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Visualization of participation: Does it contribute to successful computer-supported collaborative learning?

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Abstract

This study investigated the effects of visualization of participation during computer-supported collaborative learning (CSCL). It is hypothesized that visualization of participation could contribute to successful CSCL. A CSCL-environment was augmented with the Participation Tool (PT). The PT visualizes how much each group member contributes to his or her group's online communication. Using a posttest-only design with a treatment ($N = 52$) and a control group ($N = 17$), it was examined whether students with access to the PT participated more and more equally during collaboration, reported higher awareness of group processes and activities, collaborated differently, and performed better than students without access to the PT. The results show that students used the PT quite intensively. Furthermore, compared to control group students, treatment group students participated more and engaged more in coordination and regulation of social activities during collaboration by sending more statements that addressed the planning of social activities. However, equality of participation, awareness of group processes and quality of the group products was not higher in the treatment condition. Still, the results of this study demonstrate that visualization of participation can contribute to successful CSCL.

Keywords: Cooperative/collaborative learning; Computer-mediated communication; Distributed learning environments; Secondary education; Pedagogical issues

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1. Introduction

Over the last decades advanced information and communication technologies (ICT) have developed rapidly, which has led to many new computer applications, such as e-mail, chat rooms, video conferencing, simulations, and discussion forums. Many educational designers, policy makers, researchers, and teachers have embraced these applications as potentially useful tools for education. This interest has inspired many comparative studies, examining the effects of using ICT in education. Results of a meta-analysis showed that educational applications of ICT can have moderate positive effects on students' learning (Fletcher-Flinn & Gravatt, 1995).

In addition, new conceptions of learning have emerged. Researchers and theorists have increasingly recognized that learning is not only a cognitive, but also a social, cultural, and interpersonal, constructive process (Salomon & Perkins, 1998). As a result, instructional strategies whereby students work together in small groups, also known as *collaborative learning*, are increasingly being used in education, since these instructional strategies seem to fit well with this new conception of learning. Furthermore, the positive effects of collaborative learning have been well documented: it enhances students' cognitive performance (Johnson & Johnson, 1999; Slavin, 1996) and it stimulates students to engage in knowledge construction (Stahl, 2004).

More recently, educational researchers have begun to explore the combination of ICT applications and collaborative learning. As a result, a relatively new field of educational design and educational research has developed. This field, computer-supported collaborative learning (CSCL), deals with issues concerning collaboration, learning processes, and the use of computer-mediated communication (CMC). The primary aim of CSCL is to provide an environment that supports and enhances collaboration between students, in order to enhance students' learning processes (Kreijns, Kirschner, & Jochems, 2003). During CSCL, students work on group tasks, and produce a group product. A CSCL environment usually offers tools that facilitate sharing of information and ideas, and the distribution of expertise among group members (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). When students collaborate in a CSCL environment, they use CMC to communicate with group members. CMC can be either synchronous (e.g., through a chat facility or video conferencing), asynchronous (e.g., through a forum or e-mail), or a combination of both.

Because CSCL combines collaborative learning and the use of ICT, various educational, social, and motivational benefits of CSCL have been suggested and documented by research. First, concerning *educational goals*, students report higher levels of learning in CMC groups, compared to FTF groups (Hertz-Lazarowitz & Bar-Natan, 2002). More importantly, when compared to FTF groups, students in CMC groups deliver more complete reports, make decisions of higher quality, and perform better on tasks that require groups to generate ideas (Fjermestad, 2004). Second, concerning *social goals*, researchers have found that CMC groups, compared to FTF groups, engage in more complex, broader, and cognitively challenging discussions (Benbunan-Fich, Hiltz, & Turoff, 2003), and group members participate more equally (Fjermestad, 2004). Finally, CSCL also seems to affect *motivational outcomes*, since students who collaborated in CMC groups report higher levels of satisfaction (Fjermestad, 2004). Thus, it seems that CSCL can have a positive effects for education.

However, many studies have also demonstrated that several of things can, and in fact *do* go wrong during CSCL. A number of studies have shown that during CSCL, several communication- and interaction problems can occur between students. These results are in contrast with the studies mentioned above; some results even seem to contradict the results of other studies. For instance, students working in CMC groups sometimes perceive their discussions as more confusing, compared to FTF groups (Thompson & Coovert, 2003). Furthermore, Hobman, Bordia, Irmer, and Chang (2002) found higher levels of personal conflict between students working in CMC groups, compared to FTF groups. As a result, CMC groups need more time to reach consensus and make decisions (Fjermestad, 2004). Moreover, they are less productive, and group cohesiveness is lower (Straus, 1997; Straus & McGrath, 1994). These problems can also influence the results CMC groups attain. For example, compared to FTF groups, CMC groups need more time to complete tasks (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Fjermestad, 2004), perform worse on mixed-motive tasks (Barkhi, Jacob, & Pirkul, 1999), and report lower levels of satisfaction (Baltes et al., 2002). In sum, several problems can occur during CSCL, and therefore its potential may not always be realized.

2. Visualization of participation during CSCL: a solution?

In the above section, contradictory results concerning the possible benefits of CSCL were mentioned. Another important contradictory result found in CSCL studies concerns participation levels and equality of participation. Some studies report more equal participation of group members in CMC groups (e.g., Fjermestad, 2004), whereas other studies report dominance of some group members (e.g., Savicki, Kelley, & Ammon, 2002). Furthermore, in some CSCL studies researchers report low participation rates of all participating students (Lipponen et al., 2003; Veldhuis-Diermanse, 2002). It seems CMC groups may suffer from the same debilitating effects that sometimes occur in FTF groups (O'Donnell & O'Kelly, 1994; Salomon & Globerson, 1989), such as social loafing (group members invest less effort in a group, compared to working individually), or the free rider effect (students let other group members do the work).

If CSCL sometimes results in low overall participation rates or unequal participation, this is a cause for concern, since group productivity and student achievement depends on students' participation during collaboration (Cohen, 1994). When students participate equally during collaboration, every group member has the opportunity to contribute to group processes, to participate in knowledge construction, to give or request explanations, and to use and refine his or her skills (Webb, 1995). Given the importance of participation and equal participation, it is therefore important to ensure high levels of participation and equal participation of group members during CSCL.

Various strategies can be used to stimulate high levels of participation and equal participation. For example, a common strategy is to incorporate *positive interdependence* and *individual accountability* in the group task. Positive interdependence exists when all group members realize they have to work together to achieve their common goal. Individual accountability exists when group members are being held responsible for their contribution to the group goal. Positive interdepence and individual accountability may increase motivation to participate and foster social cohesion, and thus may serve to counter the free rider effect (Johnson & Johnson, 1999; O'Donnell & O'Kelly, 1994).

Another way to improve participation in CSCL may be through visualization of participation. Such a technique visualizes how much each group member relatively contributes to group discussion. It can be hypothesized that visualization of participation affects participation through *motivational* and *feedback* processes. Each of these processes will be explained below. For a detailed description of the visualization used in this study, the reader is referred to Section 5.

2.1. Motivational processes

Visualization of participation may influence collaboration through motivational processes. Motivational processes have been used to explain *why* students put effort into collaboration (Abrami & Chambers, 1996; O'Donnell & O'Kelly, 1994; Slavin, 1996). To counter productivity loss in groups (e.g., caused by free-riding), a possible solution could be to provide group members with an incentive that enhances their motivation to contribute to collaboration (Shepperd, 1993). When participation of group members is visualized, this makes the contribution of each group member to the group identifiable; establishing a link between a group member and his or her contribution to the collaboration (Jermann, 2004). This identifiability may provide several motivational incentives for group members to invest effort into collaboration. For example, visualization of participation can motivate group members to participate more, because they are unable to ''hide in the crowd'' and they can be evaluated negatively when they participate insufficiently. This *social evaluation* can motivate students to increase their participation (Shepperd, 1993). In addition, though *social comparison*, that is, through comparing themselves to other group members, students may be motivated to set higher standards and to try to increase their participation (Michinov & Primois, 2005; Wheeler, Suls, & Martin, 2001).

2.2. Feedback processes

Additionally, visualization of participation can also be considered a form of *external feedback* (Butler & Winne, 1995), that is, feedback generated by sources other than the student him- or herself (i.e., by teachers, group members, or computer displays). First, external feedback may provide students with information, which they can use to *monitor* their problem solving progress. External feedback allows students to determine whether selected strategies are working as expected, and whether group performance and products are up to standard. Thus, visualization of participation may provide group members with feedback on how well they are collaborating, and whether they have selected an appropriate collaboration strategy (i.e., equal participation of all group members). Similarly, visualization of participation can also be used for *group processing*. Group processing occurs when group members discuss how well their group is functioning and how group processes may be improved (Webb & Palincsar, 1996). These discussions may help groups pinpoint, comprehend, and solve collaboration problems (e.g., free riding by some group members) and may contribute to successful collaborative behavior (Yager, Johnson, Johnson, & Snider, 1986). Group processing is also facilitated because visualization of participation may serve a *mediating* purpose, since it may help group members to externalize and articulate their thoughts about collaboration processes by providing them with appropriate information and concepts (Fischer, Bruhn, Grasel, & Mandl, 2002; Teasley & Roschelle, 1993). For example, after examining the visualization, a group member may feel someone is free riding, which may stimulate him or her to discuss this with other group members by referring to the visualization.

Second, the external feedback provided by visualization of participation can also raise students' *awareness* of the group processes and activities taking place. Because visualization of participation shows group members' participation rates, it could raise students' awareness of group processes, and more specifically, of participation. Several researchers have suggested that awareness can play an important role in facilitating CSCL (Dourish & Bellotti, 1992; Gutwin & Greenberg, 2004; Kirschner, Strijbos, Kreijns, & Beers, 2004). When students are collaborating, they have to be aware of the activities of their group members, because it allows them to decide which activities they have to engage in. This enables them to anticipate group members' actions.

3. Collaborative activities during collaboration

In addition to stimulating participation and equality of participation, visualization of participation may also influence the way students collaborate. For example, as described above, it may stimulate students to engage in group processing. Since one of the aims of this study is to investigate the effects of visualization of participation on the manner in which students collaborate, it is important to describe the different activities students perform during 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. Group members need to share and discuss task-related information, in order to pool their informational resources, make valuable information available to all group members (Jehn & Shah, 1997), verbalize their ideas and opinions (Van der Linden, Erkens, Schmidt, & Renshaw, 2000), and ask questions that elicit important information (Johnson, Johnson, Roy, & Zaidman, 1985; King, 1994). These task-related activities contribute to a group's production function (McGrath, 1991) and stimulate successful problem solving and individual learning. For example, Henry (1995) instructed group members to share task-relevant information on a judgment task. These groups outperformed groups who did not receive this instruction. Furthermore, in a study by Teasley (1995), dyads were instructed to generate hypotheses. Dyads that verbalized their ideas and opinions produced better hypotheses than dyads that did not verbalize their ideas.

Second, groups also have a member-support and well-being function (McGrath, 1991). Thus, group members have to attend to the social and emotional element of collaboration to successfully complete a group task (Forman & Cazden, 1985; Kumpulainen & Mutanen, 1999; Rourke, Anderson, Garrison, & Archer, 1999). 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 & Shah, 1997; Rourke et al., 1999). On the other hand, behaviors such as swearing or displaying negative emotions may have a negative impact on group cohesion (Johnson et al., 1985). Thus, groups have to *perform social activities* that help to maintain the group. For example, in a study by Jehn and Shah (1997) positive communication (e.g., offering positive comments and motivating group members) was related to performance on certain group tasks.

Third, collaboration also involves *coordination or regulation of task-related activities* (Erkens, 2004; Erkens, Jaspers, Prangsma, & Kanselaar, 2005). Coordination of task-related activities involves performing them in the right order and at the right time, without conflicting with the

Table 1
Collaborative activities during collaboration

	Task-related activities	Social activities
Performance	• Discussing task information • Sharing task information • Offering task-related opinions • Asking task-related questions	• Maintaining a positive group atmosphere • Disclosing personal information • Indicating understanding or misunderstanding
Coordination/regulation	• Making task-related plans • Discussing task-related strategies • Monitoring of task progress • Evaluation of task progress	• Making plans to collaborate • Discussing collaboration strategies • Monitoring group processes • Evaluating group processes

activities of other students (Gutwin & Greenberg, 2004). During collaboration, group members need to coordinate their activities to determine a common course of action. Therefore, metacognitive activities that regulate task performance, such as making plans and monitoring task progress, are considered important to successful group performance (Artzt & Armour-Thomas, 1997; Van Meter & Stevens, 2000). For instance, in a study on computer-supported collaborative writing, planning activities were related to the quality of written texts (Erkens et al., 2005). Furthermore, Jehn and Shah (1997) demonstrated task monitoring was related to performance on group tasks.

Fourth, similar to task-related activities, collaboration requires *coordination or regulation of social activities* as well (Ellis, 1997; Erkens, 2004; Forman & Cazden, 1985). 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. For instance, studies by Yager et al. (1986) and Johnson et al. (1990) demonstrated the positive influence of group processing. That is, when group members discuss how their group is performing and how collaboration may be improved, group performance is increased.

Table 1 depicts the different types of collaborative activities group members have to engage in during collaboration: task-related and social. Furthermore, these activities refer to two levels: a performance level and a coordination or regulation level. Successful collaboration requires that group members attend to both types of activities at both levels.

4. Research questions

This study investigates the effects of visualization of participation during CSCL. An existing CSCL-environment will therefore be enhanced with a new tool that visualizes students' participation during collaboration: the Participation Tool (PT, described below). The following research questions will be addressed:

1. How intensively do students use the PT while collaborating online?
2. Do students who have access to the PT participate more, and more equally, during collaboration than students who do not have access to the PT?

3. Are students who have access to the PT more aware of group processes and activities during collaboration than students who do not have access to the PT?
4. Do students who have access to the PT engage in different collaborative activities than students who do not have access to the PT?
5. Do groups who have access to the PT perform better on an inquiry group task than groups who do not have access to the PT?

First, it is expected that the PT will contribute to students' participation during CSCL through motivational and feedback processes as described above. Second, it is expected that the PT will help students to become more aware of the group processes and activities taking place during collaboration, since it provides them with feedback about the participation rates of group members. Furthermore, it is expected that the PT will affect the way students collaborate. Because the PT gives students information about the way their group is functioning, it may stimulate students to engage in coordination or regulation of social activities (see Table 1). For example, the PT may help group members to monitor group processes, evaluate how their group is collaborating, or help them to make plans for collaboration. Finally, it is expected that, through higher levels of participation, higher awareness and different collaborative activities, the PT will contribute to groups' performance on group tasks, thus increasing the efficacy of collaboration.

5. Method and instrumentation

5.1. Design

A posttest-only design with a treatment and a control group was used to answer the research questions. Treatment group students had access to the PT; control group students did not. Three different classes participated in the study. Each class was randomly assigned to either the treatment or the control group. Thus, all students from one class were in the same condition: either treatment or control. Two classes were assigned to the treatment group, and one class was assigned to the control group. The treatment group consisted of 55 students (17 groups), and the control group of 17 students (five groups).

5.2. Participants

Participants were 72 eleventh-grade students (30 male, 42 female) from a secondary school in The Netherlands. Students came from three different classes and were enrolled in the second stage of the pre-university education track. Mean age of the students was 16 years ($SD = .58$, $min = 15$, $max = 18$). Three treatment group students were omitted from all analyses because they attended less than half of the lessons. Therefore, the final number of participants was 52 treatment group and 17 control group students.

During the experiment, the participating students collaborated in groups of three or four; students were randomly assigned to a group by the researchers. Therefore, group composition was heterogeneous with respect to ability and gender. In order to eliminate combinations of students who could not get along with each other, the group compositions were verified by their teachers. The initial group compositions were approved.

5.3. Tasks and materials

5.3.1. CSCL-environment: VCRI

Participating students collaborated in a CSCL-environment called Virtual Collaborative Research Institute (VCRI, Jaspers, Broeken, & Erkens, 2004). VCRI is a groupware program designed to support collaborative learning on research projects and inquiry tasks. Every student works at one computer. Fig. 1 shows a screenshot of the VCRI-program, detailing the most important tools.

The *Chat* tool is used for synchronous communication between group members. The chat history is stored automatically and can be re-read at any time. Students can read the description of the group task and search for relevant historical information using the *Sources* tool. The *Co-Writer* is a shared word-processor, which can be used to write a group text. Using the Co-Writer, students can work simultaneously on different parts of their texts. The *Statusbar*, in the bottom of the screen, displays who is online, and which tools group members are currently using, and thus serves as a tool to raise students' workspace awareness (Gutwin & Greenberg, 2004). Other tools of the VCRI-program, not shown in Fig. 1, include for example the *Planner*, which can be used to organize and plan group activities, the *Diagrammer*, which can be used to construct argumentative diagrams, and the *Reflector*, which is used by students to reflect on group processes.

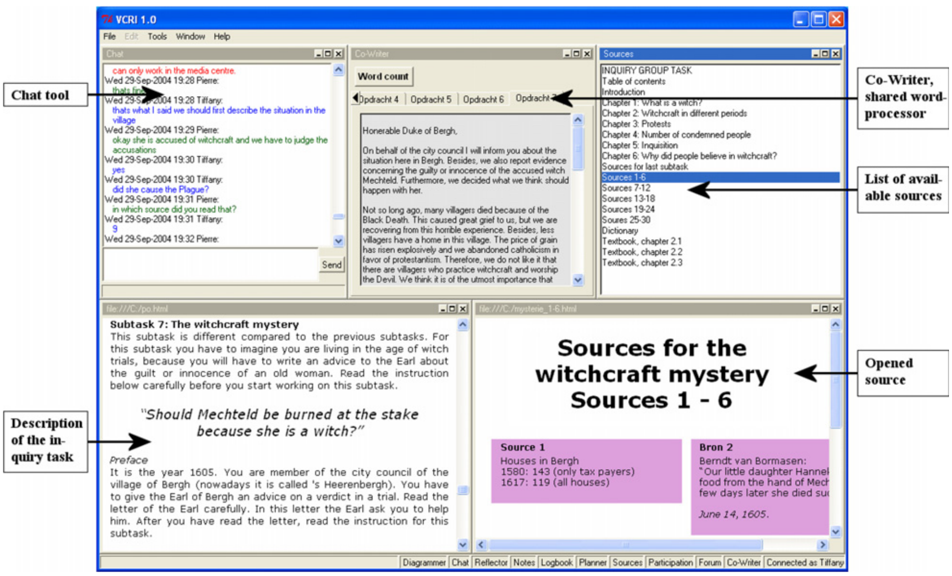

Fig. 1. Screenshot of the VCRI-program, detailing the most important tools (translated from Dutch).

5.3.2. Inquiry group task

The participating students collaborated on a historical inquiry group task. Inquiry tasks are an important part of the curriculum in the Dutch upper secondary levels. Subject of the task was "Witches and the persecution of witches". This task was developed together with the participating teachers. The task consisted of *seven subtasks* that addressed various aspects of the subject. The introduction of the task stressed the importance of working together as a group on the subtasks, and pointed out that group members were themselves responsible for the successful completion of the task. Students were instructed to use the VCRI program to communicate with group members. Students were told they had eight lessons to complete the inquiry task.

The groups had to use different historical and (more) contemporary *sources* to answer questions about: (1) the definition of a witch, (2) how witches were perceived in different historical periods, (3) protests against the persecution of witches, (4) the number of people that were condemned for witchcraft, (5) the role of the inquisition, and (6) reasons why people believed in witchcraft. Approximately 40 sources from textbooks and the Internet were available to the students through the *Sources* tool.

The final subtask[1] was somewhat different compared to the other subtasks. To complete this subtask, students had to imagine they were 17th century judges. They were asked to write an advice about the guilt or innocence of an old woman. The woman lived in a small village, plagued by the Black Death and famine.

To successfully complete the inquiry group task, all group members had to participate during the group process. *Positive interdependence* and *individual accountability* were incorporated in the group task, in order to ensure collaboration between group members (Johnson & Johnson, 1999). Positive interdependence was realized in different ways. First, because the inquiry task was quite extensive and complex, no group member was likely to solve the task on his or her own. Group members needed to make plans, generate alternatives and solutions, and give or request explanations. Furthermore, students were told they would receive a group grade for their final version of the task and the quality of their collaboration would also partly determine their grade. Finally, for several of the subtasks, group members needed to integrate their perspectives in a jointly written text. Individual accountability was realized in several subtasks. For example, in the final subtask each student was responsible for a specific part of the advice, while the group as a whole was responsible for making the advice into a coherent whole. Thus, although task division between group members could be efficient, the present group task required high levels of collaboration in order to successfully complete the task.

5.4. Treatment: Participation Tool

To answer the research questions the VCRI was augmented with a new tool, the PT. The PT visualizes how much each group member contributes to his or her group's *online communication*, through for example the Chat tool shown in Fig. 1. The PT does not take into account students' activities in other tools, such as the shared word processor.

[1] This subtask was based on a task developed for the *Active historical thinking* textbook (De Vries, Havekes, Aardema, & Van Rooijen, 2004).

In the PT, each student is represented by a sphere; group member's spheres are grouped together. For example, Fig. 2 shows a class of students. The students from this class were assigned to several groups. For instance, the four spheres in the upper right of the Figure represent one group of four students. While students are communicating with each other in the online environment, the PT is continually updated, allowing students to compare their participation rates to those of their group members.

In the PT, the *distance* of a sphere to the group center indicates the *number of messages sent* by the student, compared to the other group members. If a sphere is close to the center, the student has sent more messages compared to a student who is farther away from the center. The *size* of a sphere indicates the *average length of the messages* sent by a student, compared to the other group members. If a sphere is smaller, the student has sent shorter messages compared to a student whose sphere is bigger.

Using the PT, students can zoom in, to examine their own group more closely, or zoom out to examine the whole class. In Fig. 2, the PT is zoomed out, displaying much of the class. This enables students to examine the participation rates of students from other groups. For instance, the *distance of a group* to the center of the whole class indicates the *number of messages* this group has sent, compared to other groups. Thus, a group that has sent many messages is located closer to the center of the class, compared to a group that has sent a few messages. In addition, the *size of the grey circles* in the middle of each group, indicate the *average length of the messages* sent by the groups. If a grey circle is bigger, this group has sent longer messages compared to a group whose grey circle is smaller.

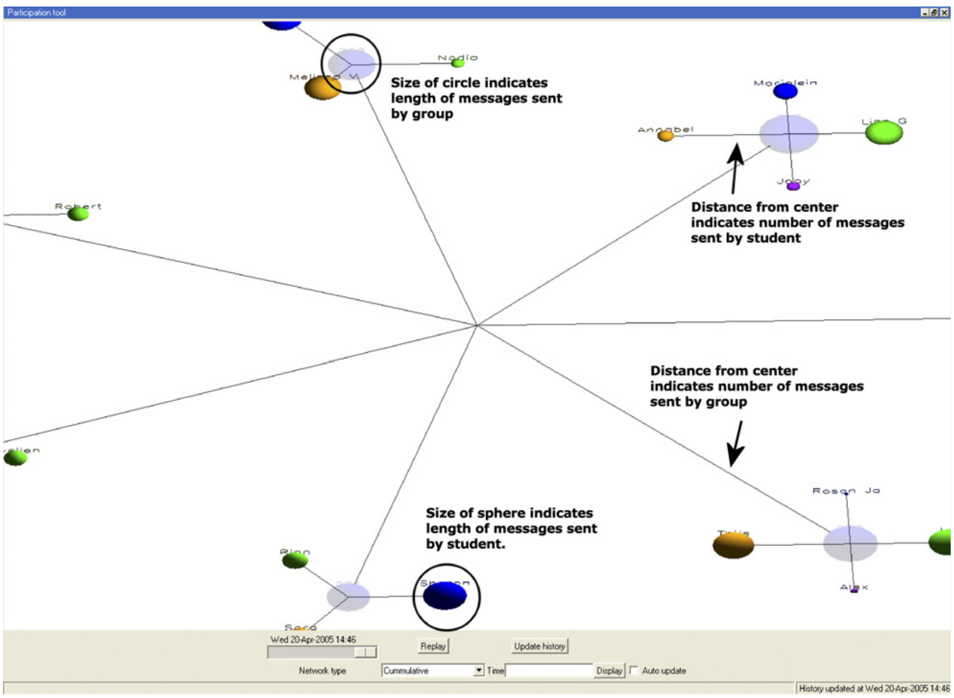

Fig. 2. Screenshot of the Participation Tool.

The PT can be opened and examined by students at any time. The visualization can be rotated using the mouse, to examine the visualization from a different perspective. The PT can display students' cumulative participation rates (i.e., total number of messages sent), but can also display a moving average. The moving average displays students' participation rates during the past 20 min. After a while, the moving average display is more sensitive to changes than the cumulative display. This is because when students have sent many messages, sending one long message does not influence the cumulative display very much. But in a period of 20 min, the number of messages is limited, which means that sending one long message has more impact on the visualization (i.e., the size of the sphere will increase more dramatically). Furthermore, it is important to note that students are *not forced* to use the PT. In order words, it is available and students can use it whenever they want, but they can also choose to ignore or close it whenever they want.

Finally, it should be noted that the PT visualizes the *quantity* of the online communication between group members and the equality of participation between group members. Obviously, the quality of the messages sent by the students is also very important for successful collaboration. The PT does not visualize the quality of the messages sent by the students. Nonetheless, quantity of communication is also important for successful collaboration. For example, when unequal participation exists between group members, this is an indication of free riding behavior. Furthermore, if a group member only types a few messages, he or she cannot be regarded a full-fledged group member, although his or her messages may be of high quality. In short, quality and quantity of collaboration should go hand in hand. Ideally, group members should contribute many, high-quality messages to the online discussion.

5.5. *Units of analysis*

To answer the research questions regarding the influence of the PT on participation and collaboration, a decision had to be made regarding the unit of analysis. To determine participation in CSCL settings, researchers have mostly used the number of messages sent (e.g., Adrianson, 2001; Lipponen et al., 2003), or the number of words written (e.g., Savicki et al., 2002; Straus, 1997) as the unit of analysis. However, using the message as a measure of participation can be considered arbitrary in CSCL, since CMC discourse differs considerably from FTF discourse. For example, in synchronous CMC there are fewer conventions about the acceptable length of messages. As a result, some users only send one proposition per chat message, while other users type multiple sentences, combining several propositions (Howell-Richardson & Mellar, 1996). The chat messages sent by the participating students, were therefore segmented into *dialogue acts* (Erkens, 2004). Dialogue acts indicate the communicative function of a chat message (responding, informing, argumentation, commanding, or eliciting). One dialogue act corresponds to one proposition.

The computer program Multiple Episode Protocol Analysis (MEPA) was used for the analyses of chat protocols (Erkens, 2003). To segment chat messages, a segmentation filter was used. A filter is a program, which can be specified in the MEPA program for automatic rule based coding or data manipulation. The filter automatically segments message into dialogue acts, using over 300 decision rules. Punctuation marks and connectives (e.g., "and", "but") are used to segment a chat messages into dialogue acts. For example, the chat message "The first answer is okay, but the second is not" is split into two dialogue acts ("The first answer is okay" and "but the second is not"), whereas the message "That's fine" is treated as one dialogue act.

Dialogue acts were also used as the unit of analysis to answer the fourth research question. This was done because chat messages can also refer to multiple collaborative activities. For example, the message "Hi, let's start task 6" contains two communicative functions and can therefore be segmented into "Hi" and "let's start task 6". These two parts also refer to different collaborative activities. The first part is a greeting, whereas the second part refers to the planning of task-related activities.

5.6. Use of the Participation Tool

In order to analyze how intensively students used the PT (research question one), all user actions were logged and stored. Based on the log files, two scores were calculated. First, the total number of times a student used the PT (e.g., opening and closing the tool, rotating the view) was calculated. Second, the total time (in minutes) a student displayed the PT on his or her screen was calculated. For example, when a student opened or maximized the PT, and closed or minimized the tool 5 min later, 5 min were added to the total time.

5.7. Student participation and equality of participation

It is expected that the PT will influence student participation during collaboration. Moreover, it is expected that the PT will lead to more equal participation between group members (research question two).

Measure of student participation. As described above, dialogue acts were used as the unit of analysis to determine participation. A distinction was also made between *long* (>5 words) and *short dialogue acts* (⩽5 words). Short dialogue acts are used mainly for back channeling, supporting, and confirming (e.g., "okay", "I agree"), whereas longer dialogue acts are used mainly for transfer of content and regulation of task and group processes. The former can be considered non-substantive contributions, since they are less important for the development of the conversation. In contrast, the latter can be considered substantive contributions, which are expected to contribute to whether one is considered a useful participant during conversation (Bonito, 2000).

Measure of equality of participation. To examine the influence of the PT on equality of participation, the Gini coefficient was used. The Gini coefficient is a *group level measure*, which was calculated for all 22 groups involved in this study. The coefficient sums, for each group, the deviation of its group members from equal participation. This sum is divided by the maximum possible value of this deviation (Alker Jr., 1965; Dubrovsky, Kiesler, & Sethna, 1991; Warschauer, 1996). Thus, the coefficient ranges between 0 (perfect equality; all students contribute equally to discussion) and 1 (perfect inequality; one student completely dominates discussion).

5.8. Awareness of group processes and activities

To measure students' awareness of group processes and activities during collaboration, a questionnaire was administered to the participating students. Based on the work of other researchers (Gutwin & Greenberg, 2004; Mendoza-Chapa, Romero-Salcedo, & Oktaba, 2000), 14 items were formulated. The items addressed: (a) awareness of the activities of others in the VCRI,

(b) awareness of group members' tasks, (c) awareness of group members' participation during online collaboration, and (d) awareness of conversational processes.

An exploratory factor analysis using principal axis factoring was conducted to identify latent variables underlying the 14 items. Based on the examination of the screenplot and the K1-rule (Hetzel, 1996), two factors were extracted. Using an oblique Promax rotation with a salience level of |.40|, factor one was identified as "Awareness of participation". This factor consisted of four items (e.g., "I knew how much my group members contributed to the discussion") with a Cronbach's α of .72. Factor two was identified as "Awareness of group members' tasks". This factor consisted of three items (e.g., "I knew what my group members were working on") with a Cronbach's α of .78. In total, the two factors explained 34.30% of the total variance. As can be expected when using oblique rotations, the two factors correlated significantly, $r = .62$, $\mathrm{df} = 61$, $p = .00$. Because of this significant correlation, it was examined whether it was possible to extract only one factor instead of two. This was not the case, as the resulting solution could not be interpreted in a meaningful way. It was concluded that the two-factor solution was more meaningful, because the two factors seemed to represent two different types of awareness. Factor scores were subsequently used in analyses of differences between treatment and control groups.

5.9. Collaborative activities

To answer the fourth research question, regarding the influence of the PT on students' collaborative activities, a coding scheme was developed. The aim of this coding scheme was to provide insight into the task- and group-related processes taking place between students while working on the inquiry group task. This section describes the development and interobserver reliability of the coding scheme.

Description of the coding scheme. As described above, and summarized in Table 1, different types of activities are necessary to successfully complete a group task. These types of activities are reflected by the four different dimensions of the coding scheme. Each dimension contains two or more coding categories. In total, the scheme consists of 19 categories.

The first dimension referred to *performance of task-related activities*. This dimension 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*). In brackets, the abbreviations of the codes are given. These abbreviations will be used from time to time in the analyses presented below.

The second dimension referred to *regulation and coordination of task-related activities*, encompassing four categories. First, planning (*MTaskPlan*) involved discussion of strategies necessary to complete the task, choice of appropriate strategies, 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 positive (*MTaskEvl+*) or negative (*MTaskEvl−*).

Performance of social activities was the third dimension of the coding scheme. This dimension contained five categories. First, greetings (*SociGree*) were included, since they contribute positively to group atmosphere and a feeling of social presence (Rourke et al., 1999). Second, social support remarks (*SociSupp*) referred to comments that contributed positively to group atmosphere, such as exchanging positive comments, displaying positive emotions, and disclosure of personal information. Third, social resistance remarks (*SociResi*) referred to behaviors that contributed negatively to group atmosphere, such as insulting group members and displaying negative emotions. Fourth, shared understanding (*SociUnd+*) referred to confirmations, acceptances, and indications of agreement, which serve to reach and maintain shared understanding during collaboration. Similarly, loss of shared understanding (*SociUnd−*) referred to denials, disagreements, and expressions of incomprehension.

The fourth dimension referred to *regulation and coordination of social activities*. This dimension contained four categories. First, planning (*MSociPlan*) involved discussion of collaboration strategies instead of discussion of task-related strategies, such as helping each other or proposals to work together on certain tasks. Second, monitoring (*MSociMoni*) referred to the exchange of information that could be used to monitor group processes. Finally, evaluation involved appraisal and discussion of group processes and collaboration, which could be positive (*MSociEvl+*) or negative (*MSociEvl−*). These four categories reflect *group processing*; they indicate group members discuss how well their group is performing and how collaboration can be improved. It was expected that the PT would stimulate group members to engage more in these types of activities.

Statements that addressed neutral, negative, or positive technical aspects of the CSCL environment were also included in the coding scheme (codes *TechNeut*, *TechNega*, and *TechPosi*). Although these statements can refer to task-related activities, it was decided to separate them from the other codes, because they are different in nature and focus (i.e., they are aimed more at the discussion of the CSCL environment, instead of discussion of the task). Finally, statements that did not fit into any of the previously mentioned categories were coded as *Other*. These codes mostly referred to nonsense remarks.

Interobserver reliability. Two researchers were involved in the development and refinement of the coding scheme. In order to examine interrater agreement 601 dialogue acts were coded independently by two raters. An overall Cohen's κ of .86 was found, a satisfactory result. The category Kappa's (Cicchetti, Lee, Fontana, & Dowds, 1978) are shown in Table 2. Note that for the codes

Table 2
Collaboration acts (*abbreviation*) and category Kappa's

	Task-related activities		Social activities	
	Codes	κ	Codes	κ
Performance	• Info exchange (*TaskExch*)	.85	• Greetings (*SociGree*)	.89
	• Asking questions (*Taskques*)	.89	• Social support (*SociSupp*)	.85
			• Social resistance (*SociResi*)	.73
			• Mutual understanding (*SociUnd+*)	.92
			• Loss of mutual underst. (*SociUnd−*)	.83
Coordination/regulation	• Planning (*MTaskPlan*)	.87	• Planning (*MSociPlan*)	.86
	• Monitoring (*MTaskMoni*)	.81	• Monitoring (*MSociMoni*)	.84
	• Positive evaluations (*MTaskEvl+*)	.84	• Positive evaluations (*MSociEvl+*)	–
	• Negative evaluations (*MTaskEvl−*)	1.00	• Negative evaluations (*MSociEvl−*)	.88
Other	• Neutral technical (*TechNeut*)	1.00	• Other/nonsense (*Other*)	.67
	• Negative technical (*TechNega*)	–		
	• Positive technical (*TechPosi*)	–		

MSociEvl−, *TechNega*, and *TechPosi* it was impossible to compute a category Kappa, since these codes were not present in the dialogue acts coded by the raters. However, since most other category Kappa's are satisfactory, it can be expected that the category Kappa's for these three codes are also sufficient.

5.10. Group performance scores

The quality of the texts written by the groups for the subtasks of the inquiry group task was examined in order to answer the final research question regarding the influence of the PT on group performance. For this purpose an assessment form was developed.

Using this assessment form, three quality aspects were assessed for each subtask. *Use of sources* referred to the manner how students incorporated the available sources into their texts. This quality aspect contained two items: completeness of sources used in the written text, and copy-pasting of information from sources to the written texts. *Content and argumentation* referred to the manner in which students formulated their answers and supported their answers with arguments. Since each subtask addressed different aspects of witchcraft, the content and argumentation aspect was formulated differently for each subtask. However, the scoring-scale was the same for each aspect. The amount of items that addressed content and argumentation also differed for each subtask, since some subtasks were more extensive than others. *Text construction and language* referred to the manner how students' written text had an adequate text construction and correct language. This quality aspect contained three items: text construction, text structure, and correctness of language use.

All items of the assessment form were answered on a three-point scale, with 0 indicating poor quality and 2 good quality. To determine whether students directly copy-pasted information from the sources to their text, the program WCopyFind (http://plagiarism.phys.virginia.edu/Wsoftware.html) was used. This program compares written texts to the available sources and determines how many percent of the written text is copy-pasted directly from the sources. This percentage was used to determine whether the group received 0, 1, or 2 points. Groups that copy-pasted less than 34% of their text from the sources, received 2 points; groups that pasted more than 66% of their text received no points. In total, groups could receive up to 12 points for subtasks one, five and seven, 14 points for subtasks two, four and six, and 18 points for subtask three. Thus, in total 96 could be earned. In the analyses presented below, results will be presented for total points earned and points earned for each subtask.

To check the objectivity of the scoring, two researchers independently scored a number of tasks. Each researcher filled out the assessment form for 8–10 groups for four subtasks. For use of sources, content and argumentation, and text construction and language, interrater agreement reached 88.5%, 77.5%, and 75.0%, respectively. Furthermore, to examine the internal consistency of the scoring procedure, Cronbach's α was calculated and was found to be .81.

5.11. Procedure

The participating students worked in small groups on the inquiry group task for a period of four weeks. In the first lesson, the task was introduced to the students by their teachers. During this lesson, the most important features of the CSCL-environment were also explained to the students by the experimenters. After the first lesson, another seven history lessons were devoted to the inquiry group task. During these lessons, the students collaborated on the group task. The teachers were standby to answer task-related questions, while the experimenters were standby to answer technical questions or to solve any technical problems. The students were allowed to work on the inquiry task during free periods. For example, students could work in the media center when they had spare time in their timetable. However, students could only access the CSCL-environment from school, not from their homes. After eight lessons the students were required to hand in their final versions of the group task. These final versions were graded by their teachers. After the last lesson, a questionnaire was administered to the students in order to assess students' awareness of collaborative processes and activities during online collaboration.

5.12. Data analysis

To investigate the effects of the PT on student participation during CSCL, one solution would be to compare the participation rates of students who used the PT to the participation rates of students who did not use the PT, using an independent samples *t* test with *participation* as a dependent variable and *condition* (PT or no PT) as an independent variable. However, it is important to note that students' participation rates are most likely *nonindependent* (Bonito, 2002; Kenny, Mannetti, Pierro, Livi, & Kashy, 2002). According to Kenny et al. (2002), *mutual influence* is the most important source of nonindependence when students collaborate. That is, what one group member says, is influenced by, and influences the contributions of other group members. Therefore, students who are in the same group behave in more or less similar ways. Thus, it can be expected that students who are, for example, in a group with highly active group members, will also be stimulated to participate more; whereas students in groups with low participating group members will participate less.

When nonindependence exists between group members, this violates one of the assumptions of the independent samples *t* test (and other statistical methods, such as ANOVA and regression analysis). Since the independent variable (condition) is a between-groups independent variable (i.e., its value is the same for all group members, but differs across groups), nonindependence makes a *t* test too liberal, thus resulting in an increase of Type I errors (Bonito, 2002; Kenny et al., 2002; Snijders & Bosker, 1999). Therefore, using a *t* test to determine the effect of the PT would not be appropriate.

Presence of nonindependence can be examined by computing the intraclass correlation coefficient for each dependent variable. This correlation represents the dependency between scores of students in the same group. This coefficient can also be tested for significance. However, Kenny et al. (2002) argued that, given the usual small sample sizes in small group research, the correlation coefficient may not be significant, even though it is actually large enough to bias the *t* test. Kenny et al. (2002) therefore propose to assume the data are nonindependent, even though the intraclass correlation coefficient may not be significant. As a result, *multilevel analysis* was used to examine the effects of the PT, since this type of analysis can be used when data have a hierarchically nested structure (e.g., students nested within groups) and nonindependence is present.

Multilevel analysis involved estimating two models: an empty model and a model including predictor variables. For both models, the deviance (a measure of the goodness of fit of the model) was computed. By comparing the deviance of the latter model with the empty model, a decrease in deviance can be calculated. When this decrease in deviance is significant (tested with a χ^2-test), it can be concluded the latter model is a better model. Furthermore, the estimated parameters of the predictors can be tested for significance by dividing the regression coefficient by its standard error. This so-called *t*-ratio has approximately a standard normal distribution (Snijders & Bosker, 1999).

The line of reasoning concerning the nonindependence of students' participation rates can also be extended to the other individual measures in this study (research questions three and four). Therefore, the effects of the PT on students' awareness and the manner in which students collaborated will be examined using multilevel analysis as well.

6. Results

6.1. Use of the PT

The first research question concerned how intensively students used the PT. On average, treatment group students used the PT 76.04 times (SD = 48.03, min = 9, max = 286), and displayed the PT for 64.33 min (SD = 47.89, min = .52, max = 186.80) on their screen. Since the average time a student was online in the VCRI environment was 361.01 min (SD = 79.65), most students displayed the PT a considerable amount of time (18%) on their screen and used the PT on a regular basis (about once every 5 min).

The large standard deviations for use of the PT and display time of the PT show that there were considerable differences between students in the extent to which the PT was actually used. Thus, to examine whether how intensely the PT was used, influenced the dependent measures (e.g., participation, awareness), correlations were calculated between use of the PT and display time of the PT and the dependent measures. Because the total time students were online correlated significantly positively with use of the PT and display time of the PT ($r = .36$, $p = .01$, and $r = .34$, $p = .01$, respectively), *partial correlations* were calculated, which controlled for time online.

6.2. Participation and equality of participation

Table 3 shows the descriptive statistics and effect sizes[2] for differences between treatment and control groups for participation (research question two). Overall, the mean scores of treatment group students were higher compared to control group students.

Before examining the effect of the PT on participation, it was investigated whether there were differences between the two conditions regarding the time students were online. Treatment group students were not longer online ($M = 370.68$ min, SD = 86.01), compared to control group ($M = 358.28$ min, SD = 68.67) students, $t(21) = .33$, $p = .37$. Although these differences were not significant, the total time a student was online was used as an individual level predictor variable. This was done to account for the fact that some group members worked longer in the CSCL-environment than others. For example, some students worked longer because they also

[2] Effect sizes (ESs) were calculated using Carlson and Schmidt's (1999) formula for a posttest only with control group design.

Table 3
Means, standard deviations, and effect sizes for measures of participation for treatment and control groups

Measure of participation	Treatment group students ($N = 52$)		Control group students ($N = 17$)		ES
	M	SD	M	SD	
Dialogue acts	301.21	159.86	235.24	75.32	.46
Long dialogue acts (>5 words)	114.08	70.99	72.89	30.39	.65
Short dialogue acts ($\leqslant$ 5 words)	187.13	96.69	162.35	60.53	.28

worked during free periods, whereas other students worked shorter because they were ill during a lesson.

Table 4 shows the results of the multilevel analysis for the three measures of participation. For all measures of participation, time online was a significant predictor. This indicates that students who were online longer, produced more dialogue acts, $t(68) = 2.90$, $p = .00$, more long dialogue acts, $t(68) = 1.89$, $p = .03$, and more short dialogue acts, $t(68) = 3.15$, $p = .00$.

For the total number of dialogue acts, the effect of condition was not significant. Students who used the PT did not produce more dialogue acts compared to students without the PT, $t(21) = 1.11$, $p = .14$. Furthermore, students who had access to the PT did not type more short dialogue acts, compared to students who did not have access to the PT, $t(21) = .68$, $p = .25$. However, students who had access to the PT, typed more long dialogue acts, compared to students who did not have access to the PT, $t(21) = 1.76$, $p = .05$.

The effect of the PT on equality of participation was examined, using the Gini coefficient. Since this dependent variable is a *group level* variable, a *t* test for independent samples was used to examine differences between treatment and control group. As can be seen in Table 5, the Gini coefficients were not far from zero, indicating a, more or less, equal distribution of participation among group members. Note that the number of observations is different in this Table, compared to Table 3, because groups are analyzed instead of students. On average, the Gini coefficients are

Table 4
Results of multilevel analysis for measures of participation

	Dialogue acts		Long dialogue acts		Short dialogue acts	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	55.74	78.90	30.02	35.78	27.76	48.72
Predictor 1: minutes online	.58**	.20	.17*	.09	.41**	.13
Predictor 2: condition	27.34	24.64	19.11*	10.83	8.34	14.94
Variance group level	5563.73	2993.13	990.44	584.81	1952.52	1108.54
Variance student level	1245.26	2569.31	2688.50	554.60	4883.54	1006.67
Total variance explained (%)	13.44		12.57		12.75	
Deviance	865.66		757.52		799.68	
Decrease in deviance compared to empty model (df = 2)	8.93*		6.17*		10.08**	

* $p < .05$.
** $p < .01$.

Table 5
Means and standard deviations for treatment and control groups for equality of participation (group as unit of analysis)

Equality of participation	Treatment groups ($N = 17$)		Control groups ($N = 5$)		t	p	ES
	M	SD	M	SD			
Dialogue acts	.17	.09	.09	.04	1.73	.10	.88
Long dialogue acts (>5 words)	.18	.11	.14	.05	.81	.43	.41
Short dialogue acts (⩽5 words)	.17	.09	.12	.05	1.05	.31	.54

Note. The *group level* measure of equality used, the Gini coefficient, ranges from 0 to 1, with 0 indicating perfect equality and 1 perfect inequality.

higher for the treatment groups, indicating slightly more inequality of participation. Moderate ESs were found, although the differences did not reach statistical significance.

To examine how the use of the PT was related to students' participation during collaboration, a number of partial correlations (e.g., between times the PT was used and dialogue acts typed) were calculated. One significant partial correlation emerged: the total time the PT was displayed correlated significantly negatively with the Gini coefficient for long dialogue acts ($N = 14$, $r = -.62$, $p = .01$). This indicates that in groups that displayed the PT more on their screen, the number of long dialogue acts was more equally distributed.

6.3. Awareness of group processes and activities

The third research question concerned the effect of the PT on students' awareness of the group processes and activities taking place during online collaboration. One treatment and two control group students failed to complete the questionnaire. Table 6 shows the findings for students' awareness of group processes and activities. Overall, students indicated medium to high awareness of group processes and activities. Apparently, students were aware of what was happening in the VCRI, and what their group members were doing.

Multilevel analysis was used to examine differences between treatment and control group students by estimating two models. Again, the empty model was estimated first. Second, a model that included condition (PT or no PT) as a predictor was estimated. The results of these analyses are also presented in Table 6.

Table 6
Descriptive statistics indicating treatment and control group students' awareness of group processes and activities, and results of multilevel analyses with condition as predictor

Factor	Treatment group students ($N = 47$)		Control group students ($N = 15$)		Coefficient	SE	χ^2
	M	SD	M	SD			
Awareness of participation	−.09	.88	.29	.96	−.182	.149	1.40
Awareness of group members' tasks	.06	.83	−.19	1.15	.138	.155	.77

Note. Factor scores range from negative (=*no awareness*) to positive (=*high awareness*).
$p < .05$.

On average, students with access to the PT reported lower awareness of participation, but higher awareness of group members' tasks. Overall, the effect of the PT on the two factors was not significant, $t(21) = -1.22$, $p = .12$, and $t(21) = .89$, $p = .19$, respectively. For the sake of completeness, the effect of the PT was also examined for the seven items that had low pattern and structure coefficients on the two factors. Only for one item, condition was a significant predictor. Students with access to the PT reported they knew better when someone was not working hard, than students without access to the PT, $t(21) = 2.43$, $p = .01$.

Examination of the partial correlations between intensity of PT use and the two awareness measures revealed no significant relationships. Thus, how many times students used the PT, or how long students displayed the PT, did not influence students' awareness of participation and group members' tasks.

6.4. Collaborative activities

The fourth research question concerned the effect of the PT on the collaboration processes taking place between students during online collaboration. In Table 7, the mean frequencies of collaboration acts per student are presented. For the descriptions of the collaboration acts, the reader is referred to Table 2 and Section 5. The numbers in parenthesis indicate how many *percent* of the total number of collaboration acts was devoted to a specific collaboration act. The data in Table 7 show most of the collaboration acts to indicate signaling and monitoring mutual understanding (*SociUnd*+, 22%). Furthermore, many collaboration acts involved regulating the completion of the group task, such as making plans (*MTaskPlan*, 19%), or monitoring task progress (*MTaskMoni*, 13%). In order to complete the task, the students exchanged a lot of task related information (*TaskExch*, 9%), but also paid attention to the social aspect of collaboration by sending many social support remarks (*SociSupp*, 7%).

The data displayed in Table 7 also reveal some differences between treatment and control group students. These differences were examined using multilevel analyses, by estimating two models. The empty model was estimated first. Second, a model that included condition (PT or no PT) and number of dialogue acts as predictor was estimated. Number of dialogue acts was included in this model to account for the fact that some students wrote more dialogue acts during online discussion than other students. By including the number of dialogue acts as a predictor, the effect of the PT can be examined independent of the number of dialogue acts a student typed.

Table 7 lists the results of the multilevel analyses. Number of dialogue acts typed was a significant predictor for all collaboration acts, except *Other*. For example, the more dialogue acts a student typed, the more questions he or she asked (*TaskQues*). Table 7 also shows that condition was a significant predictor for several types of collaboration acts, independent of the number of dialogue acts typed. First, having access to the PT was related significantly to the number of greetings (*SociGree*) typed by a student, $t(21) = 1.89$, $p = .04$. Students who had access to the PT sent significantly more greetings. Second, the coefficient for *SociSupp* indicates a negative effect of the PT on the number of social support remarks typed by a student, $t(21) = -3.71$, $p = .00$. Thus, students who had access to the PT made significantly less social support remarks. Furthermore, the PT also had a significantly negative effect on the number of social resistance remarks (*SociResi*), $t(21) = -3.48$, $p = .00$. When students had access to the PT, they typed significantly less social negative remarks. Fourth, the PT influenced the number of messages which signaled loss

Table 7
Mean frequencies and standard deviations of collaboration acts and multilevel analyses of the effects of condition

	Treatment group students ($N = 52$)			Control group students ($N = 17$)			Total ($N = 69$)			Effect of condition		
	Mean frequency	(%)	SD	Mean frequency	(%)	SD	Mean frequency	(%)	SD	Coefficient	SE	χ^2
Performing task-related activities												
Info exchange (*TaskExch*)	34.87	(9.76)	45.64	18.06	(7.70)	16.99	30.72	(9.25)	41.03	1.985	5.270	39.62**
Asking questions (*Taskques*)	7.88	(2.59)	8.67	3.82	(1.62)	3.07	6.88	(2.35)	7.85	1.102	1.046	18.05**
Coordinating/regulating task-related activities												
Planning (*MTaskPlan*)	56.62	(19.35)	33.97	39.41	(16.94)	18.98	52.38	(18.76)	31.72	2.455	2.306	95.75**
Monitoring (*MTaskMoni*)	37.50	(13.05)	22.18	32.59	(14.51)	9.14	36.29	(13.41)	19.83	−1.256	1.612	75.58**
Positive evaluations (*MTaskEvl+*)	4.62	(1.50)	3.92	2.59	(1.13)	1.91	4.12	(1.41)	3.63	.543	.434	24.43**
Negative evaluations (*MTaskEvl−*)	5.46	(1.76)	4.92	4.41	(1.73)	3.41	5.20	(1.75)	4.60	−.130	.507	33.85**
Performing social activities												
Greetings (*SociGree*)	11.17	(4.21)	7.39	5.88	(2.55)	3.87	9.87	(3.80)	7.05	1.913*	1.015	21.02**
Social support (*SociSupp*)	18.12	(5.88)	14.06	26.06	(10.45)	16.39	20.07	(7.01)	14.94	−6.493**	1.751	45.40**
Social resistance (*SociResi*)	3.63	(1.28)	3.70	8.71	(3.66)	8.86	4.88	(1.87)	5.79	−2.889**	.830	14.36**
Mutual understanding (*SociUnd+*)	67.56	(22.57)	41.35	49.29	(21.20)	22.71	63.06	(22.23)	38.30	2.009	2.994	73.23**
Loss of mutual understanding (*SociUnd−*)	9.19	(3.37)	4.88	11.00	(4.77)	6.07	9.64	(3.72)	5.21	−1.633**	.575	32.31**
Coordinating/Regulating social activities												
Planning (*MSociPlan*)	6.44	(2.31)	4.65	2.82	(1.15)	2.16	5.55	(2.03)	4.45	1.337*	.543	28.23**
Monitoring (*MSociMoni*)	17.40	(6.23)	10.94	11.82	(5.16)	5.43	16.03	(5.97)	10.13	1.135	1.567	37.34**
Positive evaluations (*MSociEvl+*)	.58	(.19)	.85	.41	(.17)	.71	.54	(.19)	.81	.030	.110	5.90
Negative evaluations (*MSociEvl−*)	.98	(.37)	1.39	.35	(.17)	1.00	.83	(.32)	1.33	.234	.252	7.17*
Technical												
Neutral technical (*TechNeut*)	6.94	(2.66)	5.22	6.82	(2.64)	5.36	6.91	(2.65)	5.22	−.433	.778	11.55**
Negative technical (*TechNega*)	3.92	(1.36)	2.96	4.00	(1.47)	4.56	3.94	(1.39)	3.38	−.514	.443	26.24**
Positive technical (*TechPosi*)	1.10	(.34)	1.62	.71	(.25)	1.05	1.00	(.31)	1.50	.025	.231	17.12**
Other	3.19	(1.20)	5.01	6.47	(2.74)	3.86	4.00	(1.58)	4.93	−1.860**	.660	7.56*

* $p < .05$.
** $p < .01$.

of mutual understanding (*SociUnd−*), $t(21) = -2.84$, $p = .00$. Students with access to the PT, indicated less incomprehension and disagreement. Fifth, the PT had a positive effect on the number of remarks aimed at planning of group processes (*MSociPlan*), $t(21) = 2.46$, $p = .01$. Thus, students with access to the PT constructed more messages that regulated the planning of group processes. This indicates that students who had access to the PT devoted more of their online discussion to this aspect of group processing. Finally, access to the PT influenced the number of nonsense (*Other*) remarks typed by a student, $t(21) = -2.82$, $p = .01$. Students with access to the PT sent significantly less *Other* remarks. As mentioned earlier, number of dialogue acts was not a significant predictor for *Other* remarks, therefore a model which only included condition as a predictor was also estimated. Condition was also a significant predictor in this model, $t(21) = -2.50$, $p = .01$. Thus, it seems that the PT influenced students to type less nonsense remarks.

To examine how operating the PT influenced students' collaboration, partial correlations (controlling for the time students were online) between use of the PT and collaborative activities were inspected. However, no significant relationships were found.

6.5. Group performance scores

The final research question concerned the effects of the PT on groups' performance scores. Table 8 shows the results of the comparison between treatment and control groups. Note that since the performance scores were calculated for groups, not individual students, the number of observations is different from, for example, Table 8.

Differences were tested using a t test for independent samples. On average, treatment groups attained higher total performance scores, but the difference was not significant, and the resulting ES was small. Inspection of Table 8 shows that on average, treatment groups scored higher compared to control groups on four of the seven subtasks. None of the differences were statistically significant. However, for subtasks two and six, the ESs (.80 and .92, respectively) were rather high and in favor of the treatment groups. Finally, inspection of the correlations between use of the PT and group performance scores, revealed no significant relationships.

Table 8
Means and standard deviations for treatment and control groups for group performance scores

Group performance scores	Treatment groups ($N = 17$)		Control groups ($N = 5$)		t	p	ES
	M	SD	M	SD			
Total score	66.47	10.66	64.80	8.70	.32	.75	.16
Subtask 1	1.37	.33	1.47	.18	−.60	.55	−.33
Subtask 2	1.38	.32	1.14	.20	1.54	.14	.80
Subtask 3	1.27	.34	1.47	.27	−1.16	.26	−.61
Subtask 4	1.39	.36	1.49	.26	−.53	.60	−.29
Subtask 5	1.39	.30	1.27	.15	.89	.38	.43
Subtask 6	1.42	.24	1.20	.24	1.81	.09	.92
Subtask 7	1.51	.37	1.40	.45	.55	.59	.28

Note. To increase comparability, scores for the subtasks were standardized, with 0 being the minimum amount of points and 2 the maximum.

7. Conclusions

In the present study, the effects of visualization of participation during CSCL were examined. A CSCL-environment was augmented with the PT. The PT visualizes how much each group member contributes to his or her group's online communication. It is assumed that the PT would influence group members' participation, awareness, collaborative activities, and groups' performance scores.

The first research question investigated how intensively students used the PT during online collaboration. Treatment group students used the PT quite intensively, although some students used the PT very little. On average, students displayed the PT on their screen 18% of the total time they were online.

The second research question was whether students who had access to the PT (treatment group students) would participate more, and more equally during collaboration compared to students without access to the PT (control group students). The results show an effect of the PT on the participation of treatment group students. Treatment group students sent more long dialogue acts (messages containing more than five words), compared to control group students. This important, since longer messages are mainly used for transfer of information and coordination of activities. These longer, more substantial messages contribute to satisfactory collaboration (Bonito, 2000). Regarding short dialogue acts, and total number of dialogue acts, no differences were found between treatment and control group students. Furthermore, equality of participation was not higher in treatment compared to control groups. However, display time of the PT on students' screens was correlated with equality of participation for long dialogue acts. This indicates that operating the PT has an effect on equality of participation. In conclusion, some positive results were found for the effect of the PT on participation during online collaboration. Having access to the PT and operating the PT seem to partly stimulate participation and equality of participation.

The third research question was whether the PT would influence students' awareness of the group processes and activities taking place during online collaboration. To answer this question, students completed a 14-item questionnaire. From this questionnaire, seven items were grouped into two factors. The results indicate treatment group students reported similar levels of awareness of participation and group members' tasks compared to control group students. Thus, the PT did not stimulate students' awareness of the group processes and activities taking place during collaboration. Furthermore, operating the PT was not correlated with awareness. In sum, the PT did not affect students' awareness of the group processes and activities in their group. It is worth noting, however, that on a single questionnaire item that was not included in one of the two extracted factors, a significant difference emerged: treatment group students reported they knew better when a group member was not working hard, compared to control group students. This indicates that the PT may have helped students to assess whether a group member was taking a free ride.

The fourth research question was whether the PT would influence students' collaborative activities during online collaboration. It was expected that the PT would stimulate students to engage in social activities and coordination of social activities. That is, treatment group students were expected to spend more time planning, monitoring, and evaluating their collaboration (group processing). This proved to be partially the case. Treatment group student made more remarks aimed at planning of group processes. Furthermore, treatment group students made fewer remarks that indicated social resistance (e.g., swearing, displaying negative emotions). This is important because such negative behavior undermines collaboration (Jehn & Shah, 1997). Surprisingly, treatment group students also typed fewer social support remarks (e.g., offering positive comments, self-disclosure). Instead, treatment group students typed more greetings. In addition, the treatment group students signaled loss of mutual understanding on fewer occasions. Finally, treatment group students typed less nonsense remarks. Intriguingly, no relationship between use of the PT and collaborative activities was found. This may indicate that even students that did not use the PT intensively, were influenced by the PT. Possibly because they were influenced by group members that *did* use the PT more intensively. Overall, these results indicate that access to PT stimulated students to invest more effort into coordination of social activities.

The final research question was whether the PT would increase the efficacy of collaboration by improving group performance. It was hypothesized that through stimulating participation, equality of participation, awareness of group processes and activities and coordination of social activities, the PT would help groups to perform better on the inquiry group task. The results indicate that this was not the case. Treatment groups did not attain higher performance scores than control groups. Furthermore, partial correlations revealed no relationship between operating the PT and group performance. It is worth noting that for two subtasks moderate to high effects sizes were found in favor of the treatment group. In conclusion, the effects of the PT on group performance were not as profound as expected.

Overall, the results of this study demonstrate the usefulness of visualizing participation during CSCL. It stimulates students to exchange longer, more substantial messages. These results are in line with previous studies by Michinov and Primois (2005) and Zumbach et al. (2004), although these studies used different types of visualizations. In addition, operating the PT influenced equality of participation. In groups that used the PT a lot, the number of long dialogue acts was distributed more equally among group members. Finally, visualization of participation stimulated students to collaborate differently. It helped group members to engage in group processing, but also to decrease off-task and negative behavior (e.g., typing nonsense messages and swearing). This is important, since it demonstrates that the increase in participation is not caused by students sending more nonsense messages in order to manipulate the visualization. Effects of the PT on awareness of group processes and – activities and on group performance were not as strong as expected. Groups that had access to the PT did not report higher awareness and did not earn higher performance scores on the inquiry group task.

8. Discussion

In interpreting the results of this study, some possible limitations should be kept in mind. These limitations and alternative interpretations of the results will be discussed hereafter. First, the data were collected on a single school. In addition, the sample used in this study was rather small: 55 treatment and 17 control group students. This may limit the generalizability of the results.

Second, students were not forced to use to PT. They could open and close it whenever they wanted. Unsurprisingly, some students used the PT very little, whereas others used it a lot. If the PT would have been on students' screens all the time, this might have produced different, perhaps more positive, effects. However, this study demonstrated that only giving students access to the PT could still be beneficial.

Third, a possible explanation for the mixed results could be that it was difficult for students to perceive differences between the sizes of the spheres in the PT. If students do not perceive differences between each other in terms of participation, they may not change their behavior because they believe they are collaborating efficiently. This study did not investigate whether students actually perceived differences. However, examination of the online discussions revealed that students themselves mentioned and were aware of these differences (e.g., "your sphere is the biggest", "according to the PT, she participated the most"). These examples illustrate that these students were able to perceive differences between each other.

Fourth, the type of group task used in this study may have influenced the results found. This study used an inquiry group task, for which a high level of collaboration and equal participation was necessary to perform well. Positive interdependence and individual accountability were incorporated in the task, thus reducing the chance that free riding would occur (O'Donnell, 2001). As was described above, in both conditions participation was rather equally distributed among group members, indicating there were few free riders. With a different task, one in which free riding is more likely to occur, the effects of the PT may be stronger because free riders are more easily identified. Future research could investigate whether different types of task elicit different effects of the PT.

Fifth, because students were not forced to use the PT, there were considerable differences between students regarding the extent to which the PT was actually used. These differences may have made it more difficult to detect differences between treatment and control group students. However, it was found that operating the PT only had an effect on equality of participation. Thus, it seems that it is more important to be in a group that has access to the PT, than to actually observe and operate the PT. This may seem counterintuitive, but two explanations can account for this finding. Firstly, the measures used may not completely grasp whether students meaningfully used the PT. The total amount of time the PT was displayed on students' screen may not be a good indicator, because students can have the PT on their screen without paying attention to it. Using the PT may not be a good indicator, because even without using the tool, students can still be influenced by it, by simply observing the tool. Secondly, students can be influenced by the PT through their group members. As described above, students with access to the PT typed more long messages and engaged more in coordination of social activities. By observing the increased participation, or different collaborative activities of group members, even students that did not use the PT intensively may have been prompted to change their collaborative behavior.

Finally, group size may have influenced the results (Strijbos, Martens, & Jochems, 2004). This study used groups with three or four members. Bonito (2000) noted that smaller groups minimize participation differences, possibly because in smaller groups the obligation to participate is higher, lack of participation can be noticed more easily, and there is less competition for attention. Therefore, if larger groups had been used in this study, the results might have been different. In larger groups, there is more competition for attention and free riders are more likely to go unnoticed. In these groups, the PT could possibly have a greater impact on equality of participation. Similarly, in larger groups it is more difficult to know what group members are doing and which group members are participating too little. Therefore, under these circumstances the PT could possibly have a greater impact on awareness of group processes and activities. In the future research, it should be examined whether group size influences the effects of visualization of participation.

Overall, the results of this study were quite positive. In this case, access to visualization of participation seemed to stimulate participate more during online collaboration. Furthermore, students also discussed more about manner in which they were collaborating, which may help them to collaborate better. Whether these results can be replicated with other students, other types of groups or using different types of tasks, remains to be seen, although the results seem promising. In our own future research, we will explore the merits of visualization during collaboration further.

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