaboration (i.e., ability to pool resources and stimulating learning processes) and the costs of collaboration (i.e., transaction costs). This study shows that although regulation of social activities might be considered detrimental for learning and performance, this was not the case for the groups involved in our research. In contrast, when groups devoted more energy to regulating the collaboration, they performed better. It seems therefore that a minimum amount of regulation of social activities is a prerequisite for successful group performance.

Finally, a negative relationship between social activities and group performance was found. On the one hand this is surprising because a positive group climate is important for collaboration. In a positive climate for example, trust develops more quickly between group members. This trust in turn, helps group members to perform more effectively (Wilson et al. 2006). On the other hand, it might be hypothesized that group members can be *too* socially active during their collaboration. As illustrated by the collaboration episode shown in Table 7, social interaction may also distract from the goal of the collaboration: finishing the group product. This may explain the negative effect of social activities on group performance. Furthermore, in many studies the activities we consider to be social activities are considered to be off-task activities which are usually considered to be deleterious for learning and perfomance (Chiu 2004; Klein and Schnackenberg 2000).

In sum, this study yielded several unexpected results that warrant further discussion. Especially the lack of a significant relationship between information discussion and regulation of task-related activities on the one hand and group performance on the other hand, deserves further attention. In this study we did not, for example, investigate the role of the teacher. As described above, teachers could follow the progress of their groups and comment on this. Furthermore, teachers could also follow the discussions of their groups and post messages in their discussions. Teachers could have used this function to give task-related information or answer task-related questions. This may explain the relatively low frequencies we found for these collaborative activities and it may also (partly) explain why these activities did not predict group performance. Also, the teacher could also communicate with students about deadlines, strategies, and task progress and thus also affect how group members regulate the task. Clearly, the role of the teacher in CSCL environments could be investigated further (Casamayor et al. 2009).

It should also be noted that way we calculated group performance (i.e., expressing group performance as the proportion of the total amount of points earned divided by the total amount of points that could be earned), might have affected our results. This way, we assigned equal weight to all parts of the inquiry tasks. Another option would have been to assign weights to the different parts of the tasks, for example based on their complexity or the time students were expected to work on them. To facilitate interpretation of our results we did not chose for this latter option, but this may have caused unintended artifacts. That is, when a different algorithm to calculate group performance was used, other results might have been found.

Another limitation of this study lies within the fact that we did not consider how collaborative activities develop over time. It might be expected for example, that in the beginning of the collaboration students focus on social activities (e.g., to develop trust and group cohesion) and that later on they start engaging in task-related activities and start paying attention to regulation of task-related and social activities (Tuckman 1965). Clearly, an analysis that takes time into account might shed more light on how these processes develop. Furthermore, the structure and nature of the task may also have affected the results and the development of collaborative activities. During all three studies, students we are asked first to explore the environment and chat with their group members, and then the tasks required them to read and discuss information sources, before finally using these information sources to write a report or essay. This sequence of activities may also have affected students' collaboration. For example, because studying information sources was a central activity only during the beginning of the task, this might explain why we only found low amounts of task-related activities and why we did not find an effect of task-related activities on group performance.

Because of the nature of this study, we are only able to show correlations (or absence of correlation) between collaboration and group performance, no cause-effect relationships. This leaves the question what comes first—collaboration or performance—unanswered. It might be the case that groups consisting of high ability students are aware of the effectiveness of regulating the collaboration, and thus choose to perform these activities consciously. Future research should also examine in more detail the relationship between collaboration and group performance taking into account the possible effects of group composition (i.e., group composition with respect to ability). Also, in this study, a negative effect of social activities on group performance was found. However, it might be the case that this relationship is different for groups of familiar students than for groups who have no shared history (Janssen et al. 2009). For example, in familiar groups the need for social interaction might be smaller, because these groups already have established group norms. On the other hand, these groups might be more inclined to engage in social interaction (Smolensky et al. 1990). Another aspect that could be investigated in this respect is group composition with respect to ability. Do groups composed of high-ability students engage in different collaborative activities than low-ability groups? And does this affect group performance differently for high- and low-ability groups? Clearly, there is a need to examine more closely how different factors, on the individual and group level, affect the relationship between the regulation of the collaboration process and group performance.

References

Arvaja, M., Salovaara, H., Hakkinen, P., & Jarvela, S. (2007). Combining individual and group-level perspectives for studying collaborative knowledge construction in context. *Learning and Instruction, 17*, 448–459.

Baker, K., Greenberg, S., & Gutwin, C. (2001). *Heuristic evaluation of groupware based on the mechanics of collaboration.* Paper presented at the Engineering for Human-Computer Interaction: 8th IFIP International Conference, EHCI 2001, Toronto, Canada.

Baltes, B. B., Dickson, M. W., Sherman, M. P., Bauer, C. C., & LaGanke, J. (2002). Computer-mediated communication and group decision making: a meta-analysis. *Organizational Behavior and Human Decision Processes, 87*, 156–179.

Barkhi, R., Jacob, V. S., & Pirkul, H. (1999). An experimental analysis of face-to-face versus computer mediated communication channels. *Group Decision and Negotiation, 8*, 325–347.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *Journal of the Learning Sciences, 9*, 403–436.

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*, 307–359.

Casamayor, A., Amandi, A., & Campo, M. (2009). Intelligent assistance for teachers in collaborative e-learning environments. *Computers & Education, 53*, 1147–1154.

Chiu, M. M. (2004). Adapting teacher interventions to student needs during cooperative learning: how to improve student problem solving and time on-task. *American Educational Research Journal, 41*, 365–399.

Ciborra, C., & Olson, M. H. (1988). Encountering electronic work groups: A transaction costs perspective. In *Proceedings of the 1988 ACM Conference on Computer-Supported Collaborative Work*. Portland, Oregon, U.S.

Clark, H. H., & Brennan, S. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: American Psychological Association.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review, 19*, 343–374.

De Jong, F., Kollöffel, B., Van der Meijden, H., Kleine Staarman, J., & Janssen, J. (2005). Regulative processes in individual, 3D and computer supported cooperative learning contexts. *Computers in Human Behavior, 21*, 645–670.

Dennis, A. R., & Valacich, J. S. (1999, January). *Rethinking media richness: Towards a theory of media synchronicity.* Paper presented at the 32nd Hawaii International Conference on Information Systems (HICSS), Kohala Coast, HI.

Elbers, E., & Streefland, L. (2000). Collaborative learning and the construction of common knowledge. *European Journal of Psychology of Education, 15*, 479–490.

Ellis, S. (1997). Strategy choice in sociocultural context. *Developmental Review, 17*, 490–524.

Ellis, C. A., Gibbs, S. J., & Rein, G. (1992). Groupware: Some issues and experiences. In D. Marca & G. Bock (Eds.), *Groupware: Software for computer-supported cooperative work* (pp. 23–43). Los Alamitos: IEEE Computer Society Press.

Erkens, G. (2005). *Multiple Episode Protocol Analysis (MEPA). Version 4.10*. The Netherlands: Utrecht University.

Erkens, G., & Janssen, J. (2008). Automatic coding of online collaboration protocols. *International Journal of Computer Supported Collaborative Learning (ijCSCL), 3*, 447–470.

Erkens, G., Jaspers, J., Prangsma, M., & Kanselaar, G. (2005). Coordination processes in computer supported collaborative writing. *Computers in Human Behavior, 21*, 463–486.

Erkens, G., Prangsma, M., & Jaspers, J. (2006). Planning and coordinating activities in collaborative learning. In A. M. O'Donnell, C. E. Hmelo-Silver, & G. Erkens (Eds.), *Collaborative learning, reasoning, and technology* (pp. 233–263). Mahwah: Erlbaum.

Fjermestad, J. (2004). An analysis of communication mode in group support systems research. *Decision Support Systems, 37*, 239–263.

Hadwin, H. F., Oshige, M., Gress, C. L. Z., & Winne, P. H. (2010). Innovative ways for using gStudy to orchestrate and research social aspects of self-regulated learning. *Computers in Human Behavior, 26*, 794–805.

Hetzel, R. D. (1996). A primer on factor analysis with comments on patterns of practice and reporting. In B. Thompson (Ed.), *Advances in social science methodology* (Vol. 4, pp. 175–206). Stamford: JAI Press.
Hobman, E. V., Bordia, P., Irmer, B., & Chang, A. (2002). The expression of conflict in computer-mediated and face-to-face groups. *Small Group Research, 33*, 439–465.
Janssen, J., Erkens, G., & Kanselaar, G. (2007a). Visualization of agreement and discussion processes during computer-supported collaborative learning. *Computers in Human Behavior, 23*, 1105–1125.
Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007b). Visualization of participation: does it contribute to successful computer-supported collaborative learning? *Computers & Education, 49*, 1037–1065.
Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2009). Influence of group member familiarity on online collaborative learning. *Computers in Human Behavior, 25*, 161–170.
Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science, 38*, 59–88.
Jehn, K. A., & Shah, P. P. (1997). Interpersonal relationships and task performance: an examination of mediation processes in friendship and acquaintance groups. *Journal of Personality and Social Psychology, 72*, 775–790.
Johnson, D. W., Johnson, R. T., & Stanne, M. B. (1990). Impact of group processing on achievement in cooperative groups. *The Journal of Social Psychology, 130*, 507–516.
Jonassen, D. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 215–239). Mahwah: Erlbaum.
Kiesler, S., & Sproull, L. (1992). Group decision making and communication technology. *Organizational Behavior and Human Decision Processes, 52*, 96–123.
King, A. (1994). Guiding knowledge construction in the classroom: effects of teaching children how to question and how to explain. *American Educational Research Journal, 31*, 338–368.
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*, 75–86.
Kirschner, P. A., Beers, P. J., Boshuizen, H. P. A., & Gijselaers, W. H. (2008). Coercing shared knowledge in collaborative learning environments. *Computers in Human Behavior, 24*, 403–420.
Kirschner, F., Paas, F., & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains from complex learning. *Educational Psychology Review, 21*, 31–42.
Klein, J. D., & Schnackenberg, H. L. (2000). Effects of informal cooperative learning and the affiliation motive on achievement, attitude, and student interactions. *Contemporary Educational Psychology, 25*, 332–341.
Kreijns, K. (2004). *Sociable CSCL environments: Social affordances, sociability, and social presence.* Unpublished PhD thesis, Open Universiteit, Heerlen, The Netherlands.
Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research. *Computers in Human Behavior, 19*, 335–353.
Kumpulainen, K., Salovaara, H., & Mutanen, M. (2001). The nature of students' sociocognitive activity in handling and processing multimedia-based science material in a small group learning task. *Instructional Science, 29*, 481–515.
Lou, Y., Abrami, P. C., & d'Apollonia, S. (2001). Small group and individual learning with technology: a meta-analysis. *Review of Educational Research, 71*, 449–521.
Manlove, S., Lazonder, A. W., & De Jong, T. (2006). Regulative support for collaborative scientific inquiry learning. *Journal of Computer Assisted Learning, 22*, 87–98.
Massey, A. P., Montoya-Weiss, M. M., & Hung, Y. (2003). Because time matters: temporal coordination in global virtual teams. *Journal of Management Information Systems, 19*, 129–155.
McGrath, J. E. (1991). Time, interaction, and performance (TIP). *Small Group Research, 22*, 147–174.
Niederhoffer, K. G., & Pennebaker, J. W. (2002). Linguistic style matching in social interaction. *Journal of Language and Social Psychology, 21*, 337–360.
Phelps, E., & Damon, W. (1989). Problem solving with equals: peer collaboration as a context for learning mathematics and spatial concepts. *Journal of Educational Psychology, 81*, 639–646.
Phielix, C., Prins, F. J., & Kirschner, P. A. (2010). Awareness of group performance in a CSCL-environment: effects of peer feedback and reflection. *Computers in Human Behavior, 26*, 151–161.
Rourke, L., Anderson, T., Garrison, D. R., & Archer, W. (1999). Assessing social presence in asynchronous text-based computer conferencing. *Journal of Distance Education, 14*(2), 50–71.
Saab, N., Van Joolingen, W. R., & Van Hout-Wolters, B. H. A. M. (2005). Communication in collaborative discovery learning. *The British Journal of Educational Psychology, 75*, 603–621.
Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*, 351–371.
Slof, B., Erkens, G., Kirschner, P. A., Jaspers, J. G. M., & Janssen, J. (2010). Guiding students' online complex learning-task behavior through representational scripting. *Computers in Human Behavior, 26*, 927–939.

Smolensky, M. A., Carmody, M. A., & Halcomb, C. G. (1990). The influence of task type, group structure and extraversion on uninhibited speech in computer-mediated communication. *Computers in Human Behavior, 6*, 261–272.

Straus, S. G. (1997). Technology, group process, and group outcomes: testing the connections in computer-mediated and face-to-face groups. *Human-Computer Interaction, 12*, 227–266.

Strijbos, J. W., Martens, R. L., Prins, F. J., & Jochems, W. M. G. (2006). Content analysis: what are they talking about? *Computers & Education, 46*, 29–48.

Strijbos, J. W., Martens, R. L., Jochems, W. M. G., & Broers, N. J. (2007). The effect of functional roles on perceived group efficiency during computer-supported collaborative learning: a matter of triangulation. *Computers in Human Behavior, 23*, 353–380.

Suthers, D. D., Hundhausen, C. D., & Girardeau, L. E. (2003). Comparing the roles of representations in face-to-face and online computer supported collaborative learning. *Computers & Education, 41*, 335–351.

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin, 63*, 364–399.

Van Boxtel, C., Van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction, 10*, 311–330.

Van der Meijden, H., & Veenman, S. (2005). Face-to-face versus computer-mediated communication in a primary school setting. *Computers in Human Behavior, 21*, 831–859.

Van der Pol, J., Admiraal, W., & Simons, P. (2006). The affordance of anchored discussion for the collaborative processing of academic texts. *International Journal of Computer-Supported Collaborative Learning, 1*, 339–357.

Van Drie, J., Van Boxtel, C., Jaspers, J., & Kanselaar, G. (2005). Effects of representational guidance on domain specific reasoning in CSCL. *Computers in Human Behavior, 21*, 575–602.

Walther, J. B. (1992). Interpersonal effects in computer-mediated interaction—a relational perspective. *Communication Research, 19*, 52–90.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner (Ed.), *Handbook of educational psychology* (pp. 841–873). New York: Simon & Schuster Macmillan.

Wegerif, R., Mercer, N., & Dawes, L. (1999). From social interaction to individual reasoning: an empirical investigation of a possible socio-cultural model of cognitive development. *Learning and Instruction, 9*, 493–516.

Wilson, J. M., Straus, S. G., & McEvily, B. (2006). All in due time: the development of trust in computer-mediated and face-to-face teams. *Organizational Behavior and Human Decision Processes, 99*, 16–33.

Yackel, E., Cobb, P., & Wood, T. (1991). Small-group interactions as a source of learning opportunities in second-grade mathematics. *Journal for Research in Mathematics Education, 22*, 390–408.

Yager, S., Johnson, R. T., Johnson, D. W., & Snider, B. (1986). The impact of group processing on achievement in cooperative learning groups. *The Journal of Social Psychology, 126*, 389–397.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: an overview. *Theory into Practice, 41*(2), 65–70.