EFFECTS OF VISUALIZING PARTICIPATION IN 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, and collaborated differently than students without access to the PT. The results show that most 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. Although treatment group students on average did not report higher levels of awareness of group processes and activities compared to control group students, they reported they knew better when a group member was not working hard. 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

VISUALIZATION OF PARTICIPATION: DOES IT CONTRIBUTE TO SUCCESSFUL COMPUTER-SUPPORTED COLLABORATIVE LEARNING?

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 being used more and more 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) 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. For example, 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). Furthermore, 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). 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). 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 some group 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.

VISUALIZATION OF PARTICIPATION DURING CSCL: A SOLUTION?

In the section above, contradictory results concerning the possible benefits of CSCL were mentioned. Another important contradictory result found in CSCL studies concerns equal 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, low participation rates of all participating students are reported (Lipponen et al., 2003). 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 (students let other group members do the work) and the sucker effect (students want to avoid free riders taking advantage of them, and therefore decide to participate less).

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.

One 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 the method and instrumentation section.

Motivational processes

Visualization of participation may influence collaboration through motivational processes. Motivational processes have been used to explain *why* students put effort into collaboration (O'Donnell & O'Kelly, 1994). To counter productivity loss in groups (e.g., caused by social loafing or 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 group processes identifiable; it establishes a link between a group member and his or her contribution to the collaboration (Jermann, 2004). This identifiability creates opportunities for self-evaluation, social evaluation, and social comparison. These three processes may provide motivational incentives for group members to invest effort into collaboration.

Firstly, according to *self-evaluation* theory, people have a need to evaluate their abilities (Szymanski & Harkins, 1987). In addition, people want to evaluate themselves favorably in order to maintain their self-esteem (Shepperd, 1993; Tesser, 2001). Thus, because visualization of participation provides group members with an opportunity to self-evaluate, this could be a motivational incentive to increase their efforts to collaborate.

Visualization of participation also creates opportunities for *social evaluation*. When participation of group members is identifiable, they can be evaluated positively when they participate sufficiently; or negatively when they participate insufficiently. Furthermore, students are unable to "hide in the crowd", and can be held accountable by their group members when they participate insufficiently. This possibility for social evaluation may constitute another motivational incentive to increase participation (Shepperd, 1993).

Finally, the opportunity for *social comparison*, that is, the opportunity for group members to compare themselves to other group members, may be an additional motivational incentive to enhance participation. Social comparison theory states that people tend to compare themselves to others who are (marginally) better than they are (Wheeler, Suls, & Martin, 2001). This, in turn, may motivate group members to set higher standards, and to try to increase their participation (Michinov & Primois, 2005). As explained above, through the opportunity for self-evaluation, social evaluation, and social comparison created by visualization of participation, group members may be motivated to increase their efforts to participate during CSCL.

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). This feedback, in turn, may convince group members they are collaborating well, or it may stimulate group members to adapt or change their collaboration strategies (Butler & Winne, 1995).

Second, the external feedback provided by visualization of participation can also raise students' *awareness* of the group processes and activities taking place. Several researchers have suggested that awareness can play an important role in facilitating CSCL (Dourish & Bellotti, 1992; Gutwin & Greenberg, 2004). When students are collaborating, they have to be aware of the activities of their group members, because this awareness allows students to decide which activities they have to engage in, and it enables them to anticipate group members' actions. In short, awareness is expected to facilitate smooth, and natural collaboration (Gutwin & Greenberg, 2004). Since visualization of participation shows group members' participation rates, it could raise students' awareness of group processes, and more specifically, of participation. This awareness may invite group members to communicate about group processes, and thus contribute to a more sociable environment (Kirschner, Strijbos, Kreijns, & Beers, 2004).

Third, in addition to stimulating monitoring and raising awareness of group processes, the feedback provided by 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 reinforce successful collaborative behavior (Yager, Johnson, Johnson, & Snider, 1986). In FTF collaboration, the benefits of group processing have been documented. Studies by Yager et al. (1986) and Johnson, Johnson, and Stanne (1990) both demonstrated that students collaborating in groups which engaged in group processing performed better, compared to groups that did not engage in group processing.

Finally, the feedback provided by visualization of participation can also help group members to communicate about topics for which they would otherwise lack the necessary vocabulary. In other words, visualization of participation also serves 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 visualization, a group member may feel someone is contributing insufficiently, which stimulate him or her to discuss this with other group members by referring to the visualization. Thus, visualization of participation may help and stimulate group members to communicate about how their group is functioning, and facilitate group processing.

In sum, it appears that visualization of participation may be considered a form of external feedback. It possibly increases awareness of group processes and stimulates monitoring as well as group processing. Furthermore, it may serve a mediating purpose, by providing group members with a vocabulary to communicate about their group's functioning.

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) and verbalize their ideas and opinions (Van der Linden, Erkens, Schmidt, & Renshaw, 2000). These task-related activities contribute to a group's production function (McGrath, 1991) and stimulate successful problem solving and 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). On the other hand, behaviors such as swearing or displaying negative emotions may have a negative impact on group cohesion (Johnson, Johnson, Roy, & Zaidman, 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). 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, as was mentioned above, 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 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

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.

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?

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.

METHOD AND INSTRUMENTATION

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. Each class was randomly assigned to either the treatment (two classes) or the control group (one class). The treatment group consisted of two teachers and 52 students (17 groups), and the control group of one teacher and 17 students (5 groups).

Participants

Participants were 69 eleventh-grade students (27 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. During the experiment, students collaborated in groups of three or four; students were randomly assigned to a group by the researchers. In order to eliminate combinations of students who could not get along with each other, the group compositions were verified and approved by their teachers.

Tasks and materials

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. Figure 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 Figure 1, include for example the *Diagrammer*, which can be used to construct argumentative diagrams, and the *Reflector*, which is used by students to reflect on group processes.

Inquiry group task

The participating students collaborated on a historical inquiry group task. Inquiry tasks are an important part of the curriculum in 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. The students were told they had eight lessons to complete the inquiry task, and they would receive a group grade for their final version of the task.

The groups had to use different historical and (more) contemporary *sources* to write texts about, for example: the definition of a witch, how witches were perceived in different historical periods, and the guilt or innocence of an old woman accused of witchcraft[1]. Approximately 40 sources from textbooks and the Internet were available to the students through the *Sources* tool. The task was quite extensive and complex, so no single group member was likely to solve the task on his or her own. In addition, the task can be

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

characterized as an open-ended task; meaning the task does not have a single right answer and there is no standard procedure which can be used to solve the task (Cohen, 1994).

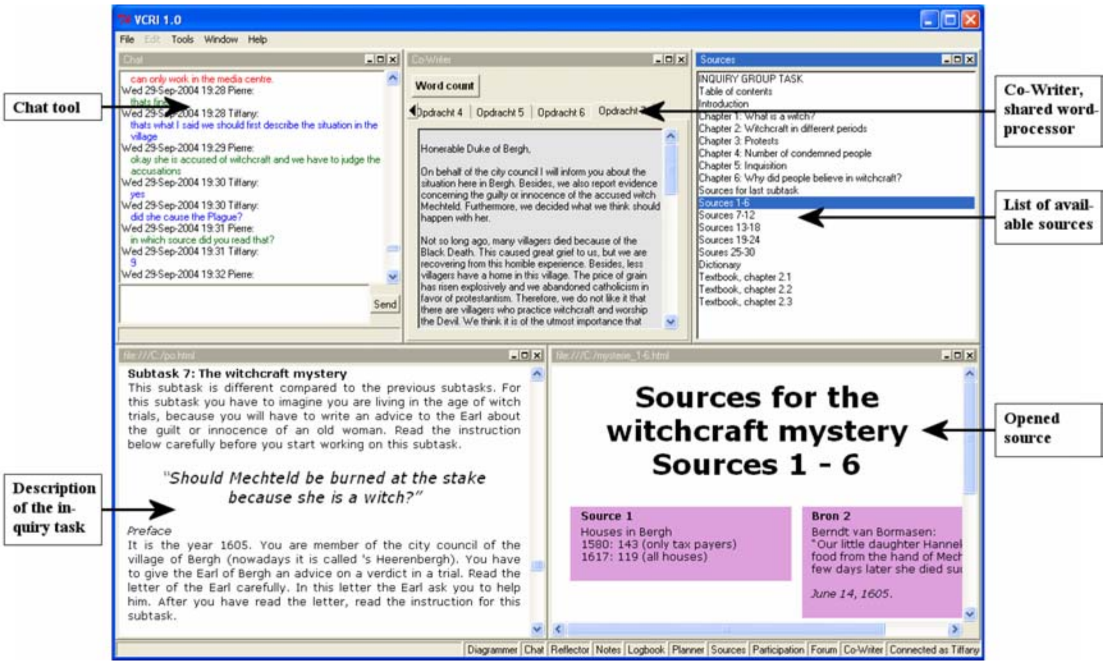

Figure 1 Screenshot of the VCRI-program, detailing the most important tools (translated from Dutch).

Treatment: Participation Tool

To answer the research questions the VCRI was augmented with a new tool, the *Participation Tool* (PT). The PT visualizes how much each group member contributes to his or her group's online communication. Figure 2 shows a screenshot of the PT.

After opening the PT, a student can compare his own participation rate to the participation rates of his group members. Each student is represented by a sphere; group member's spheres are grouped. 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. Participation of groups can be compared by examining the grey circles. These indicate a group's total participation, compared to other groups. A bigger grey circle indicates more participation.

The PT visualizes for the most part the quantity of the communication between group members, and to a lesser extent the quality of communication. Nonetheless, quantity of communication is important for successful collaboration. When unequal participation exists between group members, this is an indication a group member is being a free rider. Quality and quantity of participation are both important for collaboration. 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.

The PT can be opened and examined by students at any time. Furthermore, the PT is continually updated, in order to display the most recent situation. Students can zoom in, to examine a part of the visualization closer, while the visualization can also 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 minutes. Finally, 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 close it whenever they want.

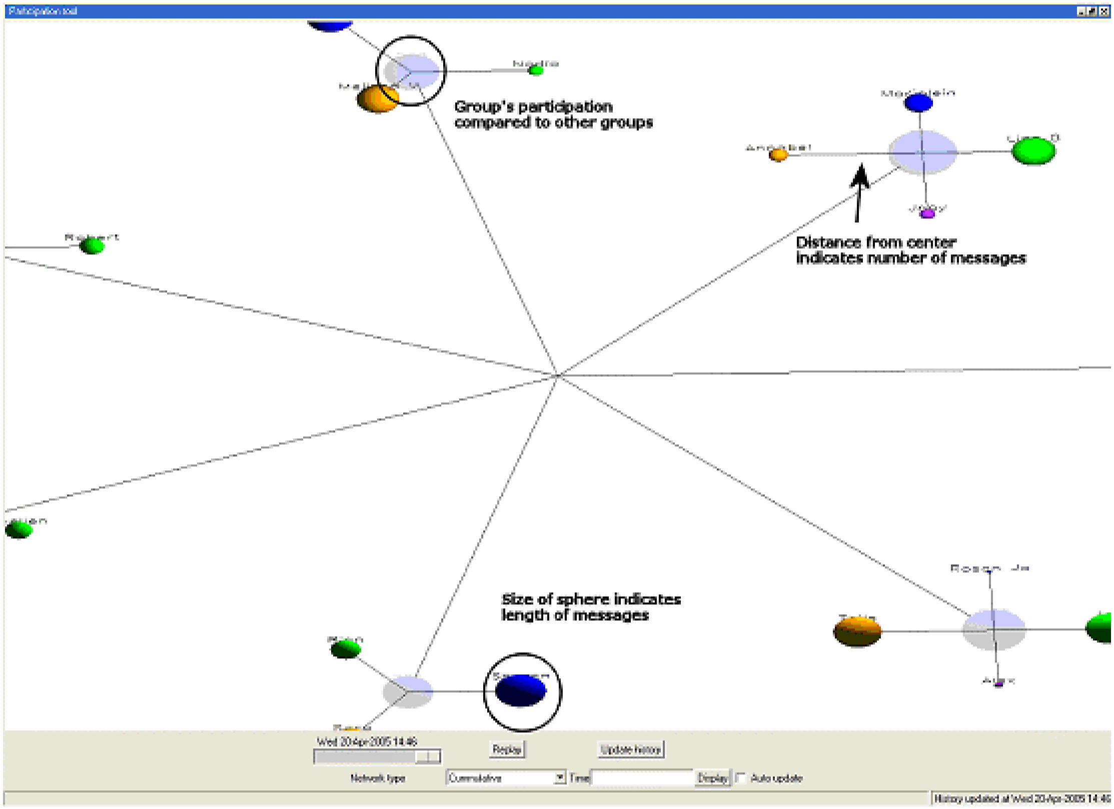

Figure 2 Screenshot of the Participation Tool.

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), or the number of words written (e.g., Savicki et al., 2002) 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, argumenting, commanding, or eliciting).

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.

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.

Use of the PT

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.

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, whereas longer dialogue acts are used mainly for transfer of content and regulation of task and group processes. The former can be considered nonsubstantive contributions, since they are less important for the development of the conversation. In contrast, the latter can be considered substantive contributions (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 sums the deviation of each group member from equal participation. This sum is divided by the maximum possible value of this deviation (Alker Jr., 1965). The coefficient ranges between 0 (perfect equality; all students contribute equally to discussion) and 1 (perfect inequality; one student completely dominates discussion).

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, for example, awareness of the activities of others in the VCRI and awareness of group members' participation during online collaboration.

An exploratory factor analysis using principal axis factoring was conducted to identify latent variables underlying the 14 items. Based on the examination of the screeplot 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", factor two as "Awareness of group members' tasks". In total, the two factors explained 34.30% of the total variance. The two factors correlated significantly, $r = .62$, $df = 61$, $p = .00$. Factor scores were subsequently used in analyses of differences between treatment and control groups. Seven items however, had low pattern and structure coefficients on each of the two factors. For the sake of completeness, for these items, results will be presented per item.

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. These are shown in Table 2.

The first dimension referred to *performance of task-related activities*. This dimension contained two categories pertaining to the discussion of relevant task-related information: sharing task-related information (*TaskExch)* and asking task-related questions (*TaskQues*).

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-*).

Table 2 Collaboration acts and category Kappa's.

	Task-related activities		Social activities	
	Codes	*Kappa*	Codes	*Kappa*
Performance	• Exchange of information (*TaskExch*)	.85	• Greetings (*SociGree*)	.89
	• Asking questions (*TaskQues*)	.89	• Social support (*SociSupp*)	.85
			• Social resistance (*SociResi*)	.73
			• Mutual understanding (*SociUnd+*)	.92
			• Loss of mutual understanding *(SociUndi*)	.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*)	-		

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. Second, social support remarks (*SociSupp*) referred to comments that contributed positively to the group's 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, 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 Kappa 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 *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.

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 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.

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 is 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. 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.

The line of reasoning concerning the nonindependence of students' participation rates can also be extended to the other individual measures in this research (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.

RESULTS

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* = 286.00), and displayed the PT for 64.33 minutes (*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 minutes (*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 minutes).

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.

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

	Treatment group (N=52)		Control group (N=17)		
Measure of participation	*M*	*SD*	*M*	*SD*	*ES*
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 (<= 5 words)	187.13	96.69	162.35	60.53	.28

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 minutes, *SD* = 86.01), compared to control group (*M* = 358.28 minutes, *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 students worked longer in the CSCL-environment than other students. For example, some students worked longer because they also 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, $t(21) = 1.76$, $p = .05$.

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

Table 4 Results of multilevel analysis for measures of participation.

	Dialogue acts		Long dialogue acts		Short dialogue acts	
	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*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**	

Note. * $p < .05$; ** $p < .01$

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. On average, the Gini coefficients are higher for the treatment groups, indicating slightly more inequality of participation. The differences did not reach statistical significance, however.

To examine how use of the PT was related to students' participation during collaboration, a number of correlations (e.g., between times the PT was used and dialogue acts typed) were calculated. No significant correlations were found at the individual level. However, at the group level, the total time the PT was displayed, correlated significantly with total number of dialogue acts typed ($N = 17$, $r = .50$, $p = .04$). This indicates that groups that used the PT more also typed more dialogue acts.

Table 5 Equality of participation (group as unit of analysis).

	Treatment group (N=17)		Control group (N=5)				
Equality of participation	*M*	*SD*	*M*	*SD*	*t*	*p*	*ES*
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 used measure of equality, the Gini coefficient, ranges from 0 to 1, with 0 indicating perfect equality and 1 perfect inequality.

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. 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 (see Table 6). 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 item three condition was a significant predictor, $t(21) = 2.43$, $p = .01$. Students with access to the PT ($M = 3.39$, $SD = 1.36$) reported they knew better when someone was not working hard, than students without access to the PT ($M = 2.53$, $SD = 1.34$). Furthermore, the model including condition as a predictor was a better model, $\chi^2(1) = 5.50$, $p = .02$, explaining 8.43% of the total variance.

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.

	Treatment group ($N = 51$)		Control group ($N = 15$)				
Factor / Item	*M*	*SD*	*M*	*SD*	*Coeff.*	*SE*	χ^2
Awareness of participation	-.09[a]	.88	.29	.96	-.182	.149	1.40
Awareness of group members' tasks	.06[a]	.83	-.19	1.15	.138	.155	.77

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

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. 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. Number of dialogue acts typed was included in the analyses 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.

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*). 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 of mutual understanding (*SociUnd-*), $t(21) = -2.84$, $p = .00$. Students with access to the PT typed less *SociUnd-* collaboration acts. 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. 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.

Table 7 Mean frequencies and standard deviations of collaboration acts.

	Treatment group (N = 52)			Control group (N = 17)			Total (N = 69)		
	M		*SD*	*M*		*SD*	*M*		*SD*
	Freq.	(%)		Freq.	(%)		Freq.	(%)	
TaskExch	34.87	(9.76)	45.64	18.06	(7.70)	16.99	30.72	(9.25)	41.03
TaskQues	7.88	(2.59)	8.67	3.82	(1.62)	3.07	6.88	(2.35)	7.85
MTaskPlan	56.62	(19.35)	33.97	39.41	(16.94)	18.98	52.38	(18.76)	31.72
MTaskMoni	37.50	(13.05)	22.18	32.59	(14.51)	9.14	36.29	(13.41)	19.83
MTaskEvl+	4.62	(1.50)	3.92	2.59	(1.13)	1.91	4.12	(1.41)	3.63
MTaskEvl-	5.46	(1.76)	4.92	4.41	(1.73)	3.41	5.20	(1.75)	4.60
SociGree	11.17	(4.21)	7.39	5.88	(2.55)	3.87	9.87	(3.80)	7.05
SociSupp	18.12	(5.88)	14.06	26.06	(10.45)	16.39	20.07	(7.01)	14.94
SociResi	3.63	(1.28)	3.70	8.71	(3.66)	8.86	4.88	(1.87)	5.79
SociUnd+	67.56	(22.57)	41.35	49.29	(21.20)	22.71	63.06	(22.23)	38.30
SociUnd-	9.19	(3.37)	4.88	11.00	(4.77)	6.07	9.64	(3.72)	5.21
MSociPlan	6.44	(2.31)	4.65	2.82	(1.15)	2.16	5.55	(2.03)	4.45
MSociMoni	17.40	(6.23)	10.94	11.82	(5.16)	5.43	16.03	(5.97)	10.13
MSociEvl+	.58	(.19)	.85	.41	(.17)	.71	.54	(.19)	.81
MSociEvl-	.98	(.37)	1.39	.35	(.17)	1.00	.83	(.32)	1.33
TechNeut	6.94	(2.66)	5.22	6.82	(2.64)	5.36	6.91	(2.65)	5.22
TechNega	3.92	(1.36)	2.96	4.00	(1.47)	4.56	3.94	(1.39)	3.38
TechPosi	1.10	(.34)	1.62	.71	(.25)	1.05	1.00	(.31)	1.50
Other	3.19	(1.20)	5.01	6.47	(2.74)	3.86	4.00	(1.58)	4.93

CONCLUSIONS

In the present study, the effects of visualization of participation during CSCL were examined. 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. It is assumed that the PT would influence group members' participation, awareness, and collaborative activities through motivational and feedback mechanisms.

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 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. These findings indicate that the PT stimulated students to invest more effort into collaboration and to type more substantial messages.

The third research question was whether the PT would influence students' awareness of the group processes and activities taking place during online collaboration. The results of this study show that overall this is not the case. Treatment group students reported similar levels of awareness, compared to control group students. It should be noted however, that 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 partly provided students' with adequate information 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 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 of their group process (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). 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. Overall, these results indicate that the PT stimulated students to invest more effort into coordination of social activities.

DISCUSSION

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). Furthermore, visualization of participation stimulated to collaborate differently. It helped group members to engage in group processing, but also to decrease their off-task behavior (typing nonsense messages). This is important, since it demonstrates that the increase in participation is not due to students sending more nonsense messages in order to manipulate the visualization.

The effects of visualization on equality of participation and awareness of group processes and –activities were not as strong as expected. Groups that had access to the PT did not demonstrate more equal participation, and did not report more awareness (except for awareness of group members who were not working hard).

In interpreting the results of this study, some possible limitations should be kept in mind. First, the data were collected on a single school, which 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. Therefore, 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, group size may have influenced the results. 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 these groups, the PT could possibly have a greater impact on equality of participation. In the future, it could be examined whether group size influences the effects of visualization of participation.

In the introduction it was hypothesized, visualization of participation would influence collaboration through motivational (self-evaluation, social evaluation, and social comparison) and feedback processes (providing information which can be used to monitor group processes, which raises awareness, which can be used for group processing, or which serves a mediating purpose). As this study showed, visualization of participation can raise students' awareness of free riders and can stimulate to engage in group processing. However, it remains unclear if motivational processes associated with visualization of participation also influence collaboration.

In sum, the results of this study were quite positive. In this case, 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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