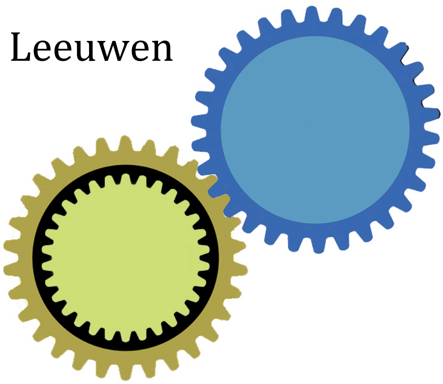
Teacher Regulation of CSCL

Exploring the complexity of teacher regulation and the supporting role of learning analytics

Anouschka van Leeuwen



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Exploring the complexity of teacher regulation and the supporting role of learning analytics

Verkenning van docentregulatie van computerondersteund samenwerkend leren
en de ondersteunende rol van learning analytics
(met een samenvatting in het Nederlands)

Proefschrift

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Chapter 1: Introduction

1.1 Problem Statement

Teachers increasingly implement computer-supported collaborative learning in their classrooms. Collaborative learning is an instructional strategy shown to have positive effects on student achievement (Kyndt et al., 2013), but requires adequate support to lead to the development of the intended knowledge and skills (Gillies, Ashman, & Terwel, 2008; Salinas, 2008). For example, dividing a class into groups and providing them with a collaborative task does not guarantee that successful collaboration will occur (Kirschner & Erkens, 2013). Teacher support is needed to monitor and steer the interaction between students, with careful 'calibration' of the teaching strategies to each group of students (Kaendler, Wiedmann, Rummel, & Spada, 2014). By collaboratively solving a task, students are challenged to share ideas, express their thoughts and engage in discussion. Using a computer-supported setting can help to achieve these goals because it can support shared activities of exploration and social interaction (Stahl, Koschmann, & Suthers, 2006). Furthermore, it can support teachers while monitoring students' activities. Because usually during CSCL all student activities are automatically logged and can be made available to the teacher, this could help teachers to maintain a more complete and more accurate overview of the activities each collaborating group engages in (Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder 2012). However, because there are multiple groups to monitor, the amount of available information can also be overwhelming (Dyckhoff et al., 2012). Monitoring and adapting to the needs of multiple groups is therefore a challenge (Schwarz & Asterhan, 2011).

In Part I of this thesis, the complexity of teaching in a computer-supported learning environment is explored. In Part II, it is examined how visualizing student activities may support teachers. The hypothesis is that these visualizations can decrease the complexity of the teacher's task for example by aggregating the available information concerning student activities to a manageable level. When analyses of student data are used to improve learning processes (in this case by supporting teachers), this is called *learning analytics* (Siemens & Gasevic, 2012). The main goal of this thesis is therefore to contribute to the knowledge about teaching during computer-supported collaborative settings and the supporting role of learning analytics, which is still relatively scarce (Chatti, Dyckhoff, Schroeder, & Thüs, 2012). In this thesis, the following two questions are answered:

> *Main Research Question 1*: How do teachers regulate students' learning activities in multiple computer-supported collaborating groups, in terms of teachers' diagnosing and intervening strategies?
>
> *Main Research Question 2*: What are the effects of learning analytics tools that visualize various types of students' activities on teacher regulation of CSCL, in terms of teacher diagnoses and teacher interventions?

The remainder of this chapter is organized as follows. First, the background of Part I and Part II of the thesis are described, followed by a description of the employed methodology and an explanation of the practical relevance of the thesis. Lastly, an overview of the entire thesis is given.

1.2 Part I: Exploring Teacher Regulation of Computer-supported Collaborative Learning

1.2.1 Synchronous computer-supported collaborative learning

Computer-supported collaborative learning (CSCL) denotes settings during which people learn together with the help of computers (Stahl, Koschmann, & Suthers, 2006). It combines collaboration, a method that has been shown to have positive effects on learning outcomes (e.g., Kyndt et al., 2013), with recent technological advancements. The fundament of CSCL is that it is an instructional method and therefore it has as its main goal the facilitation and stimulation of *learning*. As proposed by Kirschner and Erkens (2013), a more appropriate name for CSCL that stresses the precedence of pedagogy might therefore be "Learning Collaboratively Supported by Computers in Networks" (p. 2). However, the affordances offered by the technology and the consequences of the chosen medium on the occurrence of learning should not be neglected. CSCL can be implemented with different types of computer support, each with its own potentials and restrictions (Van Diggelen & Overdijk, 2007). For example, computers can connect learners who are separated in time or space, so that all communication occurs online. In this case, communication could be synchronous, i.e., occur real-time, or asynchronous, i.e., when learners are not necessarily online at the same time, for example in a discussion forum (Hrastinski, 2008). CSCL can also entail that multiple learners share one computer screen and solve tasks together, meanwhile communicating face-to-face (Van Diggelen & Overdijk, 2007).

The research presented in this thesis is situated in a co-located, synchronous CSCL setting (Petrou & Dimitracopoulou, 2003). This means that all learners have their own computer, equipped with a digital learning environment, in the same physical classroom and communication between learners occurs in a synchronous way. In contrast to distance education or for example discussion forums, the classroom setting ensures that students do not need to spend time to get to know each other before starting on the assignment, because the class already has a common history and a set of behavioral norms (Asterhan & Schwarz, 2010b). Although the shared physical space offers the possibility for face-to-face communication, all communication occurs online through the learning environment. Digital communication ensures that not only the learners themselves can retrace their conversations but also that a teacher can constantly monitor each group's activities (Petrou & Dimitracopoulou, 2003). Furthermore, online communication lowers the chance of classroom disturbances or interruptions (Asterhan & Eisenmann, 2011). Although some might argue that the absence of facial cues is a disadvantage (leading to lower social presence, see Kreijns, Kirschner, Jochems, & Van Buuren, 2004), digital communication through for example a chat-tool can also be argued to lead to more precise articulation of thoughts in order to avoid misunderstandings between group members (Asterhan & Schwarz, 2010b). In the studies reported in this thesis, collaboration in the groups of students within this setting is regulated by the presence of a teacher, who has access to a separate interface of the digital learning environment. This interface allows the teacher to monitor all students' activities and to interact with the students in real-time.

1.2.2 The role of the teacher during CSCL

Collaborative learning means that knowledge is constructed through discourse with other students by sharing and discussing resources and jointly building on task products (Roschelle & Teasley, 1995; Stahl et al., 2006; Stegmann, Wecker, Weinberger, & Fischer, 2012). This means that students take an active role and that they are to a large degree responsible for their own learning (Webb, 2013). The role of the students has consequences for the expected role of the teacher (Salinas, 2008; Urhahne et al., 2010; Vermunt & Verloop, 1999). More learner control of the learning process means the teacher takes less control and becomes a facilitator instead of a director of learning. The teacher's role moves from transmission of knowledge to supporting self-regulated knowledge construction (Salinas, 2008; Webb, 2013).

During CSCL, the role of the teacher is thus foremost to stimulate meaningful interaction between group members and to offer assistance when needed (Johnson & Johnson, 2008; Kaendler et al., 2014). Teachers can play an important role during the problem solving activities of groups of students especially when they adapt their support to the understanding of the students. The teacher's challenge is to provide just-in-time interventions, aligned to the needs of each specific group (Lin et al., 2014; Van de Pol, Volman, & Beishuizen, 2010). To decide in which groups, how and when to intervene requires that teachers first observe and diagnose the progress and quality of the groups' activities (Kaendler et al., 2014; Persico, Pozzi & Sarti, 2010). An intervention without diagnosis of the situation within a group can have detrimental effects. For example, a study by Chiu (2004) showed that when the teacher was not aware that students already understood the task, teacher interventions tended to harm students' subsequent problem solving instead of supporting it. Thus the teacher continuously observes and diagnoses students' activities, leading to interventions when needed (Lajoie, 2005; Puntambekar & Hübscher, 2005). Ideally, diagnosing precedes teacher intervention and helps the teacher to decide on the appropriate action in a given situation, at the appropriate time.

The object of the teacher's attention mirrors the various types of learning activities performed by students (Urhahne et al., 2010; Vermunt & Verloop, 1999). Many different categorizations exist for learning activities (see, among others, Baker et al., 2007; De Laat & Lally, 2003; Kirschner & Erkens, 2013; Janssen, Erkens, & Kanselaar, 2007; Persico et al., 2010; Meier, Spada, & Rummel, 2007; Weinberger, Ertl, Fischer, & Mandl, 2005). Generally, when groups collaborate, a distinction is made between cognitive, social and metacognitive activities (Kaendler et al., 2014). Cognitive activities are those related to the task at hand, for example asking questions about the subject matter or relating concepts to each other (see for example Baker et al., 2007 and Janssen et al., 2007). Social activities are those related to social and communicative aspects of collaboration, such as engaging in constructive discussion, solving the occurrence of conflicts and maintaining shared responsibility of the task (see for example Kirschner & Erkens, 2013 and Persico et al., 2010). Metacognitive activities are concerned with regulation of cognitive activities, such as determining a strategy to solve the task or monitoring task progress (see for example Meier et al., 2007 and Molenaar, Chiu, Sleegers, & van Boxtel, 2011). Some authors include both the metacognitive and metasocial activities within one category (for example, the category 'Coordination' in

Meier et al. (2007) that includes both time management, a metacognitive aspect, as well as task division, a metasocial aspect). In line with Janssen et al. (2007), Kirschner and Erkens (2013) and Baker et al. (2007), metasocial activities are in this thesis distinguished as a separate type of activity. Metasocial activities include for example the division of tasks among group members and monitoring or evaluating the group's social activities.

Thus, groups of students perform one of these four types of activities. The teacher, in turn, may *regulate* these same types of activities by diagnosing and intervening. Teachers either regulate students' cognitive, social, metacognitive or metasocial activities. For example, when students discuss the definition of a particular concept, they engage in a cognitive activity. The teacher could regulate this activity by giving an explanation about this concept. When students discuss a strategy for solving the task, a metacognitive activity, the teacher could regulate this activity by communicating a deadline to the students.

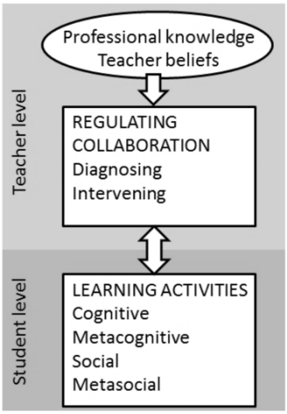


Figure 1.1. *Teacher regulation of collaborative learning, based on Kaendler et al. (2014).*

In their review study, Kaendler et al. (2014) provide a schematic overview of teacher regulation of (computer-supported) collaborative learning. Before and after the actual implementation of collaborative learning (the pre- and post-active phase), it is important that teachers respectively plan and reflect on the use of this instructional method. During lessons (the interactive phase), teachers interact with students and regulate the collaborative process by diagnosing and intervening, which is based on the type of learning activities that the collaborating groups engage in. All of these aspects are influenced by teachers' professional knowledge and beliefs, for example knowledge about how to perform these tasks and beliefs about what the role of the teacher should be. Figure 1.1 displays the teacher's and students' activities during the interactive phase of collaborative learning, which is the focus of this thesis.

1.2.3 Previous research concerning teacher regulation of CSCL

The framework of teacher regulation explained in Section 1.2.2 is applicable to both face-to-face and computer-supported settings (Kaendler et al., 2014). In this section, specific findings for CSCL are discussed.

Much research over the last years has been devoted to analyzing the types of interventions teachers employ during CSCL (Asterhan & Schwarz, 2010b; Azevedo, Cromley, Winters, Moos, & Greene, 2005; Greiffenhagen, 2012; De Smet, Van Keer, & Valcke, 2008; Vlachopoulos & Cowan, 2010), in some cases leading to a characterization of roles or functions the teacher fulfills. For example, De Smet et al. (2008) described three types of teachers, namely 'Motivators', 'Informers' and 'Knowledge constructors', meaning for example that a Motivator primarily focuses on social activities and tries to stimulate each student to participate.

Besides providing a description of teacher interventions, research in the field of CSCL has also aimed at uncovering whether and how teacher interventions have an effect on students' learning, the quality of the group product and group collaboration (Akyol & Garrison, 2008; Asterhan, Schwarz, & Gil, 2012; Hsieh & Tsai, 2012; Mazzolini & Maddison, 2003; Onrubia & Engel, 2012). For example, Akyol and Garrison (2008) found a positive relation between teacher presence and students' perceived learning and satisfaction. In a study by Hsieh and Tsai (2012) teacher interventions led to improved quality of the group product only in one of three sessions when compared to a group without a teacher present. Asterhan et al. (2012) found that different types of teacher interventions led to different results: regulation of cognitive activities led to improved argumentation and regulation of social activities led to improved participation and interactivity. Although the results of these studies are not conclusive, there is increasing empirical data available to uncover the relationship between teacher interventions and results of students' collaborative processes.

Research in the field of CSCL has given relatively little attention to the strategies teachers use to diagnose students' activities. This is surprising not only considering the importance of diagnosing, but also given the related opportunities and challenges that are unique to CSCL settings (Vlachopoulos & Cowan, 2010). Teachers can generally use two strategies to diagnose students' level of understanding, namely by actively questioning students and by observing students' activities (Van de Pol et al., 2010). In contrast to questioning, which requires teacher-student interaction, observing is a non-intrusive way of diagnosing. When teachers regulate collaborating groups in a synchronous setting, the teacher can observe real-time what activities the collaborating groups engage in, for example their continuous updates in written texts or changes in visual representations of students' arguments (see for example the ModellingSpace environment; Avouris et al., 2003). In other settings, teachers diagnose the progress of the task by reading students' work after or between lessons (termed "offline diagnosis" by Smit, Van Eerde, & Bakker, 2013). Thus, during CSCL teachers can be said to have a much greater amount of data available for diagnosis than in regular classroom settings. As explained, research in face-to-face settings (Chiu, 2004; Lin et al., 2014) seems to indicate that for teacher regulation to have an effect, timing and type of interventions is fundamental. Even in highly structured collaborative learning environments, students show differentiated paths of learning (De Laat & Lally, 2003), requiring the teacher to adapt interventions to these differences. The opportunities for diagnosing during CSCL could mean that choosing the appropriate intervention is easier, because the larger amount of information about students' activities could provide a more detailed impression of the needed regulation of each group. It is therefore important to study how teachers diagnose students' activities and how they decide upon interventions.

Recently, several studies have been conducted focusing on teachers' decisions while regulating CSCL, both using teacher interviews and case studies (e.g., Schwarz & Asterhan, 2011; De Laat & Lally, 2003; De Smet, Van Keer, De Wever, & Valcke, 2010b). For example, De Laat and Lally (2003) describe a teacher's decisions about when and how to intervene and show how this teacher focuses especially on students' social activities. Within the relatively small group of learners, the teacher is able to diagnose in an in-depth way the needs of the group. Schwarz and Asterhan (2011) show the complexity of diagnosing and supporting *multiple* groups at the same time and the resulting demands on the teacher, for example the choice when and how to intervene and how to balance between the needs of the groups and the needs of individual learners within those groups. The general conclusion from findings regarding both teacher diagnosis and interventions is that teacher regulation of CSCL is a challenging task (Packham, Jones, Thomas, & Miller, 2006). The teacher has to "orchestrate" students' activities (Dillenbourg & Jermann, 2010; Dimitriadis, 2012; Kollar & Fischer, 2013; Looi & Song, 2013) within the context of a specific CSCL environment that offers opportunities as well as challenges for teacher regulation. While teacher regulation has received increasing interest, more research is needed to uncover the mechanisms that play a role during this complex interplay between teacher, student and technology (De Laat & Lally, 2003).

1.2.4 Research goals for Part I

The aim of Part I of the thesis is to further explore two aspects of teacher regulation of CSCL. First of all, the aim is to provide a nuanced description of teacher interventions by studying multiple aspects of these interventions. As described above, many researchers have aimed at characterizing teachers' interventions, arriving at a typology of teaching styles. These descriptions are often based on one aspect of teacher interventions, for example *what* learning activity the teacher regulates or *how* the teacher does so. In the first presented study, a different perspective on the types of interventions a teacher employs is presented, namely a description not in terms of the style of the teacher, but in terms of the needs of each collaborating group. Furthermore, this is done by considering multiple time points. During CSCL, students generally work on complex tasks that take multiple lessons or sessions to complete (cf. De Laat, Lally, Lipponen, & Simons, 2007). This temporal aspect is often not taken into account in CSCL research (Barbera, Gros, & Kirschner, 2014; Reimann, 2009). Therefore, a case study is presented that describes multiple aspects of teacher interventions over a period of 8 weeks (see Chapter 2).

Secondly, a study is conducted into the diagnosing strategies employed by teachers during CSCL and the choices made concerning subsequent interventions. As described, one of the fundamental tasks of teachers during CSCL is to engage in ongoing diagnosis of multiple groups, who all perform multiple types of activities. The synchronicity and complexity of this task (Doyle, 2006) are not extensively researched yet. In the second study, we try to uncover teachers' strategies and decisions concerning the issue of synchronicity by studying two teachers that regulate seven collaborating groups. The aim is to examine the opportunities and challenges experienced by these teachers as related to regulating multiple groups and the resulting amount of available information about students' activities (see Chapter 3). Together, these two studies aim to answer the first main research question (see Section 1.1): *how do teachers regulate students' learning activities in multiple computer-supported collaborating groups, in terms of teachers' diagnosing and intervening strategies?*

1.3 Part II: Effects of Learning Analytics Tools on Teacher Regulation of Computer-supported Collaborative Learning

1.3.1 The balance between being informed and being overloaded

As described, teacher regulation of CSCL is a complex task. It might be argued that the opportunities for continuous diagnosis are at the core of this complexity. Having access to students' activities in real-time is an advantage for the teacher, because students' collaborative process is no longer a black box (Petrou & Dimitracopoulou, 2003). However, because a typical classroom will include five or six groups of students and all groups perform multiple activities, there is a large amount of information available to the teacher. The resulting challenges may be illustrated with the framework of cognitive load. Teachers think and act within the capacities of the human processing system, which consists mainly of working and long-term memory (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Working memory has limited capacity, which means only a limited amount of information can be actively processed. In case of ongoing diagnosis of students' activities, it can be a challenge for the teacher to keep up with all student activities (Persico et al., 2010), possibly turning the opportunity to *oversee* those activities into a problem of *overload* of information (Dyckhoff et al., 2012).

When cognitive load theory is applied to educational settings, it is often used to describe the mental effort of learners, i.e., students, but rarely to describe the mental effort needed during teaching. Cognitive overload for learners could mean that task performance decreases (Paas et al., 2003). The effects of cognitive overload on teaching are less clearly documented. Feldon (2007) describes how increased cognitive load could lead teachers to use their previously stored knowledge, because it takes less effort than processing current, newer information. A possible consequence of access to a large amount of information could therefore be that teachers cannot accurately diagnose the activities of each collaborating group. Instead, the teacher's focus of attention and the decisions to intervene may at least partly be based on previous experiences (Feldon, 2007), which could mean that interventions are not specifically tailored to the need of the learners at a specific moment. Besides the possible problems related to high amounts of available information, a further complicating factor is that some aspects of collaboration are not reducible to a single event, but span across time. For example, the amount of effort put in by a single group member only becomes apparent as time progresses; it is a cumulative property. Aspects such as these therefore require the teacher to monitor the group at multiple time points (Tabak, 2004), which again increases the difficulty of adequately diagnosing the group's progress.

In short, it is demanding to monitor the full complexity of all activities during CSCL. This could lead to teachers missing out on important moments, or teachers using the same kind of interventions for all groups, which possibly do not fit the needs of all students (Schwarz & Asterhan, 2011). Therefore, teachers could benefit from support concerning the process of diagnosing (Casamayor, Amandi, & Campo, 2009; Chen, 2006; Strijbos, 2011). A possibility to do so is by adding *learning analytics* tools to the CSCL environment that display information about each group's activities.

1.3.2 Learning analytics as a means to support teachers

Because all students' actions within a CSCL environment are usually automatically logged, they could serve as input for learning analytics tools. Learning analytics (LA) have been defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Siemens & Gasevic, 2012, p. 1). The result of the collection and analysis of data should be actionable knowledge; i.e., knowledge that can for example be used for decision making. Thus, LA typically involves the collection of data, analysis of the data and the application of those analysis within an educational setting, for example to predict learning outcomes given the records of students' activities and interactions (Chatti et al., 2012; Clow, 2012).

A large body of research concerning LA has focused on supporting students with analyses (for example, in the form of visualizations) of their activities, showing that LA can increase students' awareness of group processes and for example improve coordination of the group's activities (Janssen & Bodemer, 2013). Recently, the opportunity of supporting teachers by means of LA has also received attention (Chatti et al., 2012). Using students' activities as input, LA can support teachers in multiple ways. These methods differ in the amount of control that is left to the teacher (Jermann, Soller, & Muehlenbrock, 2005). For example, the analyzed data could be used behind the scenes by the CSCL environment to make automated decisions about what kind of guidance to offer to students. A second way is to show the analyses of the data in some form to the teachers. In this case, the teacher interprets the analyses and decides what actions (if any) to take (Jermann et al., 2005). LA can thus serve a multitude of functions, such as monitoring, assessment and recommendation (Chatti et al., 2012; Papamitsiou & Economides, 2014).

Collection and analysis of learner data can deliver actionable knowledge for teachers on multiple levels. On course or curricular level, LA can detect patterns from completed courses to warn teachers if students seem to be in danger of failing a task or a course (for example the Signals project, see Tanes, Arnold, King, & Remnet, 2011, or the Open Academic Analytics Initiative, see Jayaprakash, Moody, Lauría, Regan, & Baron, 2014). Many applications now offer LA tools for teachers (for an overview, see Verbert et al., 2014), such as the Performance Dashboard within Blackboard (2014) or the Course Reports offered by Moodle (2014; see also Romero, Ventura, & Garcia, 2008).

On the level of teacher-student interaction, the focus of this thesis, LA can be used for real-time assessment to support teachers' moment-to-moment decision making, thereby possibly supporting adaptive teaching. Returning to teacher regulation of CSCL and the danger of information overload, by providing summaries of students' activities, the information load imposed on working memory could be lowered. This means that teachers, instead of monitoring *all* activities, can derive an overview of the situation more easily which could help to diagnose the groups, in turn leading to increased adaptivity to students' needs (Feldon, 2007; Schwarz & Asterhan, 2011).

Another function LA could fulfill is to analyze and report characteristics of collaboration that otherwise require diagnosis at multiple time points. Aggregating aspects of collaboration that are not reducible to a single event into a visible summary means information about such processes is more easily accessible to the teacher. For example, during computer-supported collaborative assignments, because group collaboration is logged, LA could provide the teacher with up-to-date reports about collaborative processes that would otherwise be hard to keep track of. In short, analytics could "track and record previously ephemeral process data, which could benefit assessment for learning in significant new ways" (Knight, Buckingham Shum, & Littleton, 2014, p. 41). Besides lowering the mental effort required for diagnosis, another expected effect of LA is therefore that teachers are able to more easily diagnose the occurrence of problems concerning time-spanning aspects of collaboration.

Many articles have described how such tools may be designed, making use of techniques such as data mining to discover patterns between student activities in learning environments and their resulting learning gains (cf. Romera & Ventura, 2010; Soller et al., 2005). These studies all lead to the actionable knowledge described above; i.e., the obtained knowledge could be used for purposes of supporting teachers with diagnostic tools (Bakharia & Dawson, 2011). However, the step of actually providing teachers with these tools and, consequently, studying how they are used, is rarely taken (Chatti et al., 2012; Papamitsiou & Economides, 2014). A few exceptions are described here. Dyckhoff et al. (2012) developed diagnostic tools in collaboration with teachers and subsequently interviewed the teachers about their opinion of the usefulness of the tools, which led to further improvements in design regarding usability. Mazza and Dimitrova (2007) also created diagnostic tools, and besides interviewing teachers also performed a small scale experimental study (with 6 participants) which showed that teachers could more quickly and more accurately gain an overview of students' activities when they used the tools. Casamayor et al. (2009) found that when a teacher was notified of possibly problematic situations during students' collaboration, the teacher intervened more and was able to solve more conflicts. A qualitative study that focused both on diagnosing and intervening was conducted by Schwarz and Asterhan (2011). These authors described the choices of a single teacher concerning diagnosis and interventions and how the LA tools support the teacher to achieve adaptivity ("approximate attunement", p. 436) to the needs of each group. In particular, the tools gave the teacher an overview of activities, which resulted in the mental space needed to carefully consider the appropriate intervention at the appropriate time. Similarly, Chounta and Avouris (2014) found that as class size increased, teachers had more need of LA. After teachers focused on a particular group or on an individual student, the LA helped them to regain an overview of the rest of the class.

Thus, LA seem to be a promising direction for supporting teachers during regulation of synchronous CSCL. However, research in this area is still scarce and primarily small scale and there is a need for further examination of the effects of LA. The goal of the second part of this thesis is to add to this knowledge base, specifically focusing on the effects of LA on teacher diagnosing and intervening.

1.3.3 LA tools based on students' social and cognitive activities

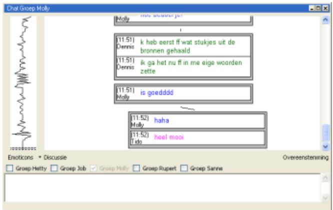
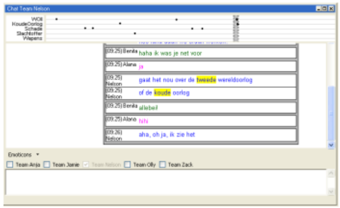
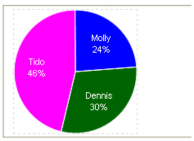
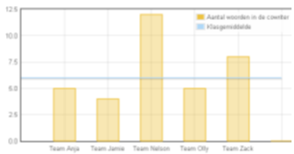
In Part II of the thesis, the effects of several LA tools on teacher regulation are investigated. As explained, the first phase of LA is to collect and analyze data. Concerning the specific LA tools used in this thesis, this section explains what data are collected, how the data is analyzed and how it is reported to the teachers. In the present case, the input for the analyses are students' activities. From these activities, both real-time, continuous properties as well as cumulative properties can be derived. For example, when groups discuss the task materials, a continuous property is whether the group is on task or not. An example of a cumulative property, on the other hand, is the amount of effort put in by each of the individual group members over time. The properties displayed by the LA tools in this thesis concern both students' social and cognitive activities. The visualized properties are all aspects that are known to be important for learning yet could be problematic for collaborative groups to achieve without regulation (Weinberger et al., 2005), for example, engaging in critical yet constructive discussion (Mercer, 2000).

LA can be designed as either embedded or extracted tools (Wise, Zhao, & Hausknecht, 2014). Wise et al. (2014) defined both types in case of LA used by learners: embedded analytics were described as "integrated into the learning environment itself that can be used by learners in real-time to guide their participation", whereas extracted tools are "presented for interpretation as a separate exercise from participating in the learning activity itself" (p. 52). In the present case, both types of tools are provided to the teacher. We slightly adjusted the definitions of Wise et al., in the sense that both embedded and extracted tools are included *within* the CSCL environment and can be used by the teacher while groups collaborate. The difference is that the embedded analytics are included within the tools students used to work on the task, whereas the extracted analytics are displayed as a separate tool, thus being physically separated from the activity the analytics are based on. The continuous properties of the groups' activities are displayed to teachers as LA tools embedded in the existing groups' tools, for example in the Chat-tool that was used for discussion, so that they would give teachers real-time information on activities in progress. The cumulative properties are extracted and displayed as a separate tool within the learning environment.

A final consideration for the development of the LA tools is the lay-out. Because the goal of the LA tools is to lower the teachers' information load and to offer information that is easy to process, for all LA tools a visual representation was chosen. Visual information takes less time to understand than a textual representation (Janssen, 2008, Mazza, 2009; Tergan & Keller, 2005). Table 1.1 displays an overview of the LA tools in the studies of this thesis. The columns represent the type of activity that is analyzed and visualized in the LA tool and the rows display whether it is an embedded or extracted tool. Two studies are performed to respectively investigate the effects of LA tools concerning students' social activities and students' cognitive activities.

First, LA tools are investigated that show information about social aspects of collaboration (see Chapter 4). The real-time, embedded tool is the Shared Space, which is a line that, based on automatic coding of students' messages in the Chat-tool, shows whether there is agreement or disagreement within a group by moving from left to right (Janssen et al., 2007). The extracted tool is the Participation Statistics, which shows the relative contribution of each group member to the total activity within the group, based on the number of keystrokes. The first column of Table 1.1 shows screenshots of the layout of both tools. Second, LA tools are investigated that show information about cognitive aspects of collaboration (Chapter 5). Again, there is an embedded and an extracted tool. The Concept Trail, embedded in each group's window for chat communication, shows whether and when the groups mentioned task-related concepts in their discussion. The Progress Statistics show how much progress the groups make on the task by displaying the number of written words in the shared text editor and in the chat discussion, with the class average showing a comparison between the groups. Table 1.1, second column, shows screenshots of the layout of these two tools.

Table 1.1. Overview of learning analytics tools used in our studies.

	Focus of LA tools	
Type of information	**Social activities**	**Cognitive activities**
Embedded tools: Continuous characteristics of discussion	Occurrence of agreement and disagreement (Shared Space) 	Use of task-related keywords (Concept Trail) 
Extracted tools: Cumulative quantity of activities	Statistics about participation  	Statistics about task progress 

The description of the LA tools makes clear why there is a coupling of continuous properties to embedded tools and cumulative properties to extracted tools. In case of the LA tools that display continuous properties, a direct link to the groups' activity is necessary for the LA tools to be useful to the teacher. For example, in the Concept Trail (see Table 1.1), a teacher can see during which times in the group discussion there is mention of concepts related to the task. This may give the teacher an indication of how the group is doing and when the teacher thinks it is necessary, he or she can immediately scroll the active window to the part of the stored conversation that the teacher thinks is remarkable or important. The cumulative properties, on the other hand, have no direct relationships to specific events and are therefore not coupled directly to activities within each group.

All LA tools are meant to support teachers while diagnosing students' activities, thereby possibly resulting in more adapted regulation and, ultimately, improved learning outcomes.

1.3.4 Research goals for Part II

The main goal of Part II of the thesis is to examine the effect of LA tools on teacher regulation of CSCL in terms of diagnosing and intervening. Concerning the scarce amount of existing empirical studies in the field of LA (Chatti et al., 2012; Papamitsiou & Economides, 2014), the aim is to contribute to the knowledge base with two experimental studies. An experimental simulation set-up is used with both quantitative and qualitative data collection and analyses, with the aim of examining whether LA tools may support teachers and if so, how (see Section 1.5.2). Part II of the thesis thus aims to answer the second main research question (see Section 1.1): *what are the effects of learning analytics tools that visualize various types of students' activities on teacher regulation of CSCL, in terms of teacher diagnoses and teacher interventions?*

1.4 Methodology

This thesis has two main goals. First, in Part I, to explore the complexity of teaching in a computer-supported learning environment by studying multiple aspects of teacher regulation (focus, means and experienced cognitive load) and examining the influence of multiple factors (time and multiplicity of collaborating groups). Second, in Part II, to study how visualizations of student activities may support and influence teachers during CSCL. Part I and Part II of the thesis differ in methodology, which is further explained below.

1.4.1 Methodology of classroom studies

In Part I of this thesis, teacher regulation of CSCL is explored in the form of two classroom studies, which means data is collected in authentic situations in secondary education. Within the participating classrooms, collaboration between students in small groups is facilitated by a digital learning environment called Virtual Collaborative Research Institute (VCRI, Jaspers, Broeken, & Erkens, 2004). In VCRI, students typically work on ill-defined tasks that require them to discuss task materials, resulting in a collaboratively written essay. For example, in history education, one of the assignments is to explore why the Cold War had not resulted in a Third World War. All materials for solving the task are included within VCRI, i.e., tools for communicating and writing as well as the domain specific sources that can be used to solve the task. VCRI is used for synchronous collaboration. Figure 1.2 displays a screenshot of VCRI as students use it. The collaborating groups have to read and analyze historical sources (using the Sources-tool), discuss the information (using the Chat-tool), order their findings in a diagram (using the Debate-tool) and write a report (using the Cowriter-tool). For all group members, these types of activities are all automatically logged by VCRI in the form of opening and closing of tools, sent messages, written words in the Cowriter, etc.

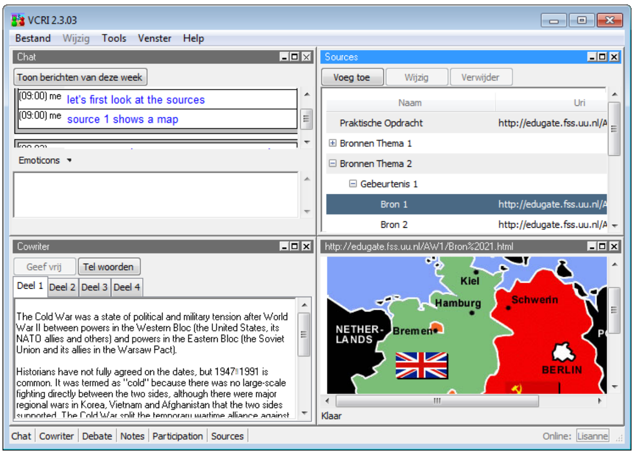


Figure 1.2. *Screenshot of VCRI student interface, with Chat-tool (top left), Cowriter-tool (bottom left), Sources-tool (top right) and one opened source (bottom right).*

A separate interface of VCRI exists for teachers, through which they can monitor the groups' activities. They can open each group's Chat-tool and see the content of each group's Debate and Cowriter-tool. Through the Chat-tool, teachers can join each group's discussion and intervene when they think it is necessary. Multiple screens can be opened at once, thus enabling the teacher to monitor multiple groups at a time. VCRI can be enhanced with several additional LA tools that show information based on the logged students' activities described above.

To answer main research question 1, multiple types of data are collected. A large part of the data consists of the user log files of both teachers and students while they work with VCRI, which gives information about how teachers use VCRI and when and how they intervene during the students' collaboration. In addition, interviews are held with the teachers to answer questions such as what information teachers seek during diagnosis and what intervention decisions they make (Van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009). More specifically, stimulated recall interviews are used to reveal teachers' thoughts and decisions during specific events (Lyle, 2003; cf. De Smet et al.,2010b).

1.4.2 Methodology of experimental studies

In Part II, two empirical studies are reported that examine what effect LA tools have on how teachers regulate students' activities during CSCL, thereby moving beyond a technical description of LA tools.

The experimental setup is realized by creating a simulation version of the existing VCRI learning environment. The simulation takes as input authentic user data derived from usage of VCRI in classrooms and displays these data in real-time. Thus, when a teacher is shown the simulation software, it will appear that groups of students are collaborating real-time, the only difference being that when the teacher sends a message to a group, the students will not respond. The vignettes contain groups that experience problems concerning specific types of activities. The simulation setup makes it possible to show the same situations (i.e., vignettes) to all participating teachers. In the control condition, the simulation software is essentially the same as VCRI as it is used in classrooms, i.e., without any additional LA tools (see Section 1.2.1). In the experimental conditions, the simulation is enhanced with different types of teacher supporting LA tools (see Table 1.1 and Section 1.3.3 for the theoretical rationale for the design of the tools). Thus, in both conditions teachers are asked to regulate student collaboration in the vignettes as if it were a real classroom setting by monitoring students' activities and intervening when they think it is necessary.

Figure 1.2 shows a screenshot of the teacher interface in the experimental condition with the Progress Statistics and the Concept Trail. In this case, the teacher has opened the Statistics for one of the groups (top left), the Sources-tool that shows the task materials (bottom left) and the Chat-windows from two of the collaborating groups that integrate the Concept Trail (top and bottom right).

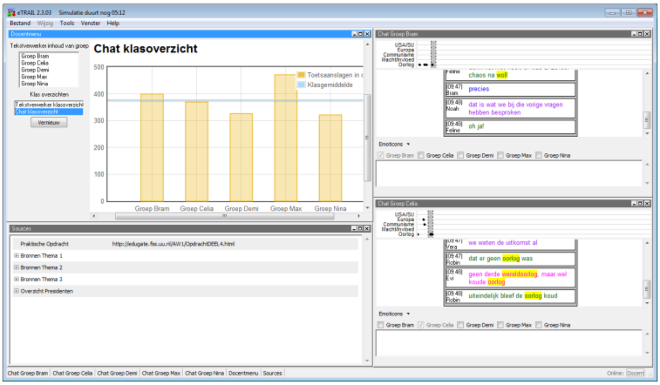


Figure 1.2. *Screenshot of teacher interface during experimental setup, with Progress Statistics (top left), Sources-Tool (bottom left) and Chat-tools of two groups (right).*

Each vignette lasts about 8 minutes. After each vignette, teachers are asked to give a diagnosis of each group in terms of a grade for various aspects, such as the quality of the discussion and the progress that was made on the task. Additional comments can be given to these diagnoses. Log files are obtained of the way teachers act during and after the vignettes. The collected log files thus include how often and which tools teachers use to monitor the groups, the number of teacher interventions and the diagnoses scores given by the teachers to the collaborating groups. By comparing teacher regulation in the control condition and the experimental condition, the effect of the LA tools is examined.

1.5 Practical Relevance

The results of the thesis are of practical relevance for several reasons. First of all, information and communication technologies (ICT) are currently rapidly developing and increasingly being used in educational settings. Besides relatively simple programs used for text editing and practicing skills such as arithmetic tables, new software allows for more advanced uses of technology, for example to support collaborative learning. Schools within Europe are increasingly well equipped with ICT and the use of ICT by teachers, as well as their confidence in using ICT, is increasing (European Commission, 2013). According to a report by Kennisnet (2013), the number of computers, laptops and tablets in Dutch schools is still rising and about 30% of teachers in secondary education and 50% of teachers in primary and vocational education use technology at least 10 hours a week during their lessons. Furthermore, the percentage of teachers who use technology for goals such as text editing or finding information on the internet is higher than those that use it for simulations, games, collaboration and social media, but the latter categories are increasing. Of course, an increased use of ICT does not necessarily mean that the quality of teaching or the quality of students' learning increases as well. There is still no conclusive evidence of improved learning outcomes as a result of ICT use in education, the results being highly dependent on the learning domain and the type of ICT (Livingstone, 2012; Cheung & Slavin, 2013). Furthermore, there is still an important step to be taken regarding teachers' knowledge and skills to integrate technology in their instructional processes in order to reach the potential of technology in the classroom (Voogt, Almekinders, Van den Akker, & Moonen, 2005). Still, the fact remains that increasing numbers of teachers are choosing to use more advanced technology in their lessons, which gives rise to new questions and ideas that are worth researching (Fischer, Wild, Sutherland, & Zirn, 2014; Volman, 2005).

Indeed, as Salinas (2008) notes, an interesting synergy seems to be emerging between student-centered types of education (such as collaborative learning) and educational technology. On the one hand, student-centered educational ideas give an impulse to the development of more advanced instructional technology. The other way around, computer-supported settings facilitate the efficient and possibly effective implementation of student-centered instructional strategies. For example, as noted, when teachers choose to let students work on collaborative assignments, they may do so because interaction among students is thought to be beneficial for learning. Technology may support both students and teachers during collaborative learning. Teachers can monitor students' activities real-time, possibly combined with LA tools. Although the use of CSCL and LA are still relatively uncommon in Dutch schools, it is expected that they will become more broadly used in years to come. CSCL and LA are emerging practices and teachers could therefore benefit from empirically tested guidelines for implementing it in a sound way.

Besides the issue of emerging technologies, another practically relevant aspect of this thesis is the role of the teacher during collaborative learning and the need for the teacher to adapt to the needs of multiple groups. During collaborative learning, the teacher is not a 'sage on the stage' but a 'guide on the side' (De Laat et al., 2007; King, 1993; Salinas, 2008). This does not mean, as is commonly thought, that the teacher becomes less important. On the contrary, the teacher fulfills a more important role than ever because student-centered instructional strategies such as collaborative learning require adequate support (Gillies, Ashman, & Terwel, 2008; Salinas, 2008). As noted in Sections 1.1 and 1.2, teacher support is needed to achieve successful collaboration (Kaendler et al., 2014). As a facilitator of the collaboration between students, each individual group can learn at their own pace. The complexity and importance of the teacher's task increases as each student or group of students requires careful 'calibration' of the teaching strategies employed. Offering individualized support is an important characteristic required in student-centered work forms, as witnessed by the current interest in increasing the quality of teaching in terms of adaptivity to the needs of different learners (Brühwiler & Blatchford, 2011; Kyriakides; Creemers, & Antoniou, 2009; Vogt & Rogalla, 2009). This is also apparent in the description of themes that are most relevant in the current field of Dutch educational research (NWO, 2012). One of those themes is *adaptive education*, not only in the broad sense of including all students (i.e., students with learning difficulties) in schools, but more particularly on an interactive level during teacher-student interaction within lessons. Adaptive teaching in this sense means that teacher support is aligned to the different needs of students or collaborating groups of students within the same classroom (Blok, 2004; Brühwiler & Blatchford, 2011; NWO, 2012). The studies in this thesis examine this important aspect and could shed light on the type of teaching skills teachers need during CSCL and what the challenges and opportunities are that teachers face while doing so. The thesis also examines whether LA could aid in achieving more adaptive teaching during CSCL.

1.6 Overview of the Thesis

As explained, the research presented in this thesis consists of two parts. In Part I (chapters 2 and 3), teacher regulation of CSCL is explored by means of two classroom studies. *Chapter 2* presents an in-depth case study of how a teacher regulates student collaboration in terms of the type of interventions over the course of eight weeks. *Chapter 3* describes two teachers who regulate multiple collaborating groups. It is explored what strategies these teachers use to diagnose the groups' progress and how and when they choose to intervene. After this initial exploration of teacher regulation of CSCL, Part II of this thesis (chapters 4 and 5) presents two experimental studies concerning the effect of LA tools on teacher regulation of CSCL. In *Chapter 4*, teachers are provided with LA tools that show information about social aspects of collaboration. The way these teachers diagnose and intervene during group collaboration is compared to teachers without access to LA tools. *Chapter 5* uses the same experimental setup, but in this study the LA tools show information about cognitive aspects of collaboration. Finally, *Chapter 6* contains a general discussion of the findings, limitations and implications of the presented research, from which a number of directions for future research will be derived. Table 1.2 schematically outlines the structure and content of the thesis.

Table 1.2. Overview of chapters in this thesis.

Ch1: Introduction		
Part 1: Exploring teacher regulation of CSCL		
	Research topic	*Methodology*
Classroom studies	*Ch2*: focus, means and temporality of teacher interventions	Explorative case study / Observation
	Ch3: diagnosing and intervening strategies of teachers regulating multiple collaborating groups	Explorative case study / Interviews
Part 2: Effects of learning analytics tools on teacher regulation of CSCL		
	Research topic	*Methodology*
Lab studies	*Ch4*: effects of learning analytics tools that focus on students' social activities	Experimental study
	Ch5: effects of learning analytics tools that focus on students' cognitive activities	Experimental study
Ch6: General discussion		

Part I
Exploring teacher regulation of CSCL

Chapter 2: Focus, means and temporality of teacher interventions[1]

2

Abstract Computer-supported collaborative learning (CSCL) environments facilitate collaboration between students. There is a growing interest in studying the role of the teacher during CSCL. This study aims to contribute to the conceptualization of teacher interventions during CSCL. A teacher and his class worked in a CSCL environment for 8 lessons. Focus and means of teacher interventions were analyzed across these 8 time points. The results show that the teacher's behavior varied greatly between lessons and also between groups, which contradicts research that has aggregated teacher behavior to types or teaching styles. Findings consistent across time points include the predominance of the teacher's focus on students' cognitive rather than social activities and a higher number of interventions in groups where student activity was higher. Suggestions are made for future research, which include studying the effectiveness of supporting tools for teachers.

2.1 Introduction

Computer-supported collaborative learning (CSCL) combines collaborative learning with the use of information and communication technologies. Its primary aim is to provide an environment that supports and facilitates collaboration between students in order to enhance students' learning processes (Kreijns, Kirschner, & Jochems, 2003). There is a broad range of types of supporting tools specifically aimed at helping students carry out the learning task (Jermann, Soller, & Muehlenbrock, 2005). It is striking that in settings in which these tools are used, there often is no mention of the presence of a teacher, i.e., the students seemingly work on their assignment independently.

However, recently there has been a growing interest in the role of the teacher during CSCL, which suggests that the teacher retains an important role. The premise of this interest is that teacher activities or interventions could have an important impact on the way students collaborate and the quality of the group products (Vlachopoulos & Cowan, 2010). The renewed interest in the teacher's role during CSCL has led to the need to develop supporting tools not only for students, but also for the teacher who regulates the students' activities (see for example the Argunaut project; Asterhan & Schwarz, 2010a). These tools could deliver teachers information that enables them to better carry out their tasks, for example information about group progress or about the way groups are collaborating (McLaren, Scheuer, & Mikšátko, 2010).

[1] Based on: Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2013). Teacher interventions in a synchronous, co-located CSCL setting: Analyzing focus, means, and temporality. *Computers in Human Behavior*, *29*(4), 1377-1386. doi:10.1016/j.chb.2013.01.028

To develop and test the effectiveness of supporting tools for teachers, there is a need to know what kind of behavior teachers employ and what kind of behavior is effective. This knowledge would enable the design of tools that are aimed at giving teachers the information and prompts needed to effectively regulate students' activities. Whether particular teacher interventions – or merely teacher presence – lead to an increase in the quality of students' collaboration and students' group products, still remains unclear (Asterhan, Schwarz, & Gil, 2012). Asterhan et al. (2012) found that differing types of teacher regualtion led to differences in learning results. In a study by Hsieh and Tsai (2012) teacher presence led to improved learning outcomes only in one of three sessions when compared to a group without a teacher present. Differences in outcomes were better explained by looking at the type of interaction patterns between students. In other words, there is no clear evidence yet of which types of teacher regulation are effective.

Many researchers have aimed at first studying which behavior teachers during CSCL display without any supporting tools present (Asterhan & Schwarz, 2010b; Azevedo, Cromley, Winters, Moos, & Greene, 2005; Greiffenhagen, 2012; De Smet, Van Keer, & Valcke, 2008; Vlachopoulos & Cowan, 2010). What appears from these studies is that teachers face a very complex task (Volman, 2005). The present study aims to contribute to this knowledge base by studying multiple aspects of teacher regulation of CSCL and the variation in teacher regulation between lessons and between groups.

2.1.1 Complexity of a teacher's task during CSCL

Regulating students' learning in an online learning environment is as much of a challenge as it is in a regular classroom (Asterhan & Schwarz, 2010b; Volman, 2005). There are several reasons why the teacher's task is so complex. First of all, comparable to face-to-face collaborative situations, teachers deal with several types of synchronicity. Not only do they regulate several groups' activities at the same time, they also have to focus on multiple aspects of students' progress, namely both cognitive as well as social activities during student collaboration. Furthermore, differences between groups require the teacher to adapt his interventions to the groups' needs (Chiu, 2004).

There are also complicating factors that are unique to CSCL. CSCL environments offer teachers information not only about the learning result but also about the learning process: teachers are able to follow discussions between students and in some digital environments, teachers are given information about students' progress, for example by displaying the amount of messages sent (Van Diggelen, Janssen, & Overdijk, 2008). It may be easier for a teacher to monitor students' learning processes when given this extra information. On the other hand, having access to such amounts of information could also cause an information overload for the teacher (Van Diggelen et al., 2008). The type of information is thus different than during face-to-face collaboration, and the cues that a teacher may normally use to determine dysfunction in a learner or a group (such as facial cues) are not physically visible.

Another unique aspect of CSCL is that teachers are able to interact with multiple groups at the same time (Schwarz & Asterhan, 2011). That is, teachers may send the same message to multiple groups simultaneously, or keep up and switch between multiple chat conversations. There is thus a challenge for the teacher to adapt to differences between groups and to make use of the ability to intervene at multi-group level.

2.1.2 Analyzing multiple aspects of teacher interventions

As was mentioned in the introduction, many researchers have aimed at studying natural teacher behavior in CSCL. Teacher interventions are often studied concerning one aspect. That is, one aspect is used to categorize teacher interventions and the categories within this aspect are mutually exclusive. In contrast, it could be argued that each intervention can be studied from multiple angles and that interventions can be assigned a category for multiple aspects.

Each teacher intervention both has a focus and a means. For example, when a teacher tells a group of students to “Start by reading the assignment”, the focus is on cognitive activities, while the means is an instruction. A similar difference between the ‘what’ (focus) and ‘how’ (means) of teacher interventions was also noticed in the literature about teacher regulation of face-to-face collaboration in a review study about scaffolding by Van de Pol, Volman and Beishuizen (2010). There are few studies that explicitly recognize and use the difference between focus and means. A study by Many (2002) discriminates between the aspects ‘focus’ (for example, ‘Use of strategies’) and ‘scaffolding processes’ (such as ‘Questioning’). Why is such a distinction useful? Van de Pol et al. (2010) suggest that “this distinction [..] enables us to look more precisely at interactions and results in more nuanced descriptions of teacher-student interactions” (p. 276).

Very few studies on CSCL analyze multiple aspects of teacher interventions. Typically, the methodologies used are similar to either focus or means. Some studies investigate the focus of teacher interventions, i.e. what the teacher’s intervention is aimed at (examples include Asterhan, 2011; De Smet et al., 2008; Lund, 2004; Onrubia & Engel, 2012). Lund (2004) for example includes the categories ‘Social’, ‘Managerial’ and ‘Pedagogical’. It is generally considered important for teachers to focus on students’ cognitive (task-related) activities as well as social activities within a group (Anderson, Rourke, Garrison, & Archer, 2001; Asterhan et al., 2012; Kreijns et al., 2003). These activities take place at what is called the object level. Next to that, it is also important that teachers focus on the meta level, i.e. whether students discuss and regulate their (cognitive and social) activities, for example by making sure that students reflect on their learning or use effective strategies (Janssen, Erkens, & Kanselaar, 2007; Molenaar, Van Boxtel, & Sleegers, 2011).

Other studies approach the means of teacher interventions, i.e. how the teacher intervenes (for example, Chiu, 2004; Gil et al., 2007; Greiffenhagen, 2012). Consider the study by Greiffenhagen (2012), in which the categories ‘Making announcements’, ‘Reminding’ and ‘Suggesting’ are used. Van de Pol et al. (2010) listed the categories of means that are most commonly identified: feeding back, hints, instructing, explaining, modeling and questioning. Giving hints might imply that the teacher takes less control, for example by activating students to think about a strategy for collaboration, while means such as instructing imply a more controlled form of regulation where the teacher directly tells students what to do (Vermunt & Verloop, 1999).

There are some examples of studies that analyze one aspect of teacher interventions but which include a combination of categories similar to both focus and means (De Laat & Lally, 2003; Gillies & Boyle, 2005; 2008; Hsieh & Tsai, 2012). Gillies and Boyle (2005; 2008) study ‘mediative-learning behaviors’ that includes both categories similar to focus (such as ‘Cognitive’) and means (such as ‘Prompts’). Although this aspect contains categories from multiple aspects of teacher interventions, still the categories themselves are mutually exclusive and thus each intervention is placed under exactly one category.

Analyzing teacher interventions in CSCL can be done at different time-levels, ranging from micro analysis of utterances to macro analysis of conversations or even whole lessons. The research question determines which level of analysis is appropriate and how the studied aspect of teacher regulation is conceptualized. From the studies mentioned above, it appears that coding the means of teacher interventions is often done using a small time scale unit (for example, Greiffenhagen, 2012). In these studies, the primary aim of the research is to report features of interaction in small detail. Studies that analyze the focus of interventions, on the other hand, often employ an analysis that results in a summary of teacher activity over larger periods of time, such as a whole lesson (Hsieh & Tsai, 2012) or the whole of the studied period (for example, Asterhan, 2011).

When interventions are studied in detail, the focus of interventions is likely to be stable. That is, when studying a particular conversation between a teacher and a student, the conversation is defined by its being about the same subject (focus). The interesting aspect of the conversation in these cases is not the what (focus), but the how (means): which type of interventions does the teacher use in a particular conversation? On the other hand, when teacher behavior is described on a larger time scale, it might be more informative to report which areas of students' work the teacher focused on instead of the means of intervening. This might explain why some studies only report on the means, while others report on the focus of interventions. Each perspective offers information on a particular aspect of teacher interventions during CSCL. Therefore, a more accurate picture of teacher interventions can be obtained when both aspects are taken into account. It is the aim of this study to analyze both focus and means of teacher interventions.

2.1.3 Change between lessons and variation between groups

The research on teacher interventions described so far has a one-dimensional character in the sense that one aspect of the teacher's task is analyzed (either focus or means). Another characteristic of these studies is that results are often presented on an aggregated level. That is, conclusions are drawn about teacher interventions at a general level. Some researchers aim to characterize particular teacher 'types' (Mazzolini & Maddison, 2003) or 'moderation profiles' (Asterhan, 2011). For example, Mazzolini and Maddison (2003) distinguish between a dominating 'sage on the stage' and a less pervasive 'guide on the side', based on summaries of teacher interventions taken as a whole.

It should be kept in mind that in CSCL environments students often work on a complex assignment that takes multiple lessons to complete. Such tasks contain multiple phases during which students perform different kinds of activities (Erkens, Jaspers, Prangsma, & Kanselaar, 2005). It is therefore likely that not only the students' behavior, but also the type of teacher's interventions change as the number of sessions progresses (Onrubia & Engel, 2012). Some researchers have therefore discriminated between the beginning, middle and ending phase of students' collaboration and displayed findings about teacher interventions for each of these phases separately (cf. Akyol & Garrison, 2008; De Laat & Lally, 2003).

This importance of time scales and temporality has recently received great attention in CSCL literature, leading to a movement that calls for a temporal analysis of interaction data. It is emphasized that “temporality matters” (Kapur, 2011; Reimann, 2009), both on a small scale in patterns of turn-taking within interaction (Hsieh & Tsai, 2012) and on a larger scale as change or variation between sessions or lessons. Not taking temporality into account can lead to a less nuanced description of teacher interventions. As Kapur (2011) notes, “By aggregating counts over time, information about temporal variation is lost” (p. 41). Even though the importance of temporality is recognized, it has played almost no role as a variable in research on education and educational technology (Barbera, Gros, & Kirschner, 2014). Too little is known yet about the change in teacher interventions between lessons and the variation of teacher interventions between groups.

2.1.4 Aim of the present study

Within the introduction, the importance of facilitating tools for the teacher in CSCL environments was pointed out. The first step towards this goal is the exploration of natural teacher behavior during CSCL. Two methods have been pointed out that could contribute to a better understanding of the complex task teachers face when they regulate students’ learning in a computer-supported collaborative learning environment. The first method is to analyze multiple aspects of teacher interventions, namely both focus and means. The second method is to analyze teacher interventions taking into account change between lessons and variation between groups. This study aims to bring together these two methods.

A case study is presented in which the interventions by one teacher, spread over multiple weeks of activity, are analyzed. Case studies provide the opportunity for in-depth investigation of processes and are especially suited when the subject has not been extensively researched yet (Yin, 2003). The aim is to contribute to the conceptualization of teacher interventions during CSCL, and to contribute empirically to the existing literature on the characteristics and dynamics of teacher interventions in CSCL. This exploration of teacher behavior is a necessary step towards the development of facilitating tools for the teacher in CSCL environments.

The following research questions have been formulated:

1) How does the teacher intervene in terms of focus and means?
2) How do the teacher’s interventions, in terms of focus and means, change between lessons and vary between groups while students work on the assignment?

2.2 Method

2.2.1 Participants

One secondary education history male teacher (age 43, with 15 years teaching experience) and 21 students (age M = 15, SD = 0.6), who were all enrolled in the third year of the pre-university education track, were involved in the study. Students were assigned by the teacher into groups of three students. There was a total number of seven groups. The teacher and students were provided with an introduction to the CSCL environment.

2.2.2 CSCL environment

Students and teacher made use of the CSCL environment called Virtual Collaborative Research Institute (VCRI, see for example Janssen et al., 2007). VCRI is a groupware program designed to support collaborative learning on inquiry tasks and research projects. It was used in a synchronous, co-located setting. All students had their own computer and synchronously communicated with their group members through the Chat-tool in VCRI. The assignment involved exploring the topic of the project by reading historical sources in the Sources-tool. Students could discuss the information through the synchronous Chat-tool. Students used the Debate-tool to construct a shared diagram of their arguments. Students used the Cowriter, a shared text processor, to write their texts.

An alternative interface of the VCRI-program was available for the teacher, which allowed him to monitor the online discussions of the students in the Chat-tool in real-time and send messages in order to answer students' questions. Messages can be sent by the teacher to a group, more than one group at a time, or the whole class. Teachers can examine the texts students are writing in the Cowriter or the diagrams they are making in the Debate-tool. The teacher thus was monitoring seven groups at a time by opening the tools the groups are working in and intervened by sending messages through the Chat-tool. The program offered the teacher some basic statistical information about students' activities in VCRI's tools (e.g., the number of keystrokes per student). Figure 2.1 shows the teacher interface.

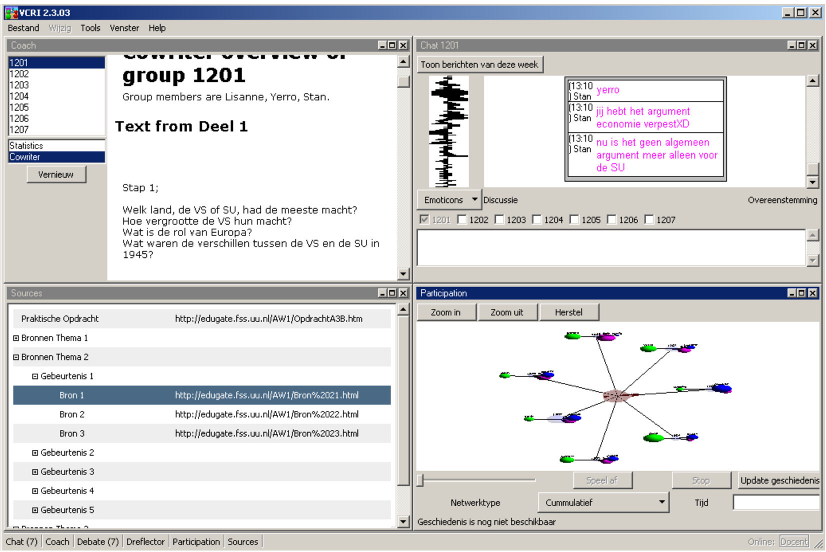


Figure 2.1. *An example of the configuration of the VCRI teacher interface. In this case, the teacher has opened a group's Cowriter (top left), one group's Chat-tool (top right), the Sources-tool (bottom left), and statistics about students' activities (bottom right).*

Because of the co-located setting, direct verbal contact was possible. However, it was explained to the participants that the purpose of the research was that they would communicate through VCRI, so that both the teacher and the students could benefit from the ability to re-read all conversations. Furthermore, each lesson the teacher tried to divide group members across the classroom, so that direct contact between group members would be minimal. As a result, there was indeed little direct verbal contact.

2.2.3 Assignment

During this study, students collaborated on an inquiry group task for the subject history about the Cold War. The task can be characterized as an open-ended group task that focused on reading, comprehending and synthesizing historical sources. The assignment was split into four parts, each resulting in an argumentative text written by the groups of students. The first part asked students to reflect on the consequences of World War II. The second part was about events during the Cold War and which role the United States and the Soviet Union played in these events. The third part required students to summarize their arguments in a graphical representation in the Debate-tool. This resulted in part four, a final text on why and how the Cold War ended. The class worked with VCRI for 8 lessons of 50 minutes.

2.2.4 Analysis of teacher interventions

VCRI automatically logs all communication in the Chat-tool. Thus, for each lesson a protocol was derived with the students' messages and teacher's interventions in the Chat-tool. Each of the teacher's interventions (messages) were coded for two aspects, namely focus and means. The codes for *focus* are based on the distinction between cognitive and social activities, which are the two categories generally considered important for teachers to support students' learning process (Salmon, 2000). These two categories are further split into the object and the meta level (Molenaar, Van Boxtel, & Sleegers, 2011) so that besides cognitive and social activities (object level), metacognitive and metasocial activities (meta level) are also incorporated into the coding scheme. A similar approach was used in for example Janssen et al. (2007). See Table 2.1 for examples of each of these four categories.

The codes for *means* were derived from the review study by Van de Pol et al (2010). Their categories feeding back, hints, instructing, explaining and questioning were used and the category questioning was further expanded by adding diagnosing and prompting. Diagnosing denotes questions that are aimed at checking students' progress. Prompting denotes questions that are meant to help or activate students. Table 2.2 shows the coding scheme for means. Explaining, Instructing and Feedback are means in which the teacher exerts a high level of control, while Prompting and Hinting are means in which the teacher takes less control (Vermunt & Verloop, 1999).

Two independent coders both coded a random sample of about 100 chat messages. Cohen's κ for focus was .77, for means it was .76. After establishing the interrater reliability of the coding procedure, all messages sent by the teacher were coded by one researcher and analyzed using the Multiple Episode Protocol Analysis-program developed by Erkens (2005).

Table 2.1. Coding scheme for the focus of interventions.

Focus	Definiton	Example
Cognitive activities (Cog)	Utterances about task content	"SU means Soviet Union"
Metacognitive activities (MCog)	Utterances about planning of the task or time management Utterances about task strategies	"Start reading the sources"
Social activities (Soc)	Utterances about the mood or other social activities within a group or the class	"John, please act more friendly"
Metasocial activities (MSoc)	Utterances about the collaboration process or strategies for collaboration	"Divide the tasks among your group"
Other	Information about (using) the program (VCRI) Remaining utterances that do not fall under any of the other categories	"Use the button on the left"

Table 2.2. Coding scheme for the means of interventions.

Means	Definition	Example
Questioning	Request for a piece of information	"Who is online?"
Diagnosing	Questions to understand the current situation, without giving help Asking what the problem is / about students' understanding of the topic on hand	"What is the problem?"
Prompting	A question that is meant as a hint (see *Hinting*)	"Didn't the Americans also have weapons?"
Hinting	Giving a hint or a reminder, without supplying the solution or detailed instructions. Students are still required to think for themselves A hint can take the *form* of an instruction	"Try to think of why a nuclear war has no winner"
Explaining	Providing direct answers or information to elaborate on something, to make it clearer. After giving an explanation, the students are able to continue their task immediately.	"SU means Soviet Union"
Instructing	The teacher instructs students to do something Recognizable mostly by the use of an imperative, but this is not necessary	"Start reading the sources"
Feedback	Direct evaluation of the behavior/work of the students	"Well done!"
Other	Remaining utterances Correcting a previous statement	"That was meant for the other group"

2.3 Results

2.3.1 Overall results

During the eight lessons the teacher and students worked in VCRI, the teacher sent 391 interventions. Of these 391 interventions, 192 (49.1%) were reactions to student questions. The teacher used the system six times between lessons to read student contributions in the Cowriter-tool. In every lesson the teacher checked the statistics right at the start of the lesson and on average another four times during the remainder of the lesson.

The means used most often by the teacher are Explaining (25.2%), Feedback (22.7%) and Diagnosing (20.1%). Prompting and Hinting together make up approximately 21.4%. The focus of interventions was most on cognitive activities (Cog, 41.8%), closely followed by focus on metacognitive activities (RegCog, 39.6%). Relatively few interventions were focused on social or metasocial activities (together making up 15.1% of all interventions).

When the focus was on cognitive activities, the most often used means were explaining and prompting. When the focus was on metacognitive activities, means often used were diagnosing and feedback. A focus on social or metasocial activities was often combined with feedback. Two percent of teacher interventions were Explanations focused on the category 'Other'; these were mostly messaged about technical matters.

2.3.2 Single group and class interventions

The teacher was able to send messages to single groups, but also to multiple (selected) groups or to the whole class (all groups). In this case, the teacher sent single group and class messages, but did not make use of the option to send messages to selected groups. Table 2.3 displays the amount of teacher interventions for each of the eight lessons, discriminating between the total number of interventions and the number of class interventions (interventions sent to all groups). From the total of 391 interventions, 49 (12.5%) were class interventions. Twenty percent of these interventions were Diagnosing, another 20 percent were greetings to the group and the remaining class interventions were a combination of other categories.

The lower half of Table 2.3 shows the amount of unique interventions per group, that is, the amount excluding the class interventions. For example, during lesson 1 the teacher sent 12 class interventions, on top of which group 2 received 8 additional interventions sent to only their group.

The total amount of student activity is shown in the last column of Table 2.3. Some groups were more active than others. It appeared that the higher student activity, the more teacher interventions within the group. The most active group (group 7) received most interventions, while the least active group (group 3) received the lowest number of interventions. Analysis of the individual lessons showed there was indeed a significant association between the number of student messages and the number of teacher interventions, $r = .38$, p (one-tailed) $< .01$.

Table 2.3. Amount of teacher interventions per lesson, displaying the total number of interventions and the number of class interventions (upper half) and number of single-group messages (lower half).

	Lesson								
	1	2	3	4	5	6	7	8	Total
Total interventions	46	41	57	56	64	27	63	37	391
Class interventions	12	3	5	9	5	2	8	5	49
Single group interventions									teacher/students
1	0	0	4	5	8	1	4	0	22 / 1172
2	8	11	4	14	7	5	23	4	76 / 583
3	3	1	0	4	2	2	2	1	15 / 301
4	6	4	2	4	9	3	7	3	38 / 743
5	8	3	4	4	13	3	3	19	57 / 705
6	1	4	5	5	8	3	3	1	30 / 402
7	8	15	33	11	12	8	13	4	104 / 2169

2.3.3 Change between lessons

Figures 2.2 and 2.3 display the focus and means of teacher interventions for each of the eight lessons that students worked on the assignment. As a measure of variation between groups, the coefficient of variation is given in Tables 2.4 and 2.5, which shows the extent of variability and is calculated by dividing the standard deviation by the mean within the groups.

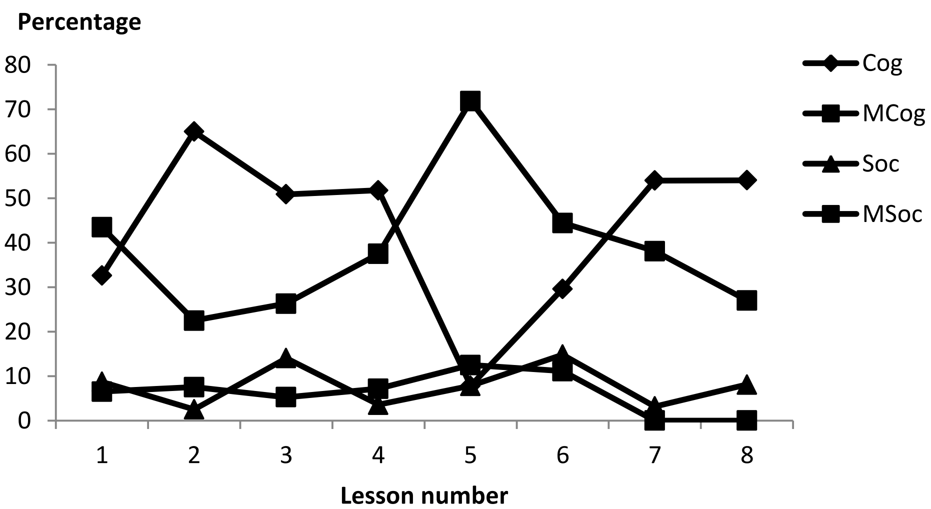


Figure 2.2. *Focus of teacher interventions in percentages, displayed per lesson.*

Table 2.4. Coefficients of variation between groups of focus of teacher interventions for each lesson.

	Coefficient of variation per lesson							
Category	1	2	3	4	5	6	7	8
Cog	0.9	0.9	1.0	0.6	1.0	1.1	0.9	1.8
MCog	0.3	0.5	0.3	0.2	0.1	0.2	0.3	0.4
Soc	0.2	0.5	0.6	0.3	0.3	1.1	0.3	0.6
MSoc	1.6	0.7	1.3	0.4	1.5	1.6	0.0	0.0

In line with the overall results (Section 2.3.1), the focus (Figure 2.2) is mostly on cognitive and metacognitive activities. However, the relative frequencies fluctuate for each lesson. For example, there is a strong predominance of focus on metacognitive activities during the middle part (lesson 5).

A relatively small portion of teacher interventions focused on social or metasocial activities. The percentages of focus on these categories is low throughout all the lessons, so there is little change between lessons. Looking at Table 2.4, the variation between groups for these categories is relatively high in some lessons. For example, the coefficient of variation for focus on metasocial activities in lesson 3 is 1.3 where the corresponding score in Figure 2.2 is 5%. This means that the standard deviation was relatively high and that the teacher's interventions focused on metasocial activities only in selected groups. The same can be said for the focus on metasocial activities in later lessons (5 and 6).

As for the means (Figure 2.3), the most occurring categories found in the overall results (Explaining, Feedback, Diagnosing) are not clearly predominant when viewing each lesson separately. For example, the relative frequency of Explaining is especially low during the middle part (lesson 5 and 6) and the relative frequency of Feedback is quite low at the beginning (lesson 1). The other way around it is apparent that categories that score relatively low overall, like Instructing (5% of total), occur relatively often during some lessons. For example, Instructing reaching 20% during the middle part (lesson 6). It thus seems that there is a change in the type of interventions between lessons. Table 2.5 shows there is also some variation of the means of interventions between groups, but this variation is not as big as the variation between groups for the focus of interventions. The coefficients of variation in Table 2.5 are relatively smaller than those in Table 2.4.

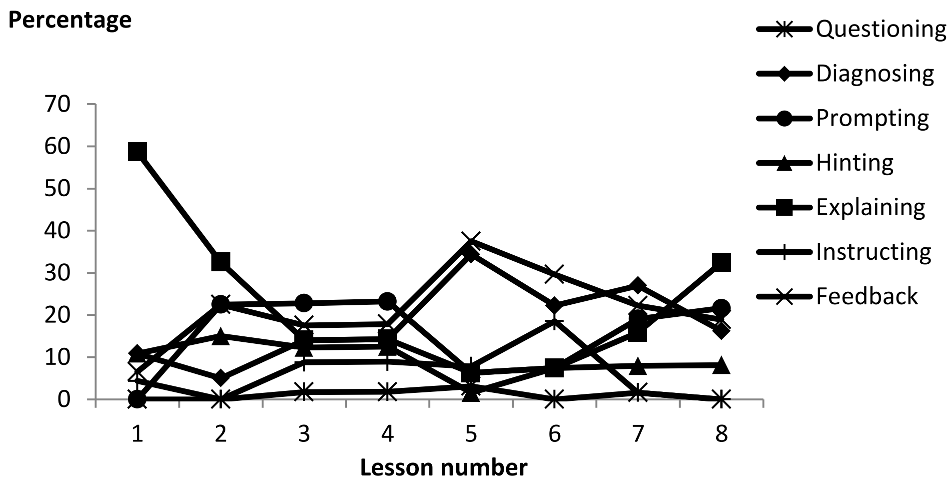


Figure 2.3. *Means of teacher interventions in percentages, displayed per lesson.*

Table 2.5. Coefficients of variation between groups of means of teacher interventions for each lesson.

	Coefficient of variation per lesson							
Category	1	2	3	4	5	6	7	8
Diagnosing	0.9	0.6	0.8	0.2	0.3	0.4	0.4	0.4
Feedback	0.3	1.0	1.7	0.6	0.1	0.7	0.4	0.3
Hinting	0.3	1.0	0.3	0.2	0.3	1.6	0.2	2.4
Instructing	0.6	0.0	0.4	0.4	0.3	0.4	0.4	0.0
Explaining	0.1	0.7	1.1	0.6	0.8	1.7	1.0	0.2
Questioning	0.0	0.0	2.4	0.0	1.6	0.0	2.4	0.0
Prompting	0.0	2.1	1.7	2.4	0.8	1.6	2.4	1.7

2.3.4 Variation between groups

Taken together, Figures 2.2 and 2.3 show that there were notable changes in the focus and means of teacher interventions between lessons. The coefficients of variation in Tables 2.4 and 2.5 demonstrate that there was also variation between groups. This means that at least for some categories, the average percentages shown in Figures 2.2 and 2.3 are not an accurate representation of the data of the individual groups. Below, some examples of teacher-student interaction are given to illustrate the change between lessons and the variation between groups. Examples were chosen from four time points that showed prominent peaks in Figures 2.2 and 2.3.

2.3.4.1 Example lesson 1: explaining

At the start of working with VCRI, there is a peak of Explaining (Figure 2.3). The focus of the teacher's interventions is equally distributed among cognitive and metacognitive (Figure 2.2). Table 2.6 contains two examples of teacher-student interaction during the first lesson. In this lesson, the teacher explains to the group how to start with the task (metacognitive activities, lines 1-4) and he also explains some basic concepts that students need throughout the assignment (lines 5-8). There are also some explanations that deal with the program itself.

Table 2.6. Two examples of Explaining during lesson 1.

Line	User	Message	Focus	Means
1	Student 1	did you read the first part?		
2	Student 2	I don't get it		
3	**Teacher**	**Start by reading the assignment, then you can use the sources to answer the questions**	Metacognitive activities	Explaining
4	Student 1	oh		
5	Student 3	what is expansion?		
6	Student 4	Idk [*I don't know*]		
7	**Teacher**	**Expansion means enlargement or growth**	Cognitive activities	Explaining
8	Student 3	thanks		

2.3.4.2 Example lesson 3: prompting

After the initial phase and all the introductions, a period follows in which the teacher focuses more on cognitive activities (Figure 2.2). The teacher uses more open forms of interventions, such as Prompting (Figure 2.3). Table 2.7 shows two examples. In line 5-9, the students are discussing the results of the Second World War. Instead of giving away the answer, the teacher responds by posting counter questions.

Table 2.7. Example of teacher interventions during lesson 3.

Line	User	Message	Focus	Means
1	Student 1	I think the US is democratic, but how can I find that?		
2	**Teacher**	**Do they hold elections in the US?**	Cognitive activities	Prompting
3	Student 2	yes		
4	Student 1	obama		
5	Student 3	I can't find any reports on damage to the US after WOII		
6	Student 4	me neither		
7	**Teacher**	**If you can't find it, maybe there isn't any? Where did they fight?**	Cognitive activities	Prompting
8	Student 3	the pacific?		
9	**Teacher**	**What does that mean?**	Cognitive activities	Prompting

2.3.4.3 Example lesson 5: diagnosing

In lesson 5 there is a peak in focus on metacognitive activities (Figure 2.2) as well as a peak in Diagnosing and Feedback (Figure 2.3). Looking at the chat protocols (see Table 2.8), there are two things that the teacher is paying attention to. First of all, he is checking how the groups are doing in terms of progress on the assignment and instructing them to move onto the next part (lines 1-3). This takes up a lot of interventions because the teacher diagnoses progress for each of the groups.

In one of the small groups, it appears there is a collaborative problem (lines 4-8). One student has been absent for a few lessons and has contributed less to finishing the assignment. The teacher does not think this is a valid reason for lagging on the assignment and tells the students to improve their collaboration.

Table 2.8. Example of teacher interventions during lesson 5.

Line	User	Message	Focus	Means
1	**Teacher**	**Can you please tell me if you think the second part of the assignment is finished?**	Metacognitive activities	Diagnosing
2	Student 1	we finished it		
3	**Teacher**	**Ok, continue with part 3**	Metacognitive activities	Instructing
4	**Teacher**	**Have you finished part 2?**	Metacognitive activities	Diagnosing
5	Student 2	no, because sally has been absent the last two lessons		
6	**Teacher**	**You are perfectly able to finish the assignment without her, I think**	Metasocial activities	Feedback
7	Student 3	She has written something I don't understand		
8	**Teacher**	**You're working as a team, so everyone is responsible for the assignment**	Metasocial activities	Feedback

2.3.4.4 Example lesson 7: cognitive activities

After the dip in focus on cognitive activities, the final lessons show an increase in focus on this area again (Figure 2.2). The means used in lesson 7 are varied (Figure 2.3). It stands out that after a steady decrease during the first half (lessons 1 to 5), Explaining rises again during the remainder of lessons. The chat protocols show that during lesson 7, there is again more time spent on the content of the task. Students start the final part of the assignment, which also accounts for the increase in Explaining. Table 2.9 shows an example.

Table 2.9. Example of teacher interventions during lesson 7.

Line	User	Message	Focus	Means
1	Student 1	Sir, is theme 4 about the overview of presidents?		
2	**Teacher**	**No, theme 4 is the final assignment in which you write your essay**	Cognitive activities	Explaining
3	Student 1	Then what should I write about that overview?		
4	**Teacher**	**that is just an extra source I added for reference**	Metacognitive activities	Explaining

2.4 Discussion

It was argued that an adequate description of teacher interventions during CSCL warrants the study of multiple aspects and a temporal analysis. In this study, focus and means of teacher interventions were analyzed and compared between lessons and between groups.

2.4.1 Focus

The results show that overall the focus was mostly on cognitive and metacognitive activities. Within the individual lessons, this focus was also visible. However, the relative frequencies fluctuated for each lesson. The number of teacher interventions focusing on social or metasocial activities was much lower, reaching a maximum percentage of about 15%. There was little change between lessons, but large variation between groups. The results from previous studies do not uniformly fit with our findings. Asterhan (2011) for example found no instance of social support at all. De Smet et al. (2008) on the other hand found comparable low frequencies for focus on social activities, which increased at the end of the studied period. This increase contradicts our finding of low variability between lessons. However, it is hard to compare the results, because in the study by De Smet et al. student activities were regulated by pairs of teachers while in our study only one teacher was involved.

Many researchers have pointed out the importance of social activities within collaborating groups (Kreijns et al., 2003; Salmon, 2000). From our data it appears that the teacher's need to focus on social activities may have been small. A possible explanation for this is that in contrast to distant learning and asynchronous settings, the students in this study already knew each other very well. Therefore, the teacher only intervened when this was absolutely necessary. For example, the fragment in Section 2.3.4.3 shows that the teacher intervened when there was a fight within a group concerning collaboration. The high coefficients of variation in Table 2.4 reflect this sensitivity to context and specific group needs. However, it could be argued that even when there are no apparent problems, it is important that a teacher focuses on the social processes during collaboration and makes students aware of their individual and group behavior (Phielix, Prins, & Kirschner, 2010).

2.4.2 Means

During CSCL, students typically get to work on their own and can rely on their group members when there are questions. The teacher does not need to exert the same amount of control over student activities compared to whole-class teaching. Therefore, it could be expected that teachers more often use open means of intervening (such as hints) than closed means (such as instructions). The results of this study show that the means most often used were feedback, explaining and diagnosing. It must be noted that there was variation between lessons (see Figure 2.3) and that the general percentages are not an accurate depiction of this variation. Some time periods showed high percentages of open forms of interventions (lessons 2 and 3) while in others closed forms were used more often (for example lesson 1 and 6).

Again, it seems the teacher's interventions were group-specific. For example, in the first lessons there were a lot of explanations. It may have been expected that this was due to getting used to working in a CSCL setting, but it turned out that not so much the system, but the assignment needed more attention. In Section 2.3.4 this was illustrated with some examples. Research has shown that if the task materials exert more control, that is, contain more detailed instructions for carrying out the task, the teacher might need less closed forms of interventions (Onrubia & Engel, 2012; Vermunt & Verloop, 1999). In this case, the task might have exerted a very low amount of control, therefore eliciting more explanations from the teacher.

The early lessons thus elicited more explanations and direct instructions. After that, in the middle lessons the teacher used more open forms of intervening such as hints and prompts to move students along with the assignment. Finally, the last stage required explanations again and more questions from students as they completed the assignment.

Our results are in line with previous research. Hsieh and Tsai (2012) found that means of teacher interventions varied during the three sessions students collaborated. However, the three sessions dealt with separate assignments, not an ongoing assignment as in our study. Gil et al. (2007) divided the data on teacher interventions in three phases; beginning, middle and end, and found differing distributions of means of intervening for each of the five teachers that were studied. The change between lessons is thus consistent with other studies that have investigated teacher interventions on multiple time points (albeit with fewer time points than in this study).

2.4.3 Implications

The combination of coding both focus and means has resulted in a comprehensive description of the interventions of the participating teacher. Although there were some indications of patterns, the general finding is that this teacher's interventions are foremost explained by sensitivity to group needs. Generalizations of teacher behavior into 'types' (Mazzolini & Maddison, 2003) or 'moderation profiles' (Asterhan, 2011) do not reflect the whole complexity of the teacher's task. Although these profiles allow a comparison between teachers, which is not possible in a case study like the present one, often information is lost about temporal variation (Kapur, 2011). It is clear from our data that the teacher's method of regulation was not the same throughout the whole timeframe. Instead, from the broad range of means of interventions it seems the teacher's behavior was context-specific. Our aim was to demonstrate how this variation can be studied by examining multiple aspects of teacher interventions.

In the introduction it was explained that if supporting tools for teacher are to be developed, it is necessary to not only know which behavior teachers demonstrate naturally, but also which behavior is effective in terms of improved quality of students' work. This study was aimed foremost at the first question. Judging whether a broad repertoire of means of interventions is an effective way of regulating students' activities can only be done when the second question is answered. For now, some suggestions may be made about the type of supporting tools to be developed, based on the results presented here.

The first suggestion would be to support teachers in monitoring the social activities of groups of students. Not only the results of the current studies, but also those of other researchers (Asterhan, 2011; De Smet et al., 2008) have indicated that teachers focus less on this area than on cognitive and metacognitive activities. The benefits of presenting visualizations of agreement and discussion processes to students have already been investigated (Janssen et al., 2007). Studying whether teacher access to such visualizations has an effect on teacher and student behavior would be an interesting step forwards.

A further suggestion for supporting tools is based on the high amount of Diagnosing interventions performed by the teacher in the current study. Interviews with teachers have shown that one of the main difficulties of regulating students' activities during CSCL is keeping track of all information (De Smet, Van Keer, De Wever, & Valcke, 2010a; Van Diggelen et al., 2008). Our results show that the frequency of Diagnosing increased in the final stage. This may have been due to the fact that in the last part of the assignment, the students started writing their final essay. As Table 2.3 shows, this also resulted in less chat messages by the students. It may have been harder for the teacher during this part to monitor the progress within the groups. This is supported by the fact that 20% of the interventions that the teacher sent to the whole class simultaneously were Diagnosing interventions. Therefore, teachers may benefit from tools that provide information to help the teacher diagnose the progress of each group, for example information about the status and quality of written products (Dillenbourg, Järvelä, & Fischer, 2009).

If a teacher's behavior, as our findings show, is primarily influenced by the behavior and needs of the collaborating groups of students, this last suggestion is most important. Giving fitting support is only possible when the teacher has a clear view of the groups' needs (Van de Pol et al., 2010). This may be accomplished by the tools mentioned above that inform the teacher of the quality of the students' activities.

2.4.4 Limitations and directions for future research

An obvious limitation of this study is that only one teacher's interventions were analyzed. It is important that more studies are performed within this area to replicate these findings. On the other hand, as was pointed out in the introduction, case studies do provide the opportunity to study the subject in great detail, which was exactly the aim of this study. Furthermore, in this particular article the added value of the study was a more elaborated conceptualization of teacher interventions, which makes the number of participants a less important issue.

Because of the co-located setting, it would have been possible to collect additional data about the students, for example by observing or recording the students' activities. Although the opportunity was there for students to talk aloud to each other, in practice this did not happen often. Therefore, there was little behavior to be observed outside of the learning environment. As explained, most behavior is captured in the log files, including which tools the students and teacher opened. Observing or recording the classroom would therefore have given duplicate data, in the sense that the log files contain the same data. Furthermore, the teacher's actions were the primary aim of our research.

Concerning the analysis, the decision was made to code both the focus and means of teacher interventions at the level of individual utterances. In the introduction, however, it was suggested that it may be more appropriate to code the focus of teacher interventions at the level of episodes or conversations. In our case it would have been difficult to identify the beginning and ending of episodes, because the teacher sometimes maintained conversations with several small groups at the same time (the complexity of switching between groups is demonstrated in Schwarz & Asterhan, 2011). Therefore, a compromise was sought between a very fine-grained analysis (as done for teacher regulation in Schwarz & Asterhan, 2011 and for student activities in Wise & Chiu, 2011) and a courser level of analysis.

Another limitation is that although we have described the complexity of studying the teacher interventions, there are many more aspects that play a role during CSCL. For example, we briefly stated that in our study, 49.1% of teacher interventions were initiated by a question from a student. Onrubia and Engel (2012) further expand on whether the teacher or the student initiates the conversation. Another aspect that could be studied is whether or not the teacher received training prior to working with a CSCL environment (De Smet, Van Keer, De Wever, & Valcke, 2010b). A challenge for future research is to connect all of these aspects into a coherent image. A further step could be to connect results about teacher interventions with student behavior and student perceptions of teacher behavior (Asterhan & Schwarz, 2010b). In this study first attempts were made to describe the teacher's sensitivity to students' activities. In subsequent analyses, a possible step would be to code students' activities and to see whether there are correlations between type of group activity and type of teacher intervention (Chiu, 2004).

2.4.5 Conclusion

The ultimate conclusion that emerges from this study is that the teacher displayed a wide range of types of interventions. Some reasons for this variation were to be expected, such as the peak of explanations and the focus on metacognitive activities at the start of the assignment, while others were highly group specific, such as the need to end a fight between students. In line with Schwarz and Asterhan, who state that all teacher interventions are useful "as long as they are attuned to the needs of the group and its individual members at that time" (p. 436), we argue for studying teacher interventions as a reaction to the current situation, not as an expression of the teacher's "style".

The starting point of the analysis presented here was the premise that combining focus and means would lead to a more nuanced view of teacher interventions (Van de Pol et al., 2010) and the complex task that teachers face during CSCL. Each of these apects on its own indicated clear differences between lessons and between groups, but taken together a broader perspective emerged that pointed to several points of interest in the data, as outlined in Section 2.3.4.

It is important that a clear picture is obtained of the complexity of a teacher's task to regulate students' learning during CSCL, not only for theoretical purposes, but also for practical reasons. Ultimately, CSCL environments may be designed that not only support students, but also the teacher. By summarizing student activity, for example, the teacher's task of Diagnosing could become easier (Dillenbourg, Järvelä, & Fischer, 2009). Gaining a complete view of what a teacher does by using appropriate methods of analysis, is the first step towards this goal.

Chapter 3: Diagnosing and intervening strategies of teachers regulating multiple collaborating groups[2]

Abstract Teachers regulating groups of students during computer-supported collaborative learning (CSCL) face the challenge of orchestrating their guidance at student, group and class level. During CSCL, teachers can monitor all student activity and interact with multiple groups at the same time. Not much is known about the way teachers diagnose student progress and decide upon appropriate interventions when they regulate multiple groups at the same time. This explorative study describes the strategies and experiences related to regulating the activities of seven groups of students, as reported by two teachers. Recurring themes included the high amount of information load teachers experienced while diagnosing students' needs, the focus and level of regulation, and the way the teachers used prior knowledge of students to decide on an intervention after diagnosis. Both teachers valued the ability to monitor student progress online and mentioned the necessity of students being able to follow the teacher's activity as well.

3

3.1 Introduction

Computer-supported collaborative learning (CSCL) denotes situations in which students collaborate using information and communication technologies. Teachers regulating CSCL face as much of a challenge as in a regular classroom (Asterhan & Schwarz, 2010b). It is important that the teacher pays attention not only to the task content or subject matter, but also to the collaboration between students in order to avoid possible collaboration problems (Kreijns, Kirschner, & Jochems, 2003). Teachers can play an important role during collaborative problem solving activities when they adapt their support responsively to the understanding of the students (Van de Pol, Volman, & Beishuizen, 2010). To do so, one must first determine the students' current level of competence by using diagnostic strategies. When teachers have ascertained students' understanding of the task, they can adapt their intervention to the needs of the groups (Puntambekar & Hübscher, 2005).

Increasing the size of face-to-face classrooms and increasing the size of collaborating groups (i.e., the number of group members) can negatively influence teaching quality (Blatchford, Baines, Kutnick, & Martin, 2001). However, not much is known about how the presence of multiple groups affects the effectiveness of teacher regulation of collaboration. Given the average class size in secondary education of 25 students, teachers often regulate at least 5 or 6 groups. Few studies have acknowledged the complex nature of diagnosis during CSCL

[2] Based on: Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (in press). Teacher regulation of multiple computer-supported collaborating groups. *Computers in Human Behavior.*

and the relationship with teachers' interventions (Schwarz & Asterhan, 2011). In particular, the possibility to regulate multiple groups at the same time and the resulting real-time decisions a teacher has to make, have not been extensively researched. The purpose of this study is to offer an exploration of the challenges a teacher may encounter when regulating multiple collaborating groups. We performed a multiple case study of two to gain insight into teachers' strategies and experiences regarding diagnosis, the decision on an intervention after diagnosis, and the intervention itself.

3.1.1 Diagnosing student activities when regulating multiple groups

Teachers can use two strategies to diagnose students' level of understanding, namely by actively questioning students and by observing students' activities (Van de Pol et al., 2010). In the present study, the computer-supported setting allowed the teacher to communicate with students by means of a Chat-tool. The teacher could perform a diagnosis by directly asking students about cognitive or social aspects of their activities. In contrast to questioning, which requires teacher-student interaction, observing is a non-intrusive way of diagnosing where no interaction is needed. Unique to a computer-supported synchronous setting is that a teacher can access students' activities and task output as it is being constructed. That is, CSCL environments can give a teacher access to the tools that students use to solve the task to diagnose the progress of the task *during* lessons as opposed to a teacher reading students' task output after or between lessons (termed "offline diagnosis" by Smit, Van Eerde, & Bakker, 2013). That is, when teacher and students are online simultaneously (synchronously), the teacher can see the students' activities in real-time, for example by continuous updates in written texts or changes in visual representations of students' arguments (see for example the Argunaut environment; Asterhan & Schwarz, 2010a). The teacher can diagnose the way students collaborate by checking student communication in a chat or forum tool, which may provide clues as to how they are collaborating (for example, dividing tasks). This communication may also provide information about cognitive aspects, for example when students correctly apply or explain a concept to a peer.

Of course, the type of information available differs according to the nature of the task and the specific characteristics of the learning environment, but in general, in CSCL settings there is a multitude of information available to the teacher. This *could* make it easier to diagnose the situation. Research in face-to-face settings has shown that it is difficult for teachers to acquire an accurate description of students' understanding (Myhill & Warren, 2005; Rodgers, 2004; Van de Pol et al., 2010). Additional information offered during CSCL settings may therefore be beneficial to the accuracy of teachers' diagnoses by complementing the teacher's observations (Cortez, Nussbaum, Woywood, & Aravena, 2009). However, there are two concerns that can complicate an increase of accuracy. First of all, because students and the teacher are online at the same time, students will engage the teacher in conversations that require immediate responses if the teacher is to make use of the direct moment (Schwarz & Asterhan, 2011). This might result in teacher responses to students being adjusted on the fly (Rodgers, 2004). On the other hand, a carefully prepared intervention based on reading students' contributions might miss the benefits of a just in time intervention.

A second concern that complicates an increase of accuracy of diagnosing is that when a teacher decides to diagnose by reading, the large amount of information could lead to an overload for the teacher instead of being helpful (Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder, 2012). Several researchers argue that an increase of information load may prevent deliberate action, thereby possibly hindering conscious diagnosing of student performance (Elliott, 2009; Feldon, 2007). This may mean that in the case of high information load, instead of obtaining and using current information on students' understanding, teachers are more likely to use their existing knowledge about students to make decisions on the appropriate intervention (Feldon, 2007).

It can be expected that both concerns are related to the number of groups a teacher is regulating. After all, the presence of more groups means that there are more group processes the teacher has to monitor. Schwarz and Asterhan (2011) point out that the possibility to switch between multiple group conversations makes it more difficult to follow and diagnose the development of discussions in a particular group. Moreover, Brühwiler and Blatchford (2011) have shown that teachers more accurately diagnose students' achievement in smaller classes. It is therefore expected that a larger number of groups will lead to teachers reporting a higher information load and problems with adaptation to students' needs.

3.1.2 Teacher interventions when regulating multiple groups

It was already pointed out there is an intricate relation between diagnosis and intervention (Van de Pol et al., 2010): in order to be adaptive, an intervention should be based on an accurate diagnosis of students' understanding. Difficulties associated with diagnosing also affect the teacher's interventions. These difficulties may - in part - come from number of students (class size) and number of groups.

Studies into class size reduction in *face-to-face* settings have indicated that smaller classes lead to more frequent and individualized interaction between teacher and students (Blatchford, Bassett, & Brown, 2011; Smith & Glass, 1980). Teacher interventions were more frequent in small classes both for cognitive and for socially focused interventions. In larger classes, teachers focus more on cognitive activities, in particular activities concerned with planning (Blatchford, 2003). Results of research in *online* settings regarding teacher interventions are not as straightforward as those for face-to-face settings. Russell and Curtis (2013) for example found that quantity and quality of teacher interventions were limited in a large online course when compared to a smaller scaled one, while Orellana (2006) found no relationship between online courses' class sizes and the intensity of teacher-student interaction. There are but a few studies that focus on *collaborative* settings instead of individual student learning. Blatchford et al. (2001) state that smaller collaborating groups of students (i.e., a smaller number of students per group) provide the teacher with more opportunity to individualize help, but these authors do not consider the effect of an increased *number* of groups.

The image that arises from studies of non-collaborative settings is that as class size increases, the teacher has less time to spend per student, resulting in less individualized help. This relationship is not as clear in collaborative situations, because students can also turn to each other for help. However, in this case the teacher gains the additional task of focusing on the groups' collaborative process and social activities in order to avoid collaborative problems (Kreijns et al., 2003). Thus arises a trade-off between intervening at individual versus small group level (and additionally, at class level). One might expect that larger classes would lead the teacher to intervene more at class or group level, as a solution to the difficulty of reaching every student (Blatchford, 2003). Contrary to this expectation, it was found that "teachers in large classes strive to maintain the same balance of individual, group and whole class teaching as their colleagues in small classes" (p. 589). Class size and number of groups could thus be related to which type of student activity teachers are focused on (for example, social activities) and who the recipient of teachers' interventions are (class, group, or individual students). Again, the question is whether the results in face-to-face settings are transferrable to an online setting.

3.1.3 Aim of the present study

Schwarz and Asterhan (2011) have given an elaborate description of the interplay between the teacher, students and the CSCL environment. They were able to show that when regulating a relatively small class divided in four groups (of three students each) the teacher is able to use teaching strategies effectively and to have an impact on students' learning processes. The authors hypothesize that in a common sized class with a larger number of groups teacher regulation would be possible too, but that the associated complexity of this task would possibly hinder deliberate and effective regulation of the students. However, there is no research yet that has investigated teachers' strategies when regulating more than four groups. There is thus a lack of research concerning this question, especially in the field of CSCL, while on the other hand the importance and benefits of collaboration are increasingly recognized.

The following research question has been formulated: What are the characteristics of teachers' diagnosing and intervening strategies when they regulate multiple collaborating groups during a synchronous CSCL setting?

To explore the diagnosis and intervention strategies we used a multiple case study design. We studied two teachers during CSCL while they regulate a class of typical size, divided in seven collaborating groups (of three students each). The aspects of teacher regulation during CSCL discussed above, such as the possibility of information overload and the trade-off in intervening at individual or group level, are investigated by means of teachers' self-reports about these topics (cf. De Smet, Van Keer, De Wever, & Valcke, 2010b).

3.2 Method

3.2.1 Participants

Two teachers and their classrooms, which were divided into seven groups of collaborating students, participated in this study. Following the guidelines by Onwuegbuzie and Leech (2007), the sample size in this study was chosen to be two teachers so that a deep, case-oriented analysis would be possible. Two male history teachers and their students in pre-university education worked on an assignment in a CSCL environment for respectively 8 and 3 lessons. Teacher 1 was 43 years old and had 15 years of teaching experience. Teacher 2 was 35 years old and had 8 years of teaching experience. We studied their experiences concerning their strategies and faced challenges and opportunities while diagnosing and intervening during student collaboration. The classes consisted of respectively 21 and 30 students, which are common numbers for Dutch secondary school classrooms. All groups of students consisted of three, four, or five student (mean age of 14 years).

Neither teacher had any experience with teaching in a CSCL environment. All teachers and students received an introduction into the CSCL software. Although the number of lessons differed, all students worked on a similar kind of assignment concerning the Cold War. The assignments were open-ended and required students to first read and discuss historical sources, to put the arguments they found in a diagram and thereafter to write a short essay collaboratively about the question why the Cold War did not result in a Third World War. The assignment was evaluated and graded as part of the history education curriculum.

3.2.2 CSCL setting

The classes of students and their teachers made use of the CSCL environment called Virtual Collaborative Research Institute (VCRI, see for example Janssen, Erkens, Kanselaar, & Jaspers, 2007). VCRI is a groupware program designed to support collaborative learning on inquiry tasks and research projects. All students had their own computer in the classroom and synchronously communicated with their group members by means of a Chat-tool. The assignment involved exploring the topic of the project by reading historical sources in the Sources-tool. Students used the Debate-tool to construct a shared diagram of their arguments. Students used the Cowriter, a shared text processor, to write their essay.

This synchronous set-up within the same physical space has multiple advantages (Petrou & Dimitracopoulou, 2003). For example, in contrast to distance education, the classroom setting ensured that students did not need to spend time to get to know each other before starting on the assignment, because the class already had a common history and a set of behavioral norms (Asterhan & Schwarz, 2010b). Furthermore, digital communication ensured that the teacher could constantly monitor each group's activities and lowered the chance of classroom disturbances or interruptions (Petrou & Dimitracopoulou, 2003). Digital communication through a Chat can also be argued to lead to more precise articulation because of the absence of non-verbal cues (Asterhan & Schwarz, 2010b).

An alternative interface of the VCRI-program was available to the teacher, which allowed him to monitor the online discussions of the students in the Chat-tool in real-time and send messages to students. The teacher could send messages to a group, more than one group at a time, or the whole class. Teachers could examine the texts students are writing in the Cowriter or the diagrams they are making in the Debate-tool. The teacher could thus monitor multiple groups at a time by opening the tools the groups are working in and could intervene by sending messages through the Chat-tool.

The program offered the teacher two additional tools. First of all, by a Statistics-tool the teacher could consult basic statistical information about students' activities in VCRI's tools (e.g., the number of keystrokes per student). Secondly, the teacher could check the relative activity of each group member in the Participation-tool, which in the form of spheres visualizes how much each group member contributed to the groups' activity (for more details, see Janssen et al., 2007). Figure 3.1 displays an example configuration of the VCRI teacher interface, in which the Statistics-tool, two Chat-tools and the Participation-tool of one group are opened.

3.2.3 Instruments

The aim of the study was to examine teachers' diagnosing and intervening strategies, the decision on interventions after diagnosis, and related aspects such as the possibility of information overload and the way teachers alternate or choose between regulating individual student or group level. These aspects are only partly mapped through observations. For example, when a teacher gives students a suggestion for solving the task, this suggestion is only observable as a written message in the Chat-tool. In previous studies, these interventions have been counted and coded by many researchers (for an overview, see Van Leeuwen, Janssen, Erkens, & Brekelmans, 2013). What remains invisible and has not been reported on in many studies, however, are the way the teacher diagnosed the students' task progress, how the teacher decided on an intervention, why the teacher focused on a particular type of student activity, and whether the teacher experienced any difficulties while doing so. Therefore, instead of the actual interventions, the primary object of study was how teachers experienced their diagnosing and intervening strategies and the associated challenges and opportunities. These experiences were retrieved by means of interviews.

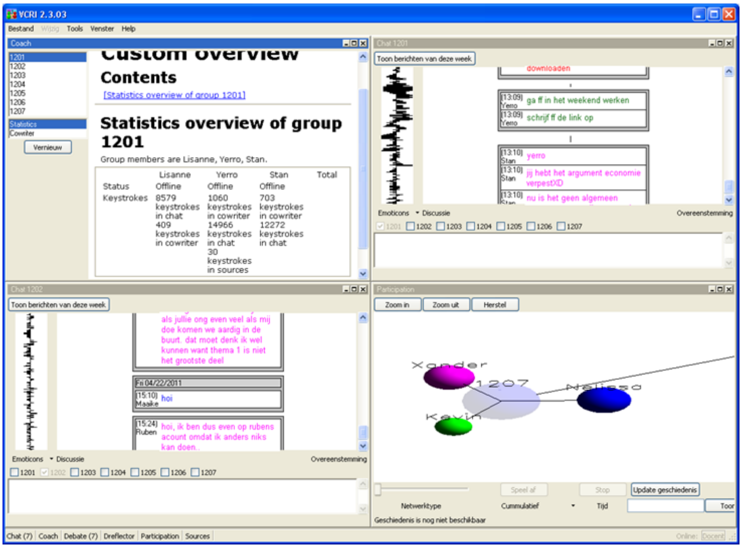


Figure 3.1. *An example of the configuration of the VCRI teacher interface. In this case, the teacher has opened the Statistics-tool (upper left), the Participation-tool (bottom right) and the Chat-tool for two of the groups.*

VCRI automatically logs all communication in the Chat-tool. Thus, for each lesson a protocol was available with the students' messages and teacher's interventions in the Chat-tool. The observable interventions were the starting point for the interviews. After each lesson, a number of fragments from the chat protocol which included teacher interventions were selected by the researcher and used in stimulated recall interviews with the teachers to reveal teachers' intentions during the specific events (cf. De Smet et al., 2010b). The stimulated interviews were held at the same day or the morning after the corresponding lesson to ensure the teacher could clearly remember the selected fragments (Lyle, 2003). The fragments were selected in such a way that they would include an intervention in each of the groups the teacher regulated, as well as different types of interventions, for example fragments in which the teacher gave an explanation or in which the teacher gave an instruction. The teachers were shown the selected fragments and asked to comment on how they monitored (i.e., diagnosed) this particular group and why they chose this particular message (i.e., intervention). Teachers were free to further elaborate on anything else they wanted to say about the fragments.

Because the number of lessons that the teachers worked with VCRI varied, so did the maximum number of possible stimulated recall interviews. It was made sure that at least two stimulated interviews were held with both teachers to ensure sufficient contact time between the researcher and both participants (Onwuegbuzie & Leech, 2007). Six stimulated recall interviews were held with T1 and two with T2. The stimulated interviews on average took 20 minutes.

At the end of working with VCRI, an overarching *semi-structured interview* was held with each teacher. In these interviews the teachers were asked about the way they regulated students' activities in VCRI and how they used the various tools to do so. Questions were asked both about opportunities as well as possible difficulties. These interviews on average took 30 minutes.

3.2.4 Analysis

All interviews were transcribed and coded with the aim of extracting the most important themes that the teachers described. To code the transcribed interviews, the Atlas.ti software was used (Atlas.ti, 2011). We combined a top-down and bottom-up approach, which meant a predefined set of themes was constructed that was further refined based on the actual findings. The aim of the coding procedure was to create a case-ordered matrix (Miles & Huberman, 1994) that would allow us to describe both teachers on each of the coded aspects. The initial coding scheme consisted of codes for 1) diagnosing strategies, 2) decisions to intervene and 3) focus and recipient of interventions.

- *Diagnosing strategies*. Concerning diagnosis, both strategies and associated experiences were coded. Strategies for diagnosing the progress and quality of students' activities was divided in Observing and Questioning (Van de Pol et al., 2010). To analyze associated experiences codes were created for teacher utterances that specifically dealt with positive or negative aspects (opportunities and challenges) they encountered while diagnosing, for example whether their strategy was efficient and enabled them to retrieve all needed information about students.
- *Intervention decisions*. A hypothesized effect of the presence of multiple groups is that due to the vast amount of available information, decisions are not based on currently available information, but on prior knowledge (Feldon, 2007). Both of these possibilities were therefore identified as coding categories.
- *Focus and recipient of intervention*. Two further characteristics of both diagnosing and intervening strategies were the *focus* and *recipient*. The focus of diagnosis or intervention denotes what type of student activity it was aimed at (Van Leeuwen et al., 2013). Commonly identified foci of teacher regulation are cognitive, metacognitive, social and metasocial aspects of students' activities (Janssen et al., 2007). When the teachers reported their strategies and experiences, it was coded whether it concerned students' cognitive or social activities, or, on the regulative

level, students' metacognitive or metasocial activities. The codes for recipient denote whether the object of the teacher's reports was an individual student, a collaborating group, or the whole class (Onrubia & Engel, 2012). Similar to the codes for diagnosing, the codes for focus and recipient also include a category for the associated teachers' experiences. For example, a teacher might report that he focused on cognitive activities and state that he found this very easy to do.

After construction of the initial coding scheme, two researchers together coded both a stimulated interview and an overarching interview to serve as a test session. When needed, subcodes were added to the three main categories listed above. For example, concerning the Diagnosing Strategy 'Questioning', a subcode was added based on teacher reports about directness of communications. When disagreement occurred about the interpretation of a quote, the rules for coding were refined. After the test session, the remaining interviews were then coded by one of the researchers.

In the final step, a cross table was made for participant × code (Miles & Huberman, 1994), resulting in an overview of the codes for both teachers. A list of quotes per participant was derived from the Atlas.ti software for each code. The results for the two teachers were compared and integrated into one overview. While the codes were straightforward and relatively coarse-grained, this step of summarizing, comparing, and integrating resulted in rich and nuanced descriptions of the commonalities between the two teachers (Boeije, 2010). The descriptions were translated to short summary phrases (Miles & Huberman, 1994).

3.3 Results

The overall results are presented in Table 3.1. For each theme, the commonalities between the teachers (in terms of strategies and experiences) are summarized. In the next subsections, the results are discussed for each theme. Fragments of teacher-student interactions, along with teacher comments, are given to illustrate the findings. In these fragments, student names are changed to preserve anonymity.

Table 3.1. Overview of results in terms of short summary phrases for each code.

Theme	**Strategy**	**Opportunities**	**Challenges**
Diagnosing strategies	- Few instances of questioning. - Observing: all tools used. Look primarily for visual cues.	- Amount of available information - Participation-tool for observing metasocial aspects	General: challenge to divide attention. Observing: - Would like more info on participation. - High information load. Questioning: - Less directness of communication. - Absence of facial cues.
Decision to intervene	Intervene whenever there is a question. Use previous knowledge of students.		Low student awareness of teacher.
Focus	Mostly metacognitive focus.	Participation-tool for observing metasocial aspects.	- Adapting to groups when their progress diverges. - Cognitive focus: punctuality of discussion.
Recipient	Equal focus on student, group, and class level.	- Ability to send class messages. - Intimacy of group conversations.	Need f2f meetings.

3.3.1 Diagnosis

Both teachers acknowledged the opportunity to access more information about students' activities than is usually available during face-to-face collaboration in the classroom. The teachers were able to observe all student activity and thus see the process as it was happening. The most frequently reported strategy of diagnosing was Observing, and almost no instances of Questioning were mentioned. Teacher T1 mentioned as a disadvantage of Questioning that he sometimes felt he would have liked to have non-verbal signs to verify whether students understand a concept or not. Because both teacher and students can delay their response during a conversation, communication is not as direct as it is face-to-face. Both teachers missed this directness. T2 remarks: "There is a delay in the communication. I like direct communication, which is there during regular teaching. It helps me to better estimate what help students need."

It seems that the function of Questioning was in part substituted by using Observing as a means to diagnose. Observing offered the teachers a multitude of information. The Chat-tool can for example show whether students are on-task or off-task, whether they use correct arguments, and how they divide tasks. The Cowriter and Debate-tool show real-time task progress. The teachers expressed a disadvantage of Observing within the VCRI environment as well. While the Chat-tool makes a distinction between group members by name and text color, the Debate-tool and Cowriter do not. In these tools, it is not visible which student added which part. The teachers would have liked to have this information.

Table 3.2. Example of delayed interaction between T2 and his students, along with T2's comment.

Time	Message
10:08	Jane: I'm hungry
10:09	Mike: Later
10:09	Jane: Pizza
10:09	Mark: No I am thirsty [*smiley*]
10:09	Mike: What??
10:19	**T2: You can use sources from all themes, as long as it supports your argumentation.**

T2 comment: "Normally, when a student asks a question you remain at their desk and the student will start writing, and later on you approach them again and you take a look and you know he got it. Or you ask about it again, you ask about the information you just provided, to see whether they understand. But this is different, it is harder. And divided. Because when I give an answer, I am simultaneously keeping an eye on the other groups.
"You see, here I respond to something I read earlier in the chat. The communication is delayed, because you have to pay attention to so many things. They probably asked me a question in the beginning and I did not answer fast enough, and then they start talking about other things."

Although both teachers mentioned the advantage of having access to all student activity, they also struggled with keeping up with all this information. The teachers therefore divided their attention between the groups, often in the middle of a conversation. Table 3.2 illustrates how this resulted in perceived delayed communication between T2 and his groups. Table 3.3 illustrates T1's activity in multiple groups at the same time. The teachers experienced a considerable amount of information load. This affected the way the teachers observed the students. Both teachers were prone to look for visual instead of semantic signs in the Chat-tool, for example the length of a student message (see the example in Table 3.3), question marks to signal whether students had questions or the use of smileys to indicate possible off-task behavior.

3.3.2 Deciding on an intervention after diagnosis

The experiences associated with the diagnostic strategy of observing had consequences for the teachers' decision to intervene. In 65% of reported instances, the teachers intervened on the basis of specific visual signs (for example question marks) or their prior knowledge about students instead of on a thorough reading of the content of the students' conversations (35%).

The ability to divide attention and switch between groups had a consequence for the teachers: students are not aware of what the teacher is doing. Students of course know that the teacher is able to see all groups' activity, but they do not know which group the teacher gives attention to at a given moment. T2: "When I am asked a question, I sometimes do not respond immediately because I am reading something else. Of course this may happen in the classroom as well, but then you can say I'll be right with you or students can see what you are doing."

Table 3.3. Example of interaction between T1 and multiple groups, along with T1's comment.

Time	Group 1	Group 2
12.36	John: Sir, where can we find the amount of victims and damage for completing the table?	
12.36	Bill: John, I put something in the table take a look	
12.36	John: Okay thanks	
12.37	John: Okay that looks good, right?	Lisa: I'm back
12.37	John: ?	Lisa: I was away for a minute
12.37	John: At least I think so	Lisa: The computer didn't work
12.38	Bill: Yes I think so as well	Terry: Sir, the links below the page, are those additional information or the original source?
12.38	**T1: John, you can find that in the sources, in theme 1**	
12.38	John: Okay	
12.39	John: What did they do to increase their power, let's take a look	**T1: Terry, that is the original source, but you can use those links to look for further information**
12.40	John: They both want to convince others of their way of reigning	**T1: How is it going with the division of tasks in this group?**
12.40		Terry: I think it's okay
12.41	**T1: How did the US and the SU do that?**	
12:42	John: They tried to increase their power by introducing the same political system (SU)	
12:42	**T1: To everyone: I expect you to have an answer for the sub question in theme 1 today!**	**T1: To everyone: I expect you to have an answer for the sub question in theme 1 today!**

T1 comment: "What I often did when I had all 7 chat windows opened, is check what is put below my message. When the students talk to each other, it is often one or two sentences. When the message is longer, it is usually a question. So when I see a longer text appearing, I first check that."

It thus seemed that not only the teachers had a need to know what students were doing, but also the other way around. The fact that students could not 'see' the teacher gave the teachers the feeling that students were waiting for their replies. Therefore, the teachers answered whenever they thought they were needed, and often did not stop to think whether intervention was necessary or whether students could work it out on their own (because a question could also be directed to and answered by another student). From the results reported here, it seems the decision whether or not to intervene requires time for teachers to perform a thorough diagnosis and enough space to reflect on the situation. Keeping up with multiple groups might require too many resources to leave space for that reflection. As teacher T2 said, he had a demanding enough task of keeping up with the group discussions and the nature of students' questions.

Table 3.3 shows a fragment of a lesson in the class of T1, which illustrates how the teacher was active in multiple conversations at the same time, and developed a strategy for monitoring the discussions. It shows the speed of the conversations, and how the teacher tried to respond to every question, even when that question was already answered by another student (in Group 1, at time 12.38). In the corresponding comment by T1, he explains how he monitored the chat windows for questions from students (see also Section 3.3.1).

3.3.3 Diagnosis and intervention: Focus

The teachers often reported a focus on Metacognitive aspects (on average 56%), more than on Cognitive aspects (on average 10%). Both teachers indeed indicated in the overarching interview that they would have liked to focus more on the task content or subject matter and to delve into deeper discussions with the groups. It was already discussed above that there was a high information load. This may have caused the teachers to have a less clear diagnosis of the groups' current understanding of the topic. In turn, this may have led to less cognitive focus. Furthermore, the Chat-tool required teachers to be more concise in their formulations. Teachers had to type their message instead of talk to students, which they said made their interventions more punctual (shorter in length). The teachers saw this as a disadvantage. They felt that especially when conversations delved deep into the subject matter, the Chat-tool made it difficult to give elaborate explanations, and to determine whether students grasped the teacher's feedback.

Table 3.4 provides an illustration. The students needed to collect evidence for why the Cold War did not result in World War III. A student has thought of a reason, and T2 tries to encourage her to think of whether this is an argument for or against war. This suggestion does not seem to get picked up by the students, and T2 reflects on this difficulty. Therefore, there sometimes were face-to-face conversations with groups during the lesson. Teacher T1 offers an additional remark. As the lessons continued, he noticed that groups started to diverge concerning their progress on the task. This made it harder to give specified help, and caused the teacher to focus more on planning and orchestrating the task (Metacognitive aspects).

Table 3.4. Example of interaction between T2 and his students, in which T2 doubted whether students grasped T2's meaning.

Time	Message
09:50	Vivian: After World War II Germany was split into four military zones
09:50	Vivian: Is that correct?
09:50	Vivian: Oh I got something
09:51	**T2: Yes that's correct!**
09:51	Vivian: Yeah
09:51	**T2: Continue this line of reasoning and think of whether it is a counterargument or not**
09:51	Vivian: Yes but would 'Tension between east and west' also be okay?
09:52	Vivian: And 'Shut down of transport into West-Berlin'
09:53	Lily: I wrote something down take a look at what I've got
09:53	Vivian: Oh yes I see, well done [*smiley*]
09:54	**T2: Why is the Marshall plan a cause for War?**
09:55	Vivian: I also added one
T2 comment: "I have the impression that I sometimes do not have a clear idea of the nature of a student question. Then you quickly have to discover exactly what they mean and I find it hard to determine whether the answer is adequate, and to what extent it guides or stimulates them. You could say that students when necessary will indicate "that is no answer, where is the answer?" and at one point a student did. What I mean is whether they grasped the feedback, normally you can see that."	

The focus of the teachers' reported strategies and experiences was also on Social and Metasocial aspects of collaboration (on average 33%). They looked for information on collaborative aspects. T1 for example used the students' colors in the Chat-tool as an indication whether all group members were contributing equally. As was said, T1 would have liked this distinction between students in colors to be available in the Cowriter and Debate-tool as well to further focus on task division. The focus on Social and Metasocial aspects is closely related to the Recipient, which is further discussed in Section 3.3.4.

Besides the Chat-tool, another source for observing Metasocial aspects were the Participation-tool and the Statistics-tool. During the stimulated recall interviews, the teachers mentioned using these tools for observing division of labor (a Metasocial aspect). The teachers were aware that these tools are based on a quantitative measure (the number of keystrokes) and that they do not say anything about the quality of a student's input. Still, they used the tools as indicators for possible collaborative problems, and sometimes intervened or asked students questions based on their observation of the Participation or Statistics-tool.

3.3.4 Diagnosis and intervention: Recipient

T1 and T2 equally mentioned student, group, and class level. T1 specifically talked about the advantages of being able to communicate in small groups without the whole class noticing. As illustrated in Table 3.5, the teacher was able to interact with the group in a playful way, by giving them hints and letting them try to work it out for themselves. Normally, this kind of interaction might make students feel uncomfortable.

While both teachers reported struggling with maintaining an overview, at the same time they talked about the advantages of being able to switch between groups. In particular, a useful option available to them was to send messages to all groups simultaneously. When one of the small groups asked a question that was relevant for the whole class, it was easy for the teacher to send out the answer to all groups. Class messages could also be used for reminders of deadlines or to encourage students to finish a particular sub task. In Table 3.2, the teacher does so at time 12.42.

At class level, for various reasons the teachers felt that there was sometimes a need to communicate with the students in a direct, face-to-face manner. The teachers indicated they sometimes walked around the classroom to show their authority and make sure the students knew the teacher was monitoring them. T1 said: "we used the face-to-face lessons to discuss remaining issues and to give the students some additional tips. I don't think it would have worked without these additional meetings." This is related to the directness of communication mentioned earlier.

Table 3.5. Example of playful interaction between T1 and his students, along with T1's comment.

Time	Message
13:07	Ken: The Pacific Ocean?
13:07	**T1: So where did they fight, which American soil?**
13:07	Ken: Uhm
13:07	Tom: Cuba
13:07	Ken: Let's see
13:08	Tom: Korea… Vietnam… or Afghanistan
13:08	**T1: American soil!!!**
13:08	Tom: Hahaha [*smiley*]
13:08	Nelly: Haha
13:08	Tom: America…
T2 comment: "This is a good thing about the system. When you do this in a regular lesson and you interact with one student, the rest of the class is watching. And that can be unpleasant for a student; you have to consider who you will play such a game with. A student can feel awkward if he doesn't know the answer, but here it's not a problem. Because it's just 3 or 4 of you and nobody notices. So that is an advantage of doing it this way. And I have to say I enjoy it very much."	

3.4 Discussion

This study aimed to provide an initial investigation of the strategies teachers employ concerning diagnosing and intervening during a synchronous CSCL setting, and the way the presence of multiple collaborating groups plays a role during these processes.

3.4.1 Findings and implications

The teachers in this study were able to diagnose student progress by monitoring students' activities in multiple groups, although the teachers experienced a high information load. The manageability of the available information decreased (Schwarz & Asterhan, 2011), which had consequences for the accuracy of their diagnosis and for the decision on an intervention. These teachers often reported acting based on their prior knowledge of students rather than on current activity in the CSCL environment. Also, teacher reports were often focused on metacognitive aspects than on cognitive (task-related) matters. This was also found in large classes in whole-class face-to-face research (Blatchford, 2003).

As described in the introduction, Schwarz and Asterhan (2011) have given an account of teacher regulation of *four* groups of students. As striking difference with our findings is that the teacher in their study explicitly pondered about whether intervention was necessary, and if so, what type of intervention. The teachers in the current study, with seven groups and higher information load, were more concerned with detecting students' needs and offering support where needed than with the question whether it was better to let students work it out themselves before intervening. It may be the case that this decision requires teachers to have a good overview of the situation; i.e., information load has to be manageable. An obvious suggestion to limit information load would be to keep the number of groups relatively small. However, decreasing the number of groups during collaborative situations would result in *increasing* group size, i.e. the number of group members per group. For example, a class of 28 students might be divided over 7 groups of 4 students, or over 4 groups of 7 students. Increasing group size, in turn, may lead to additional collaborative problems: the risk of free-riders and the formation of "islands" within the group will be more likely (Kreijns et al., 2003). Thus, there is a trade-off between the manageability of information load caused by the number of groups, and the risk of problems brought on by a large group size.

Another way to decrease information load is by the addition of teacher supporting tools, which are a form of learning analytics (Van Leeuwen, Janssen, Erkens, & Brekelmans, 2014; Siemens & Gasevic, 2012). That is, instead of or besides the full discussions and group products, CSCL environments could show the teacher analyses of student activity in the form of visualizations or textual summaries, which can be automatically generated from log files of user activity (Siemens & Gasevic, 2012). Teacher supporting tools offer at-a-glance information, which could ensure that teachers have up-to-date information during lessons to be able to effectively regulate students' learning processes (Cortez et al., 2009). In the present study, the teachers also had access to supporting tools: they could check basic statistics and visualizations thereof that showed each group member's relative contribution. The findings showed that the teachers indeed used these tools as "indicators/markers": an uneven distribution within a group led them to further investigate whether that group needed support. A suggestion is that since the teachers focused less on cognitive aspects, they may have a need for tools that analyze the texts students write and indicate weak or strong points. It is important that more research is conducted into the effects of teacher tools on teachers' strategies and experiences (Van Leeuwen et al., 2014).

While synchronous communication such as in a Chat-tool more closely resembles face-to-face communication than asynchronous communication (Cress, Kimmerle, & Hesse, 2009), all teachers mentioned that they sometimes missed the directness and the non-verbal aspects of face-to-face contact especially during whole-class interactions. On the other hand, it was useful for the teachers to act at the class level by sending a class message. The need for face-to-face or non-verbal contact was partly based on students not being aware of what the teacher was doing, because they were unable to physically see which group is receiving help at a given moment, or if for example the teacher is reading students' texts. In other words, although the teacher was in the same room as the students, teaching presence was lacking because of what Wengrowicz (2014) calls high pedagogical and communicational distance between teacher and students. Information about the teacher's activities may be helpful to students because it can inform them whether the teacher is present and has for example seen their question. Suggestions for this type of tool include showing each group a version of the Participation-tool in which the teacher is also visible as a mark so that the students can see which group(s) the teacher is currently paying attention to, or a check button that the teachers can press to indicate he is reading or monitoring a groups' activities. Another possible implication of the need for face-to-face communication is that instead of communicating solely in a digital manner, instructional strategies making use of blended learning might be employed. Blended learning, the integration of face-to-face learning experiences with online learning experiences, could combine the advantages of both of these settings (Garrison & Kanuka, 2004), which is evidenced by the fact that the teachers in this study reported both the advantage of having access to students' digital activities as well as the need for quick and efficient face-to-face communication.

A recurrent theme in the results was the way teachers distinguished between student, group, and class level. Interestingly, the question of orchestrating different levels has recently received more attention in CSCL research (Dillenbourg, Järvelä, & Fischer, 2009). It is recognized that there is a difference in terms of focus and in terms of "the interplay between different activities (e.g., how individual work is integrated in team work)" (p. 12). In the present study it was found that class messages were often used for metacognitive purposes. It might be the case that similar patterns between recipient and focus can be found for interventions at group or student level. As was stated in Section 3.1.2, research into class size has mostly focused on the size of the class as a whole, and not on the number of groups. Given the implications of the presence of multiple groups for the way the teachers in this study regulated their students' activities, it is important that this aspect of classroom organization receives more attention in CSCL research.

3.4.2 Limitations and directions for future research

Given the size of the study's sample, caution should be exerted in drawing general conclusions. Two case studies cannot provide generalizations or conclusions concerning the strategies teachers use nor the way the number of collaborating groups influences these strategies. However, as was stressed throughout this article, our aim has been to provide a qualitative exploration of the question at hand, because there is a lack of research that focuses on the often invisible yet important aspects related to teacher regulation of CSCL. The sample of this study was carefully chosen so as to ensure the right balance between being able to draw valid conclusions and the possibility for in-depth analysis (Onwuegbuzie & Leech, 2007). Studies on a larger scale could demonstrate whether the results can be replicated to show recurring patterns of how teachers diagnose and choose to intervene during CSCL. Furthermore, it should be kept in mind that the present study was conducted in history education, using tools that were designed to support learning tasks that that can be characterized as complex problems: there were no right or wrong solutions and the task involved multiple views on the subject (Munneke, Andriessen, Kanselaar, & Kirschner, 2007). Had the students worked on a task for which clear solutions exist, monitoring student activity might have been less difficult. The teachers' strategies and experiences and the possible influence of the presence of multiple collaborating groups may have been different in this case.

Our goal was to more deeply explore issues related to teacher regulation of CSCL that have not been intensively researched yet, namely the employed diagnosing and intervening strategies and their possible relationship with the presence of multiple collaborating groups. From the presented results, a number of interesting directions for future research can be derived. First of all, explorative studies like these give rise to a need for larger quantitative approaches to studying teacher regulation, including aspects such as the experienced information load and the way teachers use the tools that are provided to them. In Section 3.4.1 some suggestions were given for decreasing teachers' experienced information load. Further research could point out whether teacher supporting tools can indeed serve this purpose and how such tools may best serve the learning process. Supporting tools may help to achieve the right balance between being informed and being overloaded with information. With the development of learning analytics (Siemens & Gasevic, 2012), teacher tools may move from purely quantitative measures to semantic markers that analyze the content of data. Also, tools should not only focus on providing the teacher with student data, but also on the best way students can be informed about the teacher's actions.

3.4.3 Concluding remarks

This study has given insights into the complex task of regulating students' activities during CSCL, in particular concerning the way the presence of multiple groups of students offers opportunities as well as challenges for the teacher. While the synchronicity and associated challenges that teachers face while regulating collaborative learning also play a role during face-to-face education (Doyle, 2006), these challenges become especially clear during CSCL settings, when the possibility to monitor multiple groups simultaneously means there are new possibilities for diagnosing groups' needs and for intervening at both student, group and class level. Our results indicate the importance of being aware of the balance between number of groups and group size, as each class constellation may have different consequences for both teacher and students. This explorative study shows the need for a wider framework for describing teachers' strategies and experiences and the need for recommendations regarding the best way a learning environment can facilitate learning processes by assisting not only the students, but also the teacher.

Part II
Effects of learning analytics tools on teacher regulation of CSCL

Chapter 4: Effects of learning analytics tools that focus on students' social activities[3]

Abstract The aim of this study was to examine the effects of learning analytics (LA) tools that present summaries, visualizations and analyses of student participation and discussion on the way teachers regulate collaborating groups of students in a digital learning environment. An experimental set-up was used in which authentic student data was converted to simulation vignettes that participants could interact with, enabling them to act as the teacher. The vignettes contained groups that had a problem concerning participation or discussion. When presented with the LA tools, teachers were better able to detect the problems regarding participation, intervened more often in problematic groups as time progressed, and displayed more specific explanations of their actions.

4.1 Introduction

Computer-supported collaborative learning (CSCL) refers to settings in which students collaborate using computer technology (Stahl, Koschmann, & Suthers, 2006). Teachers need to assess students' activities to adapt their support to students' needs. During CSCL, students' activities (such as online discussion and working on task products) are usually logged and available for review. Because the amount of data can be quite large, it may be impossible for the teacher to read or interpret all available information (Borges & Baranauskas, 2003; Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder, 2012). So-called teacher supporting tools are specifically added to a digital learning environment to present summaries, visualizations and analyses of student data to the teacher (Casamayor, Amandi, & Campo, 2009). Supporting tools are a form of learning analytics (LA), which is defined as the analysis and reporting of educational data for the purpose of optimizing learning and the environment in which it occurs (Siemens & Gasevic, 2012). The present study examines how two LA tools that focus on participation and discussion among students affect teacher regulation of CSCL. First, the challenge of regulating students' activities during CSCL is further described.

4.1.1 Challenges for teachers during CSCL

Teachers regulating CSCL have access to a multitude of student information. In synchronous settings specifically, the teacher is usually able to see who is online, what products are being worked on, and to read and follow the communication between students in multiple

[3] Based on: Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2014). Supporting teachers in guiding collaborating students: Effects of learning analytics in CSCL. *Computers & Education*, *79*, 28-39. doi:10.1016/j.compedu.2014.07.007

groups. On the one hand, the ability to monitor student activities in a real-time fashion is experienced by teachers as a way to be involved with students' work and offers the possibility of dynamic, moment-to-moment assessment of learning processes (Asterhan & Schwarz, 2010b). On the other hand, large amounts of data give rise to the challenge of making sense of these data. Especially when the number of collaborating groups increases, the amount of available information may become a burden, causing what is called an information overload (Duval, 2011; Dyckhoff et al., 2012). As more information becomes available, the teacher's attention becomes more scarce (Duval, 2011). The challenge to filter the relevant information and to stay up to date with the current activities may hinder the teacher's goal to effectively help students. To reach this goal, it is important that the teacher diagnoses a student's or a group of students' current level of competence (Van de Pol, Volman, & Beishuizen, 2010). Diagnosis precedes teacher intervention and helps the teacher to decide on the appropriate action in a given situation, at the appropriate time. When information overload occurs, teachers might not be able to accurately diagnose student activities. Instead, the teacher's focus of attention and decisions to intervene may be solely based on previous experiences (Feldon, 2007), which could mean that interventions are not specifically tailored to the need of the learners at a specific moment.

Central to CSCL is the idea that learning takes place largely through collaboration among students (Stahl et al., 2006), for example by expressing and discussing thoughts. It is known that the occurrence of collaboration should not be taken for granted and that problems may occur in the social activities that students engage in (Kreijns, Kirschner, & Jochems, 2003). Therefore, an important part of the teacher's task is to diagnose those social activities and to intervene when necessary. However, studies on teacher behavior in CSCL have indicated that teachers tend to focus less on social aspects (e.g., student participation) than on cognitive aspects (e.g., quality of the group product that is being constructed) of student activities (Asterhan, 2011; De Smet, Van Keer, & Valcke, 2008; Van Leeuwen, Janssen, Erkens, & Brekelmans, 2013). A possible explanation is that some social processes are not directly observable: they are related to episodes of activity instead of isolated events. For example, when one of the members of a group of students puts in less effort than the others, this may be hard to become aware of because it is a cumulative property of the collaboration. Social processes can therefore be hard to monitor, requiring the teacher to form a diagnosis of students' social activities across multiple time points (Tabak, 2004).

4.1.2 How learning analytics tools may support teachers

A possible way to support teachers in regulating students' social activities during CSCL is by enhancing digital environments with LA tools (Casamayor et al., 2009). The traces left by student activities can be automatically collected, analyzed, and reported back to both students and teachers for the purpose of optimizing learning (Siemens & Gasevic, 2012). LA tools that are specifically aimed at supporting the teacher may serve a number of functions. They can be placed on a continuum of how much control or choice is left to the teacher (Duval, 2011): from providing overviews of data to suggesting particular actions to even undertaking those actions (for example by automatically sending a message to a student).

Concerning the issue outlined above, namely the challenge of diagnosing in particular students' social activities in a synchronous setting, teachers may be best helped by the addition of LA tools that support the process of diagnosing. Providing the teacher with summaries of the collaboration between students may lower the information load and free up time to spend on helping students. This information can complement the teacher's own knowledge and thus serves no prescriptive function; the teacher is free to decide whether or not to act on the information provided by the tools (Asterhan & Schwarz, 2010a). Having access to up-to-date information helps the teacher to decide whether intervention is necessary and if so, which intervention is appropriate (Lajoie, 2005).

LA tools may be particularly useful to diagnose social activities. Aggregating time-spanning social events to a visible summary eliminates the necessity to observe all student activities to assess the quality of student collaboration. In this study, two of such LA tools are used. They are aimed at two social aspects that are considered prerequisites for good collaboration (Janssen, Erkens, & Kanselaar, 2007; Kreijns, Kirschner, & Vermeulen, 2013). First of all, it is important that all students participate and put in equal amounts of effort, because that way each student can contribute to the group process and engage in knowledge construction. Furthermore, on-task participation positively correlates with learning outcomes (Saab, Van Joolingen, & Van Hout-Wolters, 2007). Unequal distribution of activity of individual members within groups could thus lead to reduced productivity or reduced learning outcomes for at least some of the group members (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). It was shown that providing students with a visualization of each group member's relative contribution led to increased student participation and increased coordination activities within groups (Janssen, Erkens, Kanselaar, & Jaspers, 2007). It is expected that showing such a visualization to teachers can be beneficial for students' learning processes as well, because the teacher can immediately see whether there is unequal distribution of activity and thus whether there is cause for further investigation or intervention within a group.

Secondly, the quality of students' discussion could be a problem. If students engage in discussions that are both critical and constructive, this can enhance learning (Rojas-Drummond & Zapata, 2004). However, during online discussion, it is sometimes the case that students do not critically reflect on each other's contributions and agree on everything (termed cumulative talk by Mercer, 2000), or the reverse, that students cannot reach an understanding and get stuck in a disagreement (also called disputational talk; Mercer, 2000). It is therefore important that teachers monitor the way students communicate. A possible way to support the teacher in doing so is by a tool called the Shared Space (SS, see Janssen, Erkens, & Kanselaar, 2007). The SS visualizes the degree to which students are in agreement or disagreement and when provided to students was shown to have an effect on their perceptions of the discussion (Janssen, Erkens, & Kanselaar, 2007). Again, our expectation is that this tool can be beneficial to the teacher as well by making visible an important property of discussion that otherwise would require the teacher to read students' utterances in an in-depth way. The SS serves as a summary of episodes of discussion that can help the teacher to monitor eventual problems.

Some researchers have expressed concern that instead of supporting the teacher, LA tools add an extra layer of complexity (Sharples, 2013). Of course, the interpretation of LA tools should not be a burden. The tools in this study are therefore offered as visualizations that are easy to interpret (Tergan & Keller, 2005), see Section 4.2.3.

4.1.3 Research question and hypotheses

The aim of this study is to examine the effects of two LA tools that offer moment-to-moment analysis of two social aspects of collaboration: participation and discussion. The following research question has been formulated: What is the effect of learning analytics tools that show information on student participation and discussion during collaboration on the development of teachers' diagnosis and interventions?

It is expected that teachers with access to LA tools will more easily detect problems, and that their interventions will therefore be more focused on participation and discussion. In turn, it is expected that when asked to diagnose these social aspects, these teachers will give lower scores to the groups that experienced problems. The main hypothesis is therefore: Teachers that have access to LA tools are better able to diagnose problems concerning participation and discussion.

Because participants might need some time to be fully able to interpret and make use of the LA tools, the effect of the presence of the LA tools may show itself more prominently after being subjected to several vignettes. In other words, the effect of the LA tools may show itself in a gradual change in the teachers' focus of behavior.

4.2 Method

4.2.1 Design

An experimental study with a between and within subjects design was conducted. The experimental setup was combined with the use of authentic classroom situations. Participating teachers were presented with CSCL simulation software that either contains additional LA tools or contains no additional LA tools. Teachers were presented with student data in the form of fragments lasting several minutes that are drawn from authentic CSCL data. These fragments or vignettes were the same for participants in both conditions, thereby eliminating unpredictable classroom elements such as time pressure or absence of students. The vignettes were dynamic in the sense that collaboration among students was shown (i.e., played back) to the teachers in real-time. Participants were able to monitor student activities (i.e., to diagnose) and to send messages (i.e., to intervene), and thus to act as the teacher as long as the vignette lasted. After each vignette, participants were asked to express their diagnosis of the collaborating groups in terms of a score for participation and discussion.

Participants were randomly assigned to the control (no LA tools) or the experimental (LA tools) condition. The independent variable is therefore the absence or presence of LA tools. The dependent variables are the teachers' diagnosis and interventions during and after each of the vignettes, which constitute four repeated measures.

4.2.2 Participants

Twenty-eight high school teachers and student teachers (who all had teaching experience through internships) participated in this study, 14 in each condition. The control condition consisted of 5 teachers and 9 student teachers, see Table 4.1. The experimental condition consisted of 6 teachers and 8 student teachers. The number of years of teaching experience thus varied, although overall the participants in the two conditions did not significantly differ in mean age or teaching experience. The sample consisted of teachers from both humanities and science subjects (such as biology and physics), whose distribution was the same for the two conditions. Participants voluntarily registered for the experiment and were rewarded with a small compensation.

Participants were asked about their experience with using collaborative activities and their use of ICT in the classroom. No significant differences were found between the two conditions. It was checked whether teaching experience or teaching subject had an influence on the dependent variables in this study. No such results were found.

Table 4.1. Summary of participants' characteristics.

	Participants	*N*	Age (years)		Teaching experience (years)	
			M	*SD*	*M*	*SD*
Control condition	teachers	5	41.4	15.2	16.4	12.6
	student teachers	9	21.2	1.2	1.3	0.7
Experimental condition	teachers	6	45.2	12.2	17.0	15.7
	student teachers	8	23.0	2.4	1.0	0.0

4.2.3 Simulation software and learning analytics tools

To combine an experimental setup with the use of authentic classroom situations, simulation software was created based on an existing CSCL environment called VCRI (Virtual Collaborative Research Institute, see for example Van Leeuwen et al., 2013). The simulation software is able to read student data from previous research and to display it as if students are collaborating real-time. This way, all participants in the current study could be shown the same authentic collaborative situations. At the same time, an experimental set-up was realized by creating two versions of the simulation software: the control version, which was essentially the same as VCRI, and the experimental version, which was enhanced with LA tools.

In VCRI, students work on collaborative assignments. They communicate through a Chat-tool and work on the assignment in a shared text editor, the Cowriter. In the control condition of the simulation software, participants were able to follow all students' activities. They could open Chat windows and read the task materials that were available to students (Sources). Through the Coach menu, participants could check the texts that are being written in the Cowriter. Besides these ways to diagnose, participants could intervene by sending messages in the Chat windows. Multiple windows can be opened simultaneously, allowing the teacher to monitor multiple groups and multiple tools at the same time. The control condition was thus similar to the way VCRI is normally used by teachers in actual classrooms.

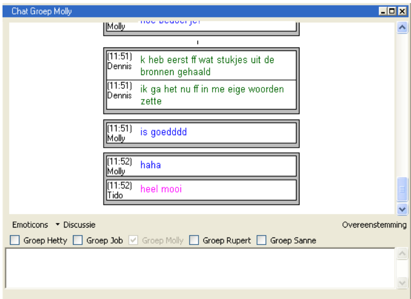
In the experimental condition, the software from the control condition was enhanced to include two additions. The first addition to the experimental condition was the availability of Statistics in the Coach menu that showed the relative contribution of each group member for each collaborating group. By calculating the total amount of keystrokes and the individual keystrokes of each student, the software generates a pie chart for each group that is continually updated. Teachers are thus able to see each group member's amount of participation.

Secondly, the Chat window of each group now contained the Shared Space, which visualizes whether the group is in disagreement or in agreement (see Janssen, Erkens, & Kanselaar, 2007 for an elaborate description). By automatically coding the students' chat utterances for specific dialogue acts, it is determined whether the students are in agreement or disagreement. The movement between agreement and disagreement is visualized as a moving line in the side bar of the Chat windows. This bar shows the complete history of the Chat conversation, thereby enabling teachers to see at a glance how the discussion evolved in the chat conversation of that particular group. Also, the Chat box that contains students' messages moves to the left or right to enhance the visibility of these movements. Table 4.2 shows screenshots of both the Statistics and the Shared Space. In the top right pane, the Statistics' pie chart is visible with three colors representing the relative contribution of the three group members. In the bottom right, the Chat-tool is displayed with the Shared Space on the left. When the line moves to the left, this means students are in disagreement; a movement to the right means agreement. The Chat box itself has also just moved, in this case to the right, indicating more agreement among students.

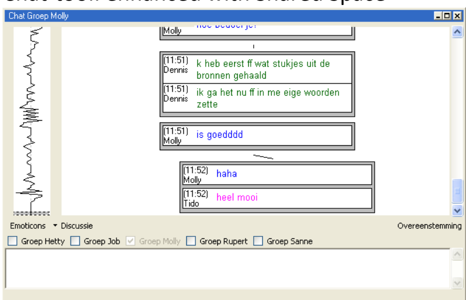
Table 4.2. Comparison of the simulation software in the control and the experimental condition.

<table>
<tr><th>Control condition</th><th>Experimental condition</th></tr>
<tr><td>Statistics: none</td><td>Statistics: distribution of activity within groups

</td></tr>
<tr><td>Chat-tool



</td><td>Chat-tool: enhanced with Shared Space



</td></tr>
</table>

Note. The text in the screenshots is in Dutch.

4.2.4 Vignettes

Each teacher went through vignettes of four collaborative situations in a random order. Each vignette contained five collaborating groups and lasted for 8 minutes, during which student activities occurred. The situations were selected from existing data from previous research, which were collected in high school classes using VCRI to work on an assignment. The students worked on an assignment concerning the Second World War and the Cold War. Because the assignment was at the level of secondary education, it was expected that all teachers (also of subjects other than history) had at least basic knowledge about this topic. By replaying students' activities in the simulation software, participants were able to act as the teacher as if the situation was happening real-time. Chat messages appeared, the texts in the Cowriter changed, and in case of the experimental condition the LA tools were constantly updated to reflect the current situation. All names were changed to preserve anonymity of students. Small changes were made in the students' Chat messages, for example when students referred to the teacher.

Four vignettes were selected to reflect the two social aspects of collaboration that the LA tools are aimed at: participation and discussion. One vignette contained a group that had a problem concerning discussion: they were continuously in disagreement (i.e., disputational talk, Mercer, 2000). One vignette contained a group in which group members participated unequally. One vignette contained both a group with a problem related to discussion, namely where students agreed with each other and had a lack of critical discussion (i.e., cumulative talk, Mercer, 2000), and a group where group members participated unequally. Table 4.3 summarizes the problems that occurred in the vignettes. One neutral vignette was used as a control vignette. Thus, except for the neutral vignette, each vignette contained one or two problematic groups and three or four neutral groups.

Table 4.3. Problem descriptions of the four vignettes.

Vignette	Problem description
Discussion (D)	Frequent disagreement
Participation (P)	Unequal participation
Combination (C)	Problematic group 1: Unequal participation Problematic group 2: Frequent agreement
Neutral (N)	-

4.2.5 Procedure

Participants were first shown an introductory movie in which an explanation was given of the procedure of the experiment and of how to use the software. The participant then logged on to the simulation software. The program went through several steps.

1. Some general background questions were asked, for example how often teachers use ICT in their classroom.
2. A test vignette was played in which teachers could practice opening windows and typing messages and thus get used to the software. This test vignette lasted 2 minutes.
3. The four experimental vignettes were offered one by one. For each participant, the order of the vignettes was randomized. Each vignette was preceded by a brief explanation of the situation the vignette was taken from, i.e., what subject the class was working on and how many lessons they had worked on the topic. Then

the vignette played, lasting 8 minutes, during which the teacher was free to type messages to the students and to check their progress. Participants were explicitly asked in the introductory movie to act as they would in a real educational setting, even though in this case the students could not respond to the participants' messages. At the end of each vignette, a screen opened with questions about the teacher's diagnosis of participation and discussion within the groups.

4. The program ended with a short questionnaire in which participants were asked about the quality of the introductory film and whether they were able to complete the task. There was also a text box in which participants could leave comments. During the experiment, participants could ask the researcher questions if they were unsure about how to use the software. In total, the task took participants one hour.

4.2.6 Instruments

The participants' actions were automatically logged during and after each vignette. This resulted in the following types of data. First of all, it was logged what tools the teacher used and how often, for example opening a group's Chat window or selecting information in the Coach menu (diagnosis). Also, all messages sent by the participants to one of the groups were automatically collected (interventions). After each vignette, participants gave scores to each of the groups and had the option to give an explanation of the given scores (overall diagnosis).

4.2.6.1 Diagnosing activities during vignettes

During the vignettes, the following actions were logged: for the Chat-tool, whether teachers opened a group's chat screen and whether they scrolled through the Chat history; for the Coach menu, whether teachers opened this menu and which information they selected for which group; and for the Sources-tool, whether teachers opened this tool and opened sources in order to read them.

4.2.6.2 Interventions

During each vignette, participants were able to intervene by sending messages in a group's Chat-tool. These interventions were coded for focus and recipient. Focus denotes *what* the teacher's intervention is aimed at (Van Leeuwen et al., 2013) and can be broadly split in four categories. Teachers may focus on students' cognitive or social activities, each further split into an object and a meta level (Baker, Andriessen, Lund, Van Amelsvoort, & Quignard, 2007; Janssen, Erkens, & Kanselaar, 2007; Kirschner & Erkens, 2013). For example, concerning social activities, teachers may give feedback on a student's participation (object level) or give a hint about strategies for collaboration (meta level). In the present article, object and meta level are joined in one category (see Table 4.4).

Table 4.4. Coding scheme for interventions, consisting of focus and recipient.

Aspect	Category	Explanation
Focus (what)	Cognitive or metacognitive activities, MCog	• Messages about task content • Messages about planning or task strategies
	Social or metasocial activities, MSoc	• Messages about the mood in the group • Messages that contribute to the mood in the group or motivate students • Messages about the collaborative process, strategies for collaboration, or consequences of the way of collaborating
Recipient (who)	Class	Messages sent to all groups simultaneously
	Student	• Messages that include a student's name • Answers to a specific student's question. This only counts when the problem was not discussed in the group prior to asking the question.
	Group	All remaining messages

Recipient denotes *who* the intervention was aimed at: the whole class, a group, or an individual student within a group (Onrubia & Engel, 2012) and gives an indication of how specific the teacher's diagnosis was, for example when a teacher addresses a specific student instead of the whole group. Table 4.4 displays the categories that were used. Two researchers independently coded a sample of 96 interventions, resulting in Cohen's Kappa of .82 and .66 respectively for the two aspects of the coding scheme. The interrater reliability for *focus* was interpreted as good. After discussion of the differences in coding and reformulating coding definitions for *recipient*, the remaining interventions were coded by one researcher.

4.2.6.3 Overall diagnosis

Overall diagnosis was measured in two ways. First of all, after each vignette participants were asked to give a score to each group for participation and discussion on a scale from 1 to 10 (where 1 = very poor and 10 = excellent). Participants could also indicate they had not been able to make a proper judgment and refrain from giving a score. In total, each vignette resulted in ten scores, two for each of the five groups.

The second measure of overall diagnosis was that participants could write a comment to explain their given score. These comments were collected and coded. Three aspects were of interest to answer our research question. First of all, the *content* of the comments was coded, which indicates what aspect of students' activities is mentioned to explain a given score. Besides the two social aspects of collaboration that are central to this study, participation and discussion, two other categories appeared when the first 100 out of 500 comments were coded: cognitive and socio-emotional aspects. Besides the content, it was coded what *source* of information participants used to come up with their score, i.e., which tool participants reported as the source of their judgment. Lastly, the *level of specificity* of the judgment was coded, as a measure of how elaborate the explanation of the diagnosis was. Table 4.5 displays the categories that were used. A second sample of 100 comments was independently coded by two researchers, resulting in Cohen's Kappa of .77, .90 and .80

respectively for the three aspects of the coding scheme. These interrater reliabilities were interpreted as good and the remaining comments were coded by one researcher.

Our expectation is that teacher behavior changes over time, especially concerning the teachers in the experimental condition, whose behavior may be influenced by continuous access to the LA tools. Therefore, the data is analyzed according to whether it was the first, second, third, or fourth vignette that participants went through. For example, participant 1 saw the vignettes in order ABCD, while participant 2 had the order of CBDA. In this case, the data for "1st vignette" includes participant 1's data on vignette A and participant 2's data on vignette C.

Table 4.5. Coding scheme for explanations of overall diagnosis scores, consisting of collaborative aspect, source and level of specificity.

Aspect	Category	Explanation
Content	Participation	Mentioning task division or participation rates
	Discussion	Mentioning characteristics of the discussion between students
	Cognitive	Mentioning the content of the group's discussion or written text
	Socio-emotional	Mentioning the atmosphere in the group or the way students react to each other
Source	Chat Cowriter Statistics SharedSpace	• Explicit mention of a particular tool (or use of a synonym, for example "Pie chart" instead of "Statistics") • Participant described seeing something that can only be seen in a particular tool (for example "Written text" refers to "Cowriter")
Level of specificity	High	• Mentioning specific information such as quoting a chat utterance, naming a particular student, or a percentage from the Statistics • Mentioning multiple timepoints (i.e., the process)
	Low	All remaining utterances

4.3 Results

4.3.1 Diagnosis

Table 4.6 shows the average frequency of using the available tools per participant and per vignette. As can be seen, the number of times tools are used for diagnosis is comparable for the two conditions. In the experimental condition, participants request Statistics for one or multiple groups on average 6.7 times per vignette. The number of times the content of the Cowriter is selected (for one or multiple groups) is relatively low in both conditions. However, opening the Coach menu is done more often, which could also indicate that previously selected information is revisited. The Sources-tool, which contains the task materials that students used, was rarely opened or selected in both conditions.

Table 4.6. Average number of actions per participant per vignette.

		Control		Experimental	
Tool	Action	*M*	SD	*M*	SD
Chat	Open, Select	21.7	6.2	18.0	4.4
	Scroll	12.7	8.7	8.9	6.9
Coach menu	Open, Select	15.0	3.5	18.6	6.4
	Cowriter	3.2	2.2	2.3	2.5
	Statistics	*(not available)*		6.7	4.8
Sources	Open, Select	1.6	1.5	1.0	1.0

Note. Opening a tool means the tool was formerly closed, whereas selecting a tool means the tool was already opened and the participant again clicked on it to get the screen into view.

4.3.2 Interventions

4.3.2.1 Frequency of interventions

In the control condition, a total number of 194 interventions occurred, compared to 220 in the experimental condition. Figure 4.1 presents the mean number of interventions per vignette and the mean percentage of interventions aimed at problematic groups. In the control condition, the number of interventions slightly increases while the percentage of interventions aimed at problematic groups decreases with each successive vignette. In the experimental condition it is the other way around: the mean number of interventions decreases, but they are relatively more often sent to problematic groups during vignette 1, the first presented vignette, and 4, the last one. Independent samples t-tests (two-tailed, significance level .05, which applies to all subsequently mentioned t-tests) revealed that the differences between the two conditions were not significant ($p > .05$).

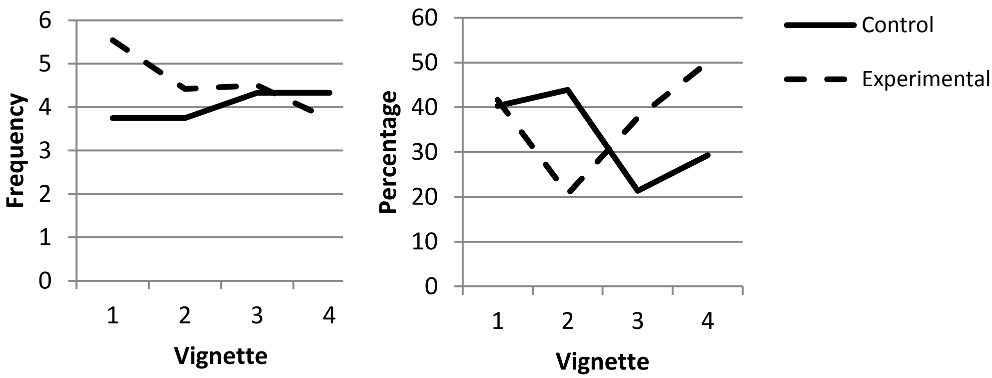


Figure 4.1. *Mean number of interventions (left) and the mean percentage of interventions sent to problematic groups (right).*

4.3.2.2 Focus of interventions

Figure 4.2 displays the mean frequency of interventions focused on cognitive or social aspects for the two conditions. In both conditions, the focus on cognitive aspects decreases (Figure 4.2, left) and the mean frequencies are comparable. In the control condition, the focus on social aspects increases with each successive vignette (Figure 4.2, right). In vignettes 1 and 3, the mean frequency of interventions focused on social aspects is higher in the experimental than in the control condition. Although the results are not significant (vignette 1: $t(22) = -1.4$, $p > .05$, $d = 0.6$; vignette 3: $t(22) = -.56$, $p > .05$, $d = 0.2$), in vignette 1 it did represent a medium-sized effect ($d = 0.6$).

Within the experimental condition, there is a significant difference between the focus on cognitive and social activities during vignette 4 ($t(11) = -3.2$, $p < .01$, $d = 0.9$, see the triangle marks in Figure 4.2). No significant differences were found within the control condition.

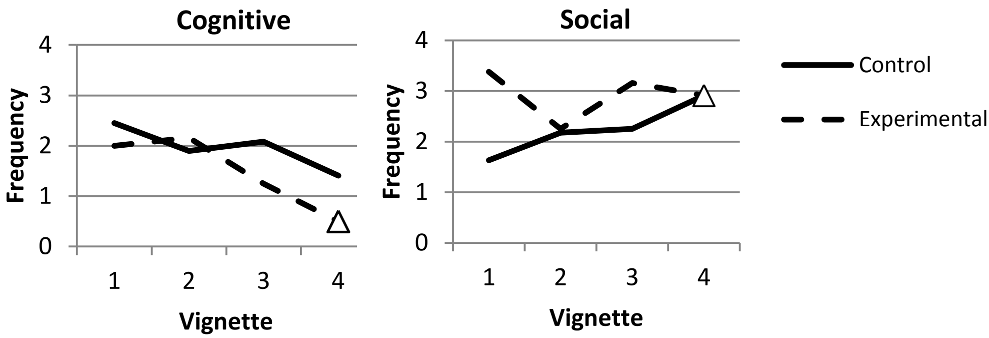


Figure 4.2. *Mean frequency of interventions focused on cognitive (left) and social (right) aspects for each vignette. Triangle marks indicate a significant difference.*

4.3.2.3 Recipient of interventions

In the control condition 3 interventions are sent to the whole class. The majority of interventions is aimed at a group (80.4% of the total) and the remaining interventions at individual students (18%). In the experimental condition, no class messages are sent. A relatively larger part of interventions are aimed at individual students (36.4%) and the remaining interventions at a group (63.6%). The mean frequencies for the recipient of the intervention (individual student or group) for the four vignettes are displayed in Figure 4.3. No significant differences were found between conditions.

Within the control condition, the mean number of interventions aimed at individual students is significantly lower than those aimed at groups (see the triangle marks in Figure 4.3) in all four vignettes ($t(10) = 3.04$; $t(9) = 2.64$; $t(11) = 2.21$; $t(11) = 2.37$ respectively, $p < .05$ in all cases and $1.3 < d < 1.9$). Within the experimental condition, no significant differences were found.

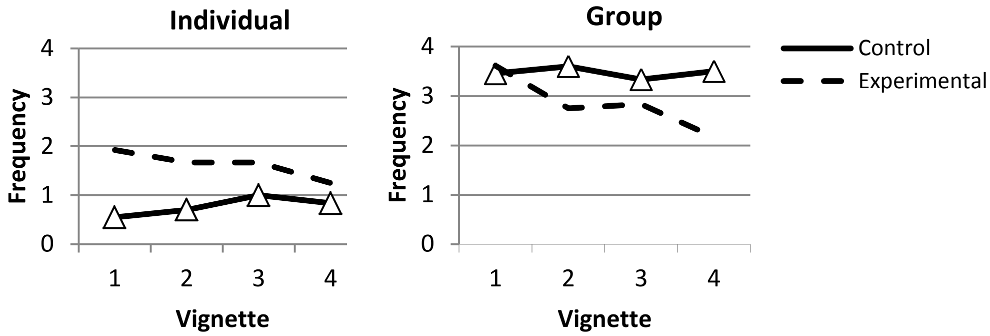


Figure 4.3. *Mean frequencies of interventions aimed at individual students (left) and groups of students (right). Triangle marks indicate a significant difference.*

Interventions aimed at individual students could be a sign of the participant having more detailed information about an occurring problem. Looking only at the interventions aimed at individual students, in the control condition 34.3% is aimed at students in problematic groups, compared to 46.3% in the experimental condition. Furthermore, in the control condition 57.1% of interventions aimed at individual students is focused on social aspects, compared to 81.3% in the experimental.

4.3.3 Overall diagnosis

4.3.3.1 Overall diagnosis: scores for participation and discussion

For all participants, the diagnosis score given to the problematic group and the mean score given to the other, non-problematic groups within each of the four succeeding vignettes were compared. This was done for the score on participation and for discussion separately. This way, it was investigated whether participants singled out the problematic group by giving it the lowest score (scores run from 1 to 10). The neutral vignette was not included in this analysis because it contains no problematic groups. Table 4.7 lists the results of the dependent-samples t-tests.

In the experimental condition, a significant difference was found for the score on participation in each of the four vignettes. In the control condition, this occurred two out of four times. In all cases, the problematic group had a significantly lower score than the other groups, indicating that the group or some of its members were indeed judged to show poorer participation. Concerning discussion, no differences were found in the experimental condition. In the control condition, there was a significant difference in the last vignette, where the problematic group scored significantly lower. Interestingly, although the result is not significant, in the first vignette in the control condition the group that had a problem concerning discussion was scored almost 1.5 points higher than the other groups, meaning that participants judged the problematic group to show better discussion than the other groups.

Table 4.7. Average scores given to groups for participation and discussion, and the results of the dependent-samples t-tests.

	Control condition					
	Participation			Discussion		
Vignette	*M*p	*M*np	t	*M*p	*M*np	t
1	4.91	6.82	-3.62**	7.96	6.58	2.74[+]
2	5.24	6.55	-1.53	5.93	6.55	-.69
3	3.85	5.68	-3.34**	5.29	5.99	-1.0
4	5.44	5.44	.00	3.23	6.09	-3.0*
	Experimental condition					
	Participation			Discussion		
Vignette	*M*p	*M*np	t	*M*p	*M*np	t
1	4.76	6.98	-3.26*	5.21	6.39	-1.25
2	4.97	6.79	-2.69*	5.81	7.14	-1.45
3	4.86	6.78	-2.51*	5.60	7.10	-1.61
4	4.93	7.42	-3.43**	6.12	6.82	-.74

Note. ‘p’ refers to the problematic group and ‘np’ to the non-problematic groups.
+ p <.10 * p < .05. ** p < .01.

Based on the results for the overall diagnosis scores, it seems that the Statistics helped the participants in the experimental condition to identify problems concerning participation. The Shared Space, that offers information on discussion, seems to have had no such role based on the scores given by the participants.

A repeated measures analysis was performed to see whether participants’ judgments of groups changed over time. Because problematic groups were singled out with a lower score at least by a part of the teachers, only the average scores for non-problematic groups were used in this analysis. A significant interaction effect between time and condition was found for the scores on participation ($F(3, 48) = 4.07$, $p < .05$): the scores given in the control condition became lower with each successive vignette, while the scores increased in the experimental condition. Participants in the control condition thus became more strict in their judgment of participation than the participants in the condition with teacher support. No such effects were found for the scores on discussion.

Participants could also indicate that they were unable to give a score to a group. Figure 4.4 shows the mean number of times this occurred, split for the scores on participation (left) and discussion (right). For example, in the first vignette in both conditions it occurred on average 1.5 times (i.e., for 1.5 groups) that participants were unable to give a score for participation. Differences in the number of times participants were unable to score did not significantly differ for participation nor discussion, although concerning participation (Figure 4.4, left) a medium effect size was found in vignette 4 ($t(24)= 1.29$, $p > .05$, $d = 0.53$).

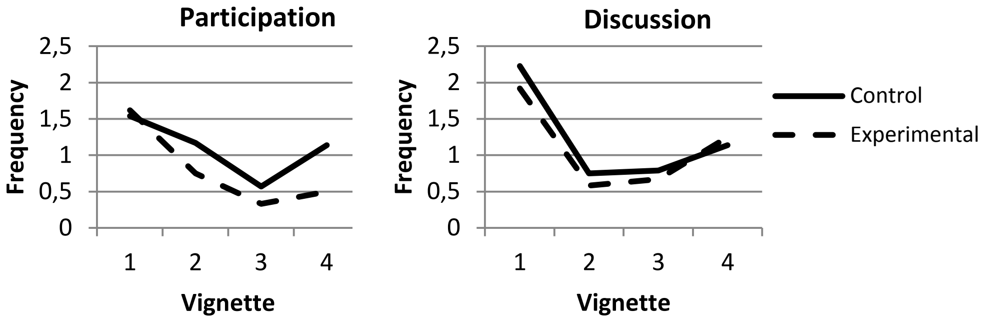


Figure 4.4. *Mean number of times participants indicated they were unable to give a score for participation (left) and discussion (right).*

In almost all cases that participants indicated they were unable to give a score, it was not the case that they had paid no attention to that specific group. On the contrary: in most cases participants had looked for information about that group, both in the control condition (by opening the Chat and reading the text in the Cowriter) as well as in the experimental condition (by the mentioned actions, plus selecting Statistics). It could be that the time spent on the information was too short to give an accurate judgment.

4.3.3.2 Overall diagnosis: explanations of scores

Participants were asked to give an explanation of the score they gave to the groups, both for the score on participation and the score for discussion. In the control condition participants did so in 72.3% of all cases, in the experimental condition it was 64.7%. Comments were coded for collaborative aspect, source and level of specificity.

Figures 4.5a and 4.5b show the content of comments given to the scores for participation (4.5a) and discussion (4.5b). The comments about participation do not significantly differ in frequency nor in content between both conditions: the majority of comments is indeed about participatory aspects. In the experimental condition, some scores for participation are accompanied by a comment that is about discussion. For example, one participant wrote about a group of students that "everyone participated equally and they asked each other questions and gave feedback to each other".

The comments about the scores for discussion (Figure 4.5b) differ between the conditions. In the experimental condition (Figure 4.5b, right), participants significantly more often mention aspects coded as 'discussion', such as reaching agreement, in vignette 2 ($t(18) = -2.17$; $p < .05$, $d = 1.02$) and vignette 3 ($t(20) = -2.53$; $p < .05$, $d = 1.13$) than in the control condition (Figure 4.5b, left), see the triangle marks in Figure 4.5b. This might indicate that the judgment given by participants in the experimental condition was influenced by the available LA tool, the Shared Space. Within the control condition, comments are relatively more often about socio-emotional aspects, such as the atmosphere in a group of students' chat conversation.

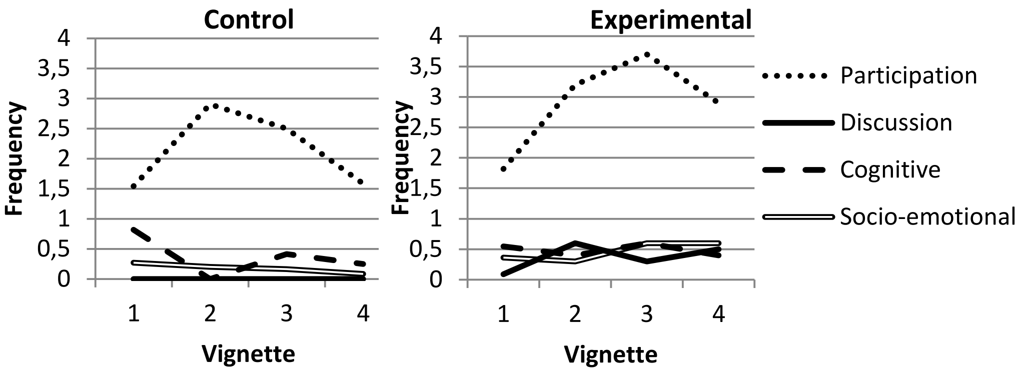
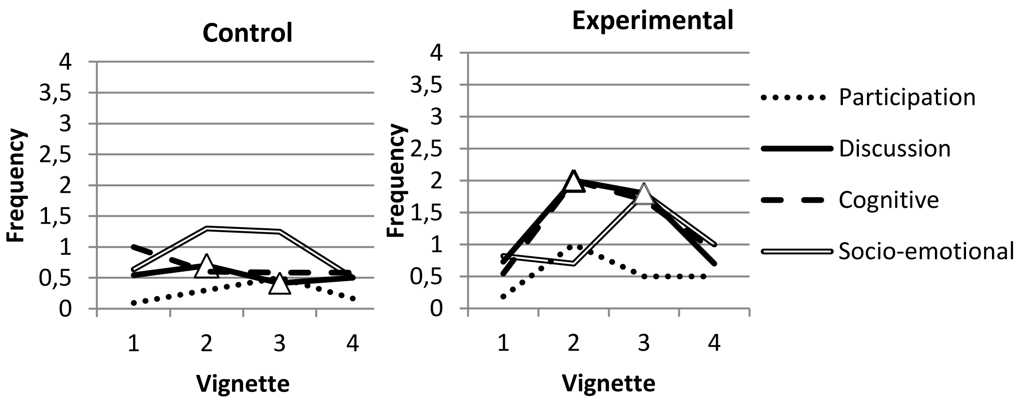


Figure 5a. *The content of comments given by participants to the scores they gave for participation, displayed as mean frequency.*



Figuur 5b. *The content of comments given by participants to the scores they gave for discussion, displayed as mean frequency. Triangle marks indicate a significant difference.*

Concerning the source of the comments, the participants in the control condition often mentioned the Chat in their explanations, both for the scores on participation (90%) and discussion (97%). The remaining comments mentioned the Cowriter as the source. In the experimental condition, the Chat-tool is mentioned 96% of all comments for the score on discussion. For the score on participation, these participants not only made use of the Chat-tool (55%), but also of the Cowriter (13%), the Statistics (30%) and the Shared Space (2%). The relatively high occurrence of the mention of Statistics is in line with the finding that participants in the experimental condition were able to single out the problematic group in all four vignettes. Apparently, the Statistics offered support to detect participatory problems.

The results for the Shared Space are not as clear. On the one hand, participants with access to the Shared Space did not score problematic groups lower on discussion (Section 4.3.3.1) and they did not often explicitly mention the Shared Space in their comments. On the other hand, the content of the comments in the experimental group were significantly more often about aspects related to discussion (Figure 4.5b), which points to the Shared Space after all. Also, because the Shared Space is contained within the Chat-tool, the high occurrence of the mention of the Chat could indicate the Shared Space as well. A possible explanation is that participants did use the Shared Space, but that they did not consider the absence of disagreement a problem and hence did not give problematic groups a lower score for discussion. In the vignettes, there were two groups with a problem concerning discussion. The first group had disagreements (D) and could not reach common ground, while the other group always agreed (A) with each other and lacked critical discussion. The comments for these two specific groups are clear: the first group (D) is described critically, while the other (A) receives praise. Table 4.8 shows examples of the comments. These examples also illustrate the difference in the content of comments as described above; for example 'friendly' and 'fighting' in the control condition (coded as 'socio-emotional') versus 'agree' and 'critical' in the experimental condition (coded as 'discussion').

Table 4.8. Examples of comments about the two groups with a problem concerning discussion.

Group	Condition	Comment
D	Control	They achieved nothing, and were not very friendly to each other.
	Control	Fighting instead of achieving results.
	Experimental	A bad discussion. They could not agree on the sources and the text.
	Experimental	The collaboration in this group was far from optimal. Students slated each other and reacted in a crude way.
A	Control	Good discussion.
	Control	They collaborated in a good and clear way.
	Experimental	Collaboration went well in the chat, good atmosphere.
	Experimental	Great, polite and critical.

The percentage of comments with a high level of specificity is generally higher in the experimental condition (on average 33.4% versus 25% in the control condition). This means that in the experimental condition the participants more often mentioned specific students or gave more elaborate explanations for their diagnoses.

4.4 Discussion

The aim of this study was to investigate the effect of LA tools on teachers' way of diagnosing and intervening whilst regulating the activities of collaborating groups in a CSCL environment. An experimental set-up was combined with the use of authentic, interactive vignettes. Two LA tools were investigated, the first aimed at participation, the second at discussion.

4.4.1 Results and implications

Information about participation was given in the form of Statistics showing each group member's relative contribution. The participants in the experimental condition gave significantly lower scores to the groups with a participatory problem in all four vignettes, in comparison to only two vignettes in the control condition. It was also found that these participants in their comments mentioned use of the Statistics. Together, this points to an effect of the Statistics, namely an increased ability to single out problems concerning participation.

Interestingly, participants' judgment of participation in non-problematic groups became more strict in the control condition, whereas participants in the experimental condition became milder in their judgment. A possible explanation for the found difference is that the Statistics tool helped participants to maintain an overview of the situation. In the control condition, participants might have focused excessively on the Chat-tool, ascribing too much significance to individual Chat utterances and as a consequence judging students' participation more strictly than in the experimental condition. In the experimental condition, it seems that as time progressed participants found a strategy to diagnose participation rates. They have been able to use the Statistics to connect the information from the various tools. A supporting finding is that in the experimental condition, the number of times participants indicated they were not able to judge participation was slightly lower.

The second LA tool, the Shared Space, showed information about discussion. The effect of the Shared Space remains unclear because of mixed findings. In the experimental condition, participants were not able to single out the groups that had a problem concerning discussion. In the control condition participants were able to do so in two of the four vignettes, albeit that the problematic group in one occasion received higher scores instead of lower ones. The written comments showed that participants in the experimental condition did focus more on discussion, but they did not explicitly mention using the Shared Space. The number of times participants indicated not being able to judge discussion did not decrease (in contrast to the aspect participation, see previous paragraph), which could indicate that in both conditions, participants were not able to develop a strategy for diagnosing discussion. Last of all, these results remain hard to interpret because there is no explicit data available about the frequency the Shared Space was used. The Shared Space was an integral part of the Chat windows and in contrast to the Statistics the participants did not need to click to see it once they had opened a chat window.

As was discussed in the Results Section, the lack of clear indications of an effect of the Shared Space might be explained by the relationship between the shown information and teachers' beliefs. The group of students that were in constant agreement were, contrary to our expectations, not judged lower than the other groups who had a fair amount of both agreement and disagreement The written comments given by the participants thus pointed to a different interpretation of what constitutes a 'problem' concerning discussion. This finding illustrates the several functions that LA tools may have on a continuum ranging from the teacher making all the decisions, to a scripted scenario in which tools automatically give alerts or connect actions to signaled problems (see for example Borges & Baranauskas, 2003; Casamayor et al., 2009). In the case of this study, the tools were aimed solely at supporting the teacher in the phase of diagnosis and the interpretation of the information shown by the tools remained the teacher's task. There is an ongoing discussion in the CSCL community about which point on the continuum of LA tools is most effective (Roschelle, Dimitriadis, & Hoppe, 2013). Although the present study cannot settle the debate, it does show that no matter the technology, the teacher is the agent: the one who makes use of the technology and decides how and when to use it (Looi & Song, 2013).

An unprecedented result is that there is no significant difference between the control and experimental condition concerning the focus on social aspects. This might be due to the fact that the questions in between vignettes, which asked participants to give a score for participation and discussion, led all participants to think and focus on these social aspects. These questions thus partly served the same function as the LA tools. However, the questions after each vignette and the LA tools served their function at two different levels and also had their own effects. The questions in between acted on a general level and probably increased participants' general focus on social aspects. This resulted in interventions having a higher focus on social aspects, both in problematic and non-problematic groups, and in both conditions. This effect is comparable to the results found by Asterhan, Schwarz and Gil (2012), who trained teachers to either focus on task-content or on social aspects before they started regulating the activities of collaborating groups. The teachers' focus changed in accordance with the training they had received.

The LA tools, on the other hand, not only pointed participants to focus on social aspects, but also gave a moment-to-moment analysis of students' participation and discussion. By aggregating information from a longer time period into visualizations that can be understood at a glance, the teacher's task of diagnosing student activities becomes less difficult. As Casamayor et al. (2009) remark, support systems that keep track of collaborative processes "lighten[s] this hard and time-consuming task" (p. 1153). So, although the questions in between probably caused an increased focus on social activities for all participants, the effect of the LA tools showed itself in more specific diagnoses of the vignettes. For example, the mean number of interventions decreased in the experimental condition, but they were relatively more often sent to problematic groups. Furthermore, the participants in the control condition more often target groups of students instead of individual students, also indicating less specific diagnoses. Last of all, the participants with access to LA tools were better able to describe their diagnosis, as can be concluded by the higher level of specificity of the written comments.

The hypothesis was that the LA tools would help participants to diagnose problems regarding participation and discussion. This hypothesis can partly be accepted: the groups that we labeled problematic were not always regarded as such by the participants. On the other hand, the LA tools did lead to more specific diagnoses.

4.4.2 Limitations and directions for future research

The set-up of the presented study had some limitations. First of all, the participants in this study did not all have a background in humanities. This might explain the low number of interventions concerning cognitive activities, because participants might not have been able to decide whether what students were writing was correct. Because the focus of the LA tools was on social aspects instead of cognitive ones and the assignment was about a topic considered basic secondary education level knowledge, our expectation was that participants would be able to judge social aspects without being hindered by a lack of content knowledge. Similarly, McElvany et al. (2012) found that teachers with a background in different subjects did not differ in diagnostic competence concerning students' ability to integrate text and pictures, an aspect that, like social activities, could be said to be largely independent of the specific task content.

The teachers in the present study also differed concerning the number of years of teaching experience, although there was no significant difference between the two conditions and no effect of experience on the outcomes of this study were found. It is an interesting question for future research whether the benefits of LA tools are different for specific types of teachers, for example for beginning teachers as opposed to more experienced teachers. Secondly, as was mentioned there was no explicit data available concerning the participants' use of the Shared Space. Because the Shared Space is one of the essential differences between the control and the experimental condition, it would have been valuable to be able to retrieve how often it was used. These data might have shed more light on the mixed findings concerning the effect of the Shared Space. If another study is performed using the Shared Space, a possible solution is that this tool only opens if the participant clicks on a button in the Chat window. The data collection could also be extended to include eye-tracking data, which would show whether and how long participants look at the Shared Space when they open a Chat window. Another previously mentioned limitation is the fact that the difference between the two conditions was not as clean or strict as intended because in both conditions the questions in between vignettes partly served the same function as the LA tools by pointing teachers' attention to collaborative aspects. To completely block this effect, each vignette should be presented to a different sample of participants. As we have shown, however, effects of the LA tools were still discernible even taking into account the effect of the questions.

Despite the described limitations, we believe the chosen set-up is a promising one. In contrast to what might have been expected, participants did not regard the task as unnatural. Participants continued to send messages in subsequent vignettes even though students could not respond. The simulation software could therefore be used in future research to study a range of topics. A lot of questions remain unanswered concerning teaching behavior in CSCL and the effect of LA tools. For example, in the present study we have measured how often teachers open or select the LA tools, but we have not yet examined in detail how teachers make a decision to act after reading the information shown by the tools. Some information will lead to the decision to intervene, while in other cases teachers may refrain from intervening after forming a diagnosis. The simulation software could be combined with other methods such as eye tracking or thinking out loud to capture and understand these teaching processes (Van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009).

The general conclusion emerging from this study is that LA tools can have an effect on the way teachers regulate the activities of collaborating groups of students. An effect was demonstrated both in the way teachers diagnose and in the way they intervene. Our next challenge is to introduce CSCL environments enhanced with teacher supporting tools in actual classrooms and to study the effects of the LA tools in a broader sense, taking into account not only teacher characteristics, but also the effects on students' learning processes. After all, the aim of learning analytics is to use supporting tools for optimizing learning and the environment in which it occurs (Siemens & Gasevic, 2012). In this article, we have given both theoretical and methodological directions for supporting the teacher's role in achieving this goal.

Chapter 5: Effects of learning analytics tools that focus on students' cognitive activities[4]

Abstract Teachers increasingly use CSCL in their classrooms when students work on ill-defined, open-ended tasks. Collaborating groups may encounter problems concerning cognitive activities (such as a misunderstanding of the task material). To provide adaptive support, teachers have to continuously be aware of students' activities in order to identify relevant events, including those that require intervention. Because the amount of available information is high, teachers may benefit from the presence of learning analytics (LA). The present experimental study explored the effect of two learning analytics tools that give information about students' cognitive activities. The results showed that when teachers had access to LA, they were not better at detecting problematic groups nor experienced less cognitive load, but they did offer more support in general and more specifically targeted groups that experienced problems. It is discussed how LA may steer teachers' focus and increase teachers' confidence to act, which in turn means students could benefit more from the teacher's presence.

5.1 Introduction

During computer-supported collaborative learning (CSCL), teachers act as coaches of students' social and cognitive activities instead of acting as the sage on the stage. Concerning cognitive activities, teachers can for example steer the discussion in the right direction, offer thoughts that deepen or broaden the discussion, and keep track of the progress that groups of students are making on the task. To do so, it is important that teachers are able to identify all relevant events, including those that require intervention. Because of the generally rapid pace of activities within synchronous CSCL settings and the large amount of available information, guiding those cognitive activities is not an easy task. In this article, we therefore explore a way of supporting the teacher, namely by visualizations of the collaborating groups' activities. The sections below describe the teacher's role during CSCL, the different types of student activities and how the teacher may be supported while regulating these activities.

5.1.1 Teaching and learning activities during CSCL

Teachers increasingly use CSCL in their classrooms when students work on ill-defined, open-ended tasks. As an instructional strategy, CSCL offers a digital environment that supports collaboration among students, based on the idea that collaboration among students is beneficial for learning. By collaboratively solving a task, students are challenged to share

[4] Based on: Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (under review). Teacher regulation of cognitive activities during student collaboration: effects of learning analytics. Manuscript submitted for publication.

ideas, express their thoughts and engage in discussion (Stahl, Koschmann, & Suthers, 2006). Learning during CSCL is seen as an interactive, constructive and largely self-regulated process. The change toward the use of collaborative learning in education also requires changes on the part of teachers. Traditionally, the teacher was seen as a "sage on the stage", whereas during collaborative learning a "guide on the side" is more appropriate (Mazzolini & Maddison, 2003). When the educational goals are to analyze, evaluate and synthesize knowledge, leading the students towards interaction and experimentation, the teacher's role is to exert less control and to turn into a facilitator or a coach (Salinas, 2008). When students exert a larger degree of control over their own learning, teacher regulation becomes more loose (Salinas, 2008; Vermunt & Vermetten, 2004). In case of CSCL, teacher regulation takes shape by monitoring the learning activities of students as they independently work with other students on their group assignments and intervening with feedback and assistance when needed (Anderson, Rourke, Garrison, & Archer, 2001).

The activities that the teacher monitors are based on the different types of learning activities that students engage in. Students' learning activities can be categorized into cognitive activities (i.e., related to the content of the task, for example structuring and analyzing task material), social activities (for example, the occurrence of discussion and conflict and participation rates of group members) and regulative activities at both the cognitive and social level (for example, discussing strategies for solving the task) (Janssen, Erkens, Kanselaar, & Jaspers, 2007; Vermunt & Verloop, 1999).

A teacher's task can be conceptualized in terms of regulation of students' learning activities (Vermunt & Verloop, 1999). During CSCL, teachers may regulate cognitive activities for example by offering thoughts that deepen or broaden the discussion. An example of regulating students' social activities is when teachers activate group members to participate. For a more elaborate discussion of teacher regulation of social activities during CSCL, the reader is referred to one of our earlier studies (Van Leeuwen, Janssen, Erkens, & Brekelmans, 2014, see Chapter 4). In the present study we focus on groups of students' cognitive learning activities. An important question is to what extent students need support from the teacher in performing cognitive activities and how teachers can offer this support.

5.1.2 Teacher monitoring and intervention during CSCL

Digital learning environments designed for collaborative learning generally integrate tools for carrying out the task as well as for communication between group members. Together, these tools facilitate students' cognitive, social and regulative activities because they support the sharing of resources and provide an opportunity for communication within the group (Erkens, Jaspers, Prangsma, & Kanselaar, 2005). Providing these tools, however, does not guarantee that students will adequately finish their task nor that they will have a high quality of discussions (Kirschner & Erkens, 2013; Pargman, 2003; Rummel & Spada, 2005). Collaborating groups may encounter problems both concerning cognitive activities (such as a misunderstanding of the task material) as well as problems concerning collaboration (such as conflict or free riding) or the regulation thereof. If these problems are not addressed and resolved in time, the collaborative process is hindered. So, even though during CSCL there is loose teacher regulation, the teacher maintains an important role. One of the teacher's tasks is to monitor the occurrence of problems and to help to resolve them. When problems arise or students do not make enough progress, teachers can offer their assistance.

While many studies in the field of CSCL have focused on group collaboration, recently the importance of the teacher has been emphasized. Many researchers have tried to analyze the types of teaching activities and their effects on learning outcomes or the quality of group products during CSCL (for example Hsieh & Tsai, 2012 and Onrubia & Engel, 2012, see Van Leeuwen, Janssen, Erkens, & Brekelmans, 2013, for an overview). For example, Asterhan, Schwarz and Gil (2012) found that teachers focusing on different types of learning activities led to different outcomes, with a focus on cognitive activities leading to improved quality of arguments in group discussions, and a focus on social activities leading to improved collaboration. The effectiveness of teaching is largely determined by the adaptivity (content and timing) of teacher interventions. Each group of students has different needs, which the teacher should adapt (Coll, Rosera, & de Gispert, 2014; Van Leeuwen et al., 2013). For example, dependent on the specific situation, a prompt may be more effective than a direct instruction. Furthermore, if the intervention does not follow within the timeframe of the event that the teacher is giving feedback on, the group of students is likely to have moved on to another activity, which makes the intervention less relevant and less likely to have the intended effect (Gibbs & Simpson, 2004). Thus, as a result of correctly timed and correctly chosen interventions, teacher regulation of CSCL can effectively help collaborating groups. Even low amounts of teacher regulation can have this positive effect (Lin, Jadallah, Anderson, Baker et al., in press).

To provide adaptive support, teachers have to continuously be aware of students' activities in order to identify relevant events, including those that require intervention. The teacher has to maintain an overview of events, a characteristic that in subsequent sections will be called a diagnosis of the current situation. In a previous study, we analyzed the importance and methods strategies of diagnosing students' social activities (Van Leeuwen et al., 2014). In the present study, diagnosis and support of students' cognitive activities is examined. In the next section, the context and task description of the current study is provided, which leads to a characterization of the types of cognitive activities students engage in and the way teachers may diagnose and support these activities.

5.1.3 Setting of the present study: students' cognitive activities

The present article is situated in the context of a collaborative writing task. Groups of students in secondary education synchronously communicate with each other through a Chat-tool and share a text editor to write an essay based on historical sources, which are all provided within the learning environment. The cognitive activities involved in this task include evaluating and discussing the task material, writing the essay and reading historical sources. At the level of regulative activities, the groups have to agree on a strategy for completing the task and to monitor their progress. As stated before, students largely self-regulate their activities, but it is known that problems may occur that could negatively influence students' learning gains or the quality of the group product. Two of those problems are described in this section.

The first problem concerns discussion of task material within groups. Researchers generally distinguish between on-task and off-task communication within group discussions (see De Wever, Schellens, Valcke, & Van Keer, 2006, for a review). Within the on-task communication, a further distinction can be made between discussing the content of the task (for example by asking, explaining, evaluating task materials) and regulative activities, discussing strategies for completing the task (Strijbos, Martens, Prins, & Jochems, 2006).

While both are important, discussing the content of the task is most clearly related to knowledge acquisition (Weinberger & Fischer, 2006; Cohen, 1994; see also Carroll's Time-On-Task hypothesis, Carroll, 1963, quoted in Baker, Corbett, Koedinger, & Wagner, 2004). When students discuss the content it means they are externalizing their knowledge, which may uncover differences in interpretations in group members, thereby stimulating discussion and deep processing of the central concepts (Fischer, Bruhn, Gräsel, & Mandl, 2002). Because of the informal character of synchronous chat communication, students may stray off-task during discussions, which could lead to decreased learning gains. When groups do stay on-task, there is another potential difficulty, namely that not all important aspects or concepts related to the task are examined by the group. That is, discussions may be superficial or one-sided when the topic of the discussion lingers on only a limited set of the concepts that are relevant to the task. The breadth of a discussion was defined by Baker, Andriessen, Lund, Van Amelsvoort and Quignard (2007) as the amount of topics mentioned. Less breadth of discussion could also mean less depth, because the students did not take into account all possible explanations or viewpoints and did not connect these views to each other (Baker et al., 2007). The difficulty of keeping track of the covered concepts within a discussion is further increased because of the pace of chat conversations. Groups may not be able to oversee the thread of their discussion, which may cause them to overlook important concepts that are relevant to the task (Fischer et al., 2002). So, the content of group discussions, in terms of on- and off-task behavior and the concept coverage (breadth) of the discussion, is one cognitive aspect that teachers can help students to regulate.

The second problem is concerned with how students alternate between cognitive activities. While solving the task, students continuously alternate between writing and discussing (Rummel & Spada, 2005), and engage in activities such as sketching, composing and reviewing the written text. Because of the collaborative setting, group members have to explicate their ideas for writing the text and decide and agree with each other on how to proceed (Pargman, 2003). Students may get stuck in the discussion about writing strategies, which not only decreases the time spent on discussing the actual task content (Pargman, 2003), but also hinders task progress in terms of lowered concrete output on the writing task. Furthermore, when discussion of the task materials occurs, it is important that the lines of thought that are created during the discussion are transferred to the written product. The groups of students may choose different strategies for writing, such as parallel exploration of the material followed by integration of ideas, or continuous joint construction of text (Onrubia & Engel, 2009). For all strategies, it is important that time is managed in an adequate way. Groups may thus need help to monitor their progress while they engage in the multiple cognitive activities involved with collaborative writing.

5.1.4 Supporting the teacher with visualizations

As described above, it is important that teachers continuously diagnose the collaborating groups' activities. From the previous description of the cognitive activities, it becomes apparent that diagnosing those activities is not an easy task. There are multiple groups to monitor and to work on the group assignment, each of them engages in multiple activities in multiple tools. The pace of the groups' discussions can be fast. Like regular classrooms, the simultaneity of the situation (Doyle, 2006) means that there is a large amount of information to tend to. This may lead teachers to experience high cognitive load, i.e., diagnosing groups of students demands a large amount of cognitive capacity (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). When cognitive load is too high, this may cause teachers to fall back on automated courses of action, which means accurate and up-to-date diagnosing of student performance does not occur (Feldon, 2007). A possible consequence is that teachers use their existing knowledge about students to decide on an intervention instead of using information about the current situation (Feldon, 2007; Schwarz & Asterhan, 2011). This could mean that the intervention is not optimally aligned with students' needs. It is therefore expected that an increase in cognitive load could lead to less adaptation to students' needs.

To lower cognitive load, teachers may be supported by the addition of learning analytics tools. At the intersection of technical analysis of data and the learning sciences, learning analytics (LA) is defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Siemens & Gasevic, 2012). In the present case, this means that teaching may be supported by analyzing student activities and reporting these analyses back to the teacher. When student activities are summarized and visualized in an easily understandable way, this could lower the time and effort needed by teachers to monitor all groups of students' activities. Aggregating information to a manageable level is one of the most basic functions learning analytics can fulfill (Duval, 2011). Besides informing teachers, LA may also suggest interventions or even perform interventions for the teacher. The present study examines the effect of two LA tools that give information about students' cognitive activities. Two LA tools were added to the existing learning environment called VCRI (which is explained in more detail in the Method Section).

5.1.5 Learning analytics used in this study

The first tool, called the Concept Trail (CT), is a timeline that displays the topics that groups are discussing in the Chat window. The CT marks the occurrence of a predefined set of task-related concepts and their synonyms by putting dots on the timeline. The development of the topics in the group discussion therefore becomes visible at a glance. As the group discussion progresses, older Chat messages will move upwards out of sight, but the CT still displays the entire history. The CT is integrated into the existing Chat windows, so that the development of the discussion becomes visible each time the teacher looks at a group's discussion.

Figure 5.1 shows a screenshots of a Chat window with the integrated CT on top. On the left side of the CT, five concepts are displayed. The dots on the timeline indicate that the concept is mentioned in the Chat conversation. Furthermore, in the conversation itself the concepts are highlighted in yellow, so that it is immediately visible in what part of the message the concept was used.

The CT gives information about cognitive activities in two ways. First of all, it can inform the teacher whether a group is on-task or not. As was described earlier, the more students are on-task, the more likely they are to acquire knowledge and to engage in meaningful discussion. Secondly, the teacher can monitor not only how often concepts are mentioned, but also the concept coverage of the discussion. For example, it might be the case that the group only covers one or two important aspects of the task, and that there are no dots on the timeline for the other concepts. The teacher can then steer the discussion and give suggestions to deepen the discussion by mentioning specific concepts. The resulting increased specificity of interventions is desirable because it helps learners to understand how well they are performing and what still needs to be accomplished (Voerman, Meijer, Korthagen, & Simons, 2012).

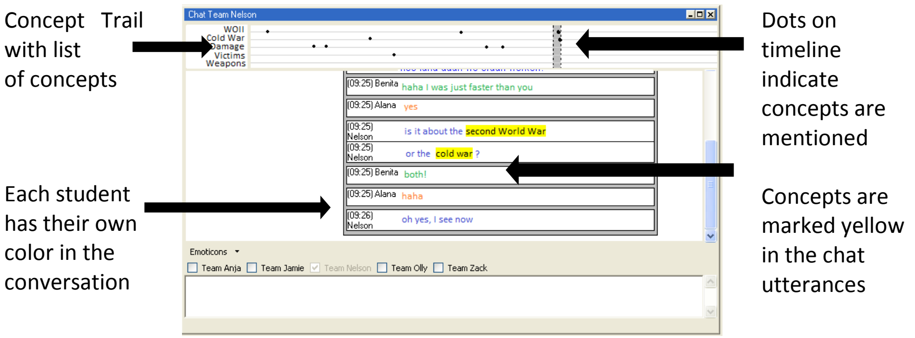


Figure 5.1. *Screenshot of the Chat-tool with integrated Concept Trail (translated from Dutch).*

The second LA tool is the availability of Progress Statistics (PS), which informs teachers of the progress of each group in terms of the number of written words in the text editor and the Chat-tool. Figure 5.2 displays a screenshot of the PS of the written texts. The five bars represent the progress of the five groups concerning the number of words they have written in the text editor. The horizontal line indicates the class average. The same type of PS are available for the number of words posted in the chat conversation, which can be selected from the menu on the left.

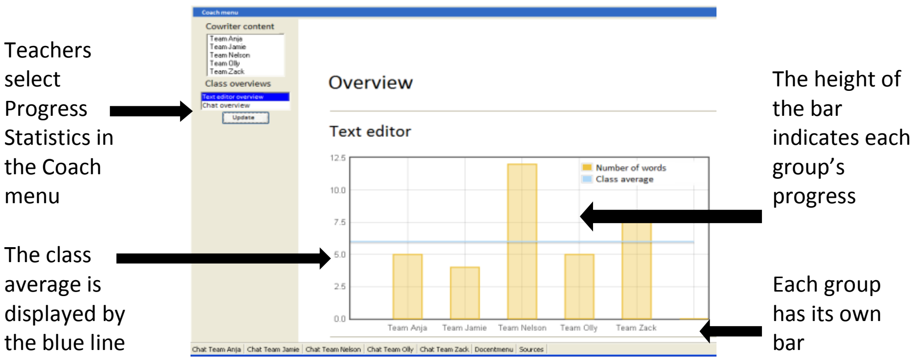


Figure 5.2. *Screenshot of the Progress Statistics tool (translated from Dutch).*

The PS give teachers an indication of the amount of activity in the groups' tool. The class average enables teachers to see at a glance whether there are any groups that show deviating amounts of activity, i.e., groups that are behind as well as those that have more written text or more chat utterances than the others. Also, teachers may compare the activity in the chat with the activity in the text editor for each group, thereby monitoring whether groups balance their activities between writing and discussing.

It is important to note two things about the LA tools. First of all, the tools on their own do not give a complete picture of all groups' activities. The quality of the written texts, for example, does not necessarily correlate with the amount of words written. Neither does mentioning a concept mean that a student understands its content. Together, however, the tools give an aggregated overview of the situation. Although the tools are based on relatively simple measures, the information shown can be an indication for the teacher whether more time needs to be spent on a particular group. This brings us to the second point. The supporting tools do what their name suggests: support the teacher, but not replace or decide for the teacher. Whether intervention is necessary remains to the teacher to decide.

5.1.6 Research questions

The following research questions were formulated: What is the effect of LA tools that show information on concept coverage in discussions and task progress of collaborating groups on:

1) Teachers' diagnosis of concept coverage within discussions and the task progress of collaborating groups?
2) The frequency, focus and specificity of teacher interventions?
3) Teachers' experienced cognitive load?

5.2 Method

5.2.1 Design

An experimental study with a between and within subjects design was conducted to test the effects of the Concept Trail and the Progress Statistics. Participants were randomly assigned to the control (no LA tools) or the experimental (LA tools) condition. In both conditions teachers went through vignettes of three collaborative situations. The independent variable is therefore the absence or presence of LA tools. The dependent variables are the teachers' diagnosis, interventions and cognitive load during and after each of the vignettes, which constitute three repeated measures.

5.2.2 Participants

Forty educational sciences students participated in this study as a part of the university course they were enrolled in concerning the subject of ICT use in education. These students have background knowledge about education and affinity with educational practice. Participants were randomly divided over the control and experimental condition, resulting in 20 participants in each condition (3 males and 17 females each), with a mean age of 21.1 years (*SD* = 3.9) and 19.9 years (*SD* = 1.4) respectively.

5.2.3 Simulation software and LA tools

To combine an experimental setup with the use of authentic classroom situations, simulation software was created based on an existing CSCL environment called VCRI (Virtual Collaborative Research Institute, see for example Van Leeuwen et al., 2013). The simulation software is able to read student data from previous research and to display it as if students are collaborating real-time. This way, all participants in the current study could be shown the same authentic collaborative situations. At the same time, an experimental set-up was realized by creating two versions of the simulation software: the control version, which was essentially the same as VCRI, and the experimental version, which was enhanced with LA tools. The same set-up was used in an earlier study (Van Leeuwen et al., 2014).

In VCRI, students work on collaborative assignments. They communicate through a Chat-tool and work on the assignment in a shared text editor, the Cowriter. In the control condition of the simulation software, participants were able to follow all students' activities. They could open Chat windows and read the task materials that were available to students (Sources). Through the Coach menu, participants could check the texts that are being written in the Cowriter. Besides these ways to diagnose, participants could intervene by sending messages in the Chat windows. Multiple windows can be opened simultaneously, allowing the teacher to monitor multiple groups and multiple tools at the same time. The control condition was thus similar to the way VCRI is normally used by teachers in actual classrooms.

In the experimental condition, the software from the control condition was enhanced to include the CT and PS (described in the theoretical introduction). Thus, whereas the control condition also had access to students' Chat-tools and their written essays, the participants in the experimental condition had additional access to the CT and the PS.

5.2.4 Vignettes

Each teacher went through vignettes of three collaborative situations. Because in our earlier study (see Chapter 4) relatively small effects of time were found, and the present study involved three instead of four vignettes, the vignettes were presented in a fixed order. Each vignette contained five collaborating groups and lasted for 8 minutes, during which student activities occurred. The situations were selected from existing data from previous research, which were collected in high school classes using VCRI to work on an assignment. The students worked on an assignment concerning the Second World War and the Cold War at the level of secondary education, of which it was expected that all teachers had at least basic knowledge. By replaying students' activities in the simulation software, participants were able to act as the teacher as if the situation was happening real-time. Chat messages appeared, the texts in the Cowriter changed, and in case of the experimental condition the LA tools were constantly updated to reflect the current situation. All names were changed to preserve anonymity of students. Small changes were made in the students' Chat messages, for example when students referred to the teacher.

Three vignettes were selected to reflect the cognitive aspects that the LA tools are aimed at: concept coverage within the discussions and task progress. The first vignette contained a group that had low task progress. The second vignette contained one group that had very high task progress because they copied text from the sources, and one group that had low concept coverage in their discussion. The third vignette contained a group with low concept coverage in their discussion. Table 5.1 summarizes the problems that occurred in the vignettes. Thus, each vignette contained one or two problematic groups and three or four neutral groups.

Table 5.1. Problem descriptions of the four vignettes, in order of appearance.

Vignette	Characterization	Problem description
(1)	Low task progress	One group of students is far behind the others concerning progress on the task. The concept coverage in the discussion is high, but they do not transfer their thoughts to the text editor.
(2)	Group 1: High task progress	One group of students has a lot more written text than the others, because they have simply copied and pasted information from the task materials.
	Group 2: Low concept coverage	The concept coverage of the discussion of one of the groups is low, caused by disagreements among the group members.
(3)	Low concept coverage	The concept coverage of the discussion of one of the groups is low; this group has a lot of off-task activity.

5.2.5 Procedure

During the experiment, participants could ask the researcher questions if they were unsure about how to use the software. In total, the task took participants one hour. Participants went through the following steps:

1. Participants were handed a 1-page summary of the Cold War to serve as background information to the task that the students in the vignettes worked on. After the participant had read this page, they preceded to step 2. The summary was available throughout the experiment.
2. An introductory movie was shown in which an explanation was given of the procedure of the experiment and of how to use the software. The participant then logged on to the simulation software. The program went through several steps.
3. A test vignette was played in which teachers could practice opening windows and typing messages and thus get used to the software. This test vignette lasted 2 minutes.
4. The three experimental vignettes were offered one by one (see Table 5.1). Each vignette was preceded by a brief explanation of the situation the vignette was taken from, i.e., what subject the class was working on and how many lessons they had worked on the topic. Then the vignette played, lasting 8 minutes, during which the teacher was free to type messages to the students and to check their progress. Participants were explicitly asked in the introductory movie to act as they would in a real educational setting, even though in this case the students could not respond to the participants' messages. At the end of each vignette, a screen opened with questions about the participant's experienced cognitive load and about their diagnosis of task progress and discussion within the groups.

5.2.6 Instruments

The participants' actions were automatically logged during and after each vignette. This resulted in the following types of data. First of all, it was logged what tools the teacher used and how often, for example opening a group's Chat window or selecting information in the Coach menu (diagnosis). Also, all messages sent by the participants to one of the groups were automatically collected (interventions). After each vignette, participants gave scores to each of the groups and had the option to give an explanation of the given scores (overall diagnosis). Furthermore, after each vignette participants were asked to give a score to their experienced cognitive load.

5.2.6.1 Diagnosis during vignettes

During the vignettes, the following actions were logged: for the Chat-tool, whether teachers opened a group's Chat screen and whether they scrolled through the Chat history; for the Coach menu, whether teachers opened this menu and which information they selected for which group; and for the Sources-tool, whether teachers opened this tool and opened sources in order to read them.

5.2.6.2 Interventions

During each vignette, participants were able to intervene by sending messages in a group's Chat-tool. We were interested in the effect of the learning analytics on the teachers' attention to the cognitive aspects shown by the tools and what kind of messages they would send to the groups. In other words, we wanted to know what learning activity the interventions were aimed at (focus) and what type of regulation (means) teachers chose (Van Leeuwen et al., 2013).

To analyze the *focus* of interventions we included four categories for the two main cognitive activities students perform to work on the group assignment, namely discussing and writing. To be able to analyze the prevalence of a focus on cognitive aspects, we added categories for interventions concerning students' social activities and general task strategy (see Table 5.2).

To analyze the *means* of interventions we included categories to reflect the degree of teacher regulation as well as how teachers evaluated the activities of students. For example, an "instruction" signifies stronger regulation than a "suggestion", and "negative or positive evaluations" are more outspoken judgments than neutral interventions such as "explanations" or "suggestions".

Besides the focus and means, interventions were also coded for *specificity*. It was hypothesized that the availability of the CT would help teachers to give more specific feedback. Therefore, interventions were coded whether or not they contained specific mention of task-related concepts.

Table 5.2 displays the full list of categories that were used for focus, means and specificity. Two researchers independently coded a sample of 100 interventions, resulting in Cohen's Kappa of .77 (focus), .81 (means) and .95 (specificity). These interrator reliabilities were interpreted as good and the remaining interventions were coded by one of the researchers.

Table 5.2. Coding scheme for interventions, consisting of focus, means and specificity.

Aspect	Category	Explanation
Focus / Learning activity	Discussion on/off task	Comments about students being on-task or off-task
	Discussion content	Comments about the content of the discussion, for example its correctness and concept coverage
	Text quality	Comments about the quality of the written texts, for example use of arguments or use of sources
	Text appearance	Comments about the appearance of the written text, for example the lay-out, amount of text and use of headers
	Strategy	Comments about general task strategy
	Social activities	Comments about students' social activities, for example group participation and occurrence of conflict
	Other	All remaining interventions
Means / Type of regulation	Diagnosing	Asking about a group's progress or current situation
	Positive Evaluation	A positive judgment of a student's behavior or of group products
	Suggestion	Giving suggestions for the discussion or for writing the text
	Explanation	Answering questions or giving explanations
	Instruction	Giving direct instructions, which usually contain a judgment
	Negative Evaluation	A negative judgment of a student's behavior or of group products
	Other	All remaining interventions
Specificity	Concepts	Mentioning concrete concepts from the discussion or the written text. Also includes quoting chat messages
	Other	All remaining interventions

5.2.6.3 Overall diagnosis

Overall diagnosis was measured in two ways. First of all, after each vignette participants were asked to give a score to each group for the concept coverage in the group's discussion and for the group's task progress on a scale from 1 to 10 (where 1 = very poor and 10 = excellent). Participants could also indicate they had not been able to make a proper judgment and refrain from giving a score. In total, each vignette resulted in ten scores, two for each of the five groups.

Table 5.3. Coding scheme for the source and specificity of comments of overall diagnosis scores.

Aspect	Category	Explanation
Source	Progress Statistics	Explicitly mentioning the Progress Statistics Tool or mentioning information that is only derivable from the Progress Statistics, for example the class average
	Concept Trail	Explicitly mentioning the Concept Trail
	Other	All remaining comments
Specificity	Concepts	Mentioning concrete concepts from the discussion or the written text. Also includes quoting chat messages
	Comparison	Making a comparison between several groups, for example by comparing to the class average
	Development	Comments that make a reference to development within a group, which demonstrate that the participant diagnosed multiple times, or comments about sequences of actions
	Other	All remaining comments

As a second measure of overall diagnosis participants could write a comment to explain their given score. These comments were collected and coded. Three aspects were of interest to answer our research question. First of all, the focus of the comments was coded, which indicates what aspect of students' activities was mentioned to explain a given score. To code the focus of the comments, the coding scheme for the focus of interventions was used, see Table 5.2. Besides the focus, it was coded what source of information participants used to come up with their score, i.e., which tool participants reported as the source of their judgment. Lastly, the specificity of the judgment was coded, as a measure of how elaborate the explanation of the diagnosis was. Besides mentioning specific concepts (see Table 5.2), specificity could also mean that groups were compared or that teachers made a reference to the development within a group. Table 5.3 displays the categories that were used. A sample of 100 comments was independently coded by two researchers, resulting in Cohen's Kappa of .84 (focus), .87 (source) and .79 (specificity). These interrater reliabilities were interpreted as good and the remaining comments were coded by one researcher.

5.2.6.4 Cognitive Load

To measure cognitive load, participants were asked after each vignette to indicate the amount of effort it took them to complete the task. Following Paas et al. (2003), mental effort is defined as "the aspect of cognitive load that refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task; thus, it can be considered to reflect the actual cognitive load" (p. 64). Using the 9-point symmetrical category mental effort rating scale (Paas et al., 2003), participants were asked to indicate the amount of effort it took them to complete the task on a scale from 1 to 9, where 1 indicates very low effort and 9 means very high effort. The following question was asked: 'How much effort did it take to maintain an overview of the collaborating groups?'. For each participant, three measurements of cognitive load were obtained.

5.3 Results

First, information is given about the usage of the LA tools (the Concept Trail (CT) and the Progress Statistics (PS)). Then, each research question is answered. When there is no specific mention of the significance level, α is set at .05. Because of the relatively small sample size, it is also indicated when effects are significant at the 10% level.

5.3.1 Use of LA tools

Table 5.4 shows the average number of actions per participant per tool per vignette. The CT was integrated in each of the groups' Chat windows. Participants in the experimental condition did not open or focus on the Chat windows more often than participants in the control condition ($t(38) = -.64$, $p = .53$). Participants could use the scroll bar to view the Chat history. Although the average amount of scrolling is twice as high in the control condition, this difference is not significant ($t(38) = 1.32$, $p = .15$).

Participants could use the Coach menu to select the content of the groups' text editors and, in the experimental condition, the PS. The number of times the content of the cowriter was selected was comparable in the two conditions ($t(38) = .71$, $p =.48$). Within the experimental condition, participants selected one of the available statistics on average 8.1 times per vignette ($SD = 4.5$). The Statistics of the Chat ($M = 1.9$, $SD = 1.6$) were consulted significantly less often than the Statistics of the Cowriter; $t(19) = -5.61$, $p = .00$.

Table 5.4. Average number of actions per participant per tool per vignette.

Tool	Selection/Action	Control (*SD*)	Experimental (*SD*)
Chat-tool	Opening Chat	25.0 (14.0)	27.5 (9.8)
	Scrolling in Chat	10.3 (13.6)	5.4 (5.3)
Coach menu	Content of Cowriter	9.7 (4.5)	8.7 (4.2)
	Statistics Cowriter	-	6.2 (3.7)
	Statistics Chat	-	1.9 (1.6)

5.3.2 Research question 1: diagnosis of concept coverage in the discussion and task progress

5.3.2.1 Overall diagnosis scores

At the end of each vignette, participants gave a score to each group for the concept coverage in the group's discussion and for the group's task progress. Each vignette contained one or more groups that showed deviating behavior concerning one of these aspects. Thus, we expected that the problematic group would receive a lower score than the other groups concerning the deviating aspect. We used a relative standard instead of an absolute standard for comparing the scores to take into account that different teachers might have different ideas of what constitutes a sufficient or an insufficient grade. In vignette 2 and 3, the problematic groups scored significantly lower than the non-problematic groups on both aspects in both conditions, so both on the deviating aspect as well as the non-problematic aspect. In vignette 1, only the problematic aspect (task progress) scored significantly lower in both conditions. It thus seems that participants in both conditions singled out the problematic groups and in most cases, judged these groups lower on task progress as well as on concept coverage in the discussion.

To see whether *individual* participants singled out the problematic group or not, a variable at participant level was created that indicates whether the problematic group received the lowest score from a particular participant in a particular vignette. Because there were four problematic groups, the maximum number of groups that could be detected was 4. On average, 1.9 groups (*SD* = 1.0) were detected in the control condition, compared to 2.1 in the experimental condition (*SD* = 1.0). This difference was not significant ($t(38) = -.62$, $p = .54$). Along with each given score, participants could give a comment. These comments were coded for focus, specificity and source.

5.3.2.2 Focus of diagnosis comments

Table 5.5 displays the distribution of focus of comments accompanying the diagnosis scores, separated for the scores for concept coverage in the discussion (left) and task progress (right). Participants who did not give any comments were excluded from this analysis. Concerning the discussion, all participants focused largely on whether or not students were on topic (*Discussion on/off task*). In the control condition, there is on average relatively less focus on the content of the discussion (*Discussion content*) than in the experimental condition (10.9% compared to 19.2%), although this difference is not significant ($t(27) = -1.14$, $p = .26$). Furthermore, in the control condition there is significantly more focus on social activities when judging the discussion than in the experimental condition (30.1% compared to 12.3%); $t(27) = 2.08$, $p = .047$).

In both conditions, task progress was judged relatively often both by considering the quality (*Text quality*) as well as the appearance (*Text appearance*) of the groups' written texts.

5.3.2.3 Specificity and Source of diagnosis comments

Comments were also coded for their specificity. In the control condition, of 220 comments, 0.9% contained comparisons between groups, 6.4% contained mention of specific task-related concepts. A further 8.6% contained references to developments within groups, which mean participant showed that they had diagnosed the situation in a group multiple times during a vignette. For example, one participant indicated that in vignette 1, for one of the groups "the discussion was on topic, although at the end the conversation was about something else". In the experimental condition, out of 259 comments, 7.3% contained comparisons between groups, 1.2% contained mention of specific task-related concepts and 7.3% contained references to developments within groups.

Table 5.5. Focus of diagnosis comments about Task progress and Discussion.

	Concept coverage in discussion				Task progress			
	Control condition (N = 14)		Experiment al condition (N = 15)		Control condition (N = 12)		Experiment al condition (N = 14)	
Focus	*M* (%)	*SD* (%)	*M* (%)	*SD* (%)	*M* (%)	*SD* (%)	*M* (%)	*SD* (%)
Discussion content	10.9	13.7	19.2	23.0	1.2	2.6	0.0	0.0
Discussion on/off task	49.9	31.8	54.3	24.9	1.8	4.5	4.0	8.3
Text quality	0.7	2.3	0.8	2.2	30.6	30.6	33.4	22.8
Text appearance	0.0	0.0	0.5	1.9	46.8	29.7	45.1	30.6
Strategy	5.3	11.5	8.2	11.6	8.0	11.9	4.9	11.8
Social activities	30.1	28.7	12.3	13.7	8.4	19.6	6.0	8.7
Other	3.1	8.8	4.7	9.7	3.1	5.5	6.5	12.4

In the experimental condition, it was investigated whether the two LA tools were mentioned as the source for the participant's comment. The CT was mentioned in 1.6% of the comments, compared to 11.2% for the PS. For example, the CT was mentioned in vignette 3 in a comment about one of the groups: "They had a good, on topic discussion. That was also clear from the number of times they mentioned the concepts". An example of a comment including the PS was "This group was ahead of group 2, but their progress was less than class average". Because the PS show a class overview, it was in line with expectations that out of 29 comments that included the PS, 9 of those included comparisons between groups. In contrast to our expectation, there were no comments that included both mention of the CT and mention of task-related concepts.

5.3.3 Research question 2: Frequency, focus and specificity of interventions

5.3.3.1 Frequency of interventions

The total amount of interventions after segmentation is 523, of which 200 in the control condition and 323 in the experimental condition. Table 5.6 shows the mean number of interventions for each vignette. The mean frequency of interventions is significantly higher in the experimental condition ($t(38) = -2.07$, $p = .045$).

Table 5.6. Mean number of interventions per participant in each vignette.

	Mean number of interventions (*SD*)	
Vignette	Control condition	Experimental condition
1	2.6 (2.1)	4.5 (3.4)
2	3.6 (3.2)	5.8 (3.9)
3	4.3 (4.6)	5.9 (4.3)
Overall	3.3 (2.6)	5.4 (3.6)

In the control condition, the mean number of interventions sent to the problematic group does not significantly differ from the mean number of interventions sent to non-problematic groups ($t(16) = 1.05$, $p = .310$). In the experimental condition, the problematic groups do on average receive more interventions than the non-problematic groups overall ($t(19) = 5.04$, $p = .00$). Comparing between conditions, the overall percentage of interventions aimed at the problematic group does not significantly differ.

5.3.3.2 Focus and specificity of interventions

Table 5.7 displays the distribution of focus of the interventions in both conditions. As can be seen, the percentages for the categories *Discussion content*, *Strategy* and *Text quality* are quite similar. The largest differences between the two conditions can be found for *Discussion content* and *Text appearance* (which are significant at the 10% level). Participants in the experimental condition seemed to have focused more on the concept coverage of the groups' discussions than those in the control condition (16.0% compared to 5.4%). In the control condition, there was relatively more focus on the appearance of the text that the groups worked on (18.8% compared to 9.4%). None of the other mean percentages were significantly different.

Besides the focus on cognitive activities, there is a relatively high focus on social activities in both conditions (24.3% control condition, 20.4% experimental condition). These interventions can roughly be split into general compliments (41.1% and 38.6%), comments about collaborative processes such as division of tasks (43.5% and 47.1%) and motivating statements or offering of help (15.2% and 14.3%).

Table 5.7. Distribution of focus of interventions in the two conditions.

	Control (N = 18)		Experimental (N = 19)		
Focus	M (%)	SD (%)	M (%)	SD (%)	*p*
Discussion content	5.4	9.6	16.0	22.1	.070
Discussion on/off task	9.4	14.4	12.5	11.1	.233
Text quality	25.9	25.3	20.1	14.9	.641
Text appearance	18.8	26.2	9.4	9.2	.075
Strategy	13.8	15.8	19.6	12.5	.126
Social activities	24.3	26.2	20.4	1.4	.988
Other	2.4	4.4	2.1	2.2	.964

When comparing the subset of interventions concerning the quality of students' work (concept coverage in discussions and text quality, i.e., *Discussion content* and *Text quality*), it was found that in both conditions about one third of the interventions contains specific mention of concepts relating to the task. There is thus no significant difference in the average specificity of the interventions between the two conditions ($t(38)=.034$, $p = .97$).

5.3.3.3 Interventions aimed at the problematic issue

For each problematic group, there were specific elements in the students' activities that could be noticed by the participants. It was coded whether participants indeed noticed and remarked upon these elements. For each intervention in a problematic group, it was coded whether it remarked upon the problematic issue of the group in terms of the combination of focus and means that the teacher employed. Whether an intervention was aimed at the problem at hand depends on the specific vignette and the specific group. For example, in vignette 1 there was a group that was behind concerning task progress, but in which the concept coverage in the discussion was very high. Thus, interventions to this group that were concerned with the problematic issue would include *instructions* or *suggestions* (means) concerning *Text appearance* (focus) as well as *positive evaluations* or *suggestions* (means) concerning *Discussion content* (focus).

Then, for each participant and each problematic group it was coded whether the participant did or did not remark upon the problematic issue by intervening. Because there were four problematic groups divided over three vignettes, the highest possible score was 4, and the lowest was 0. These scores were compared between the two conditions. In the control condition, the average score was 1.3 (SD = 1.2), compared to 2.0 (SD = 1.2) in the experimental condition. This difference was significant at the 10% level, ($t(38) = -1.85$, p = .072).

It was investigated whether the detection of a problematic groups would lead to an intervention concerning the problematic issue. It seems that especially in the control condition, giving the problematic group the lowest score did not mean that the participant would also intervene in the concerning group. In the control condition, when the group was detected, this co-occurred with an intervention in the concerning group in 29.7% of all cases, compared to 58.5% in the experimental condition.

5.3.4 Research question 3: Cognitive Load

On average, participants in the control condition reported a cognitive load of 6.4 (SD = 1.8) compared to 6.7 (SD = 1.4) in the experimental condition. There is no significant difference between the conditions ($t(38) = -.65$, p = .517). The average reported cognitive load for each of the separate vignettes lies between 6 and 7 in both conditions. Cognitive load did decrease with each successive vignette in the experimental condition, although this decrease between vignettes is not significant ($F(2, 38) = 1.39$, p = .260). Within the experimental condition, there was no relationship between the use of LA tools and cognitive load ($r(58) = -.13$, p = .342).

By means of logistic regression it was investigated whether cognitive load could contribute to predicting the detection of the problematic group, but this was not the case (B = -0.13 (SE = 0.16), p = .94). Furthermore, the mean cognitive load did not correlate with the mean number of detected problematic groups ($r(38) = -.012$, p = .941) nor with how often participants remarked upon the problematic issue in problematic groups ($r(38) = -.06$, p = .712).

5.4 Discussion

Teacher regulation of CSCL is not an easy task. Multiple collaborating groups perform multiple activities, which makes continuous diagnosis a task that could create high cognitive load. The present study examined whether LA tools could assist the teacher by visualizing analyses of students' cognitive activities. The main research question was what the effects are of LA tools on teachers' diagnosis, interventions and experienced cognitive load during CSCL.

5.4.1 Findings

Teachers were asked to give a diagnosis of each collaborating group for the concept coverage in the discussion and the general task progress. In each vignette, one or two groups had a problem concerning one of these two aspects. The results showed that providing teachers with LA tools had no effect on their diagnosis of the groups. Participants in both conditions singled out the problematic groups. Thus, in contrast to expectation, it does not seem like the LA tools increased the detection of problematic groups. Participants were able to give an explanation of their diagnosis scores, which were coded for their focus. No differences were found except for the category 'social activities', which meant that the participants without access to the LA tools more often focused on students' social activities when they judged students' discussions than the participants who had access to the tools did.

Concerning teacher interventions, we investigated frequency, focus and specificity. The mean frequency of interventions was significantly higher when teachers had access to the LA tools, and those interventions were relatively more often directed at problematic groups than at non-problematic groups. A further effect of the LA tools was that when participants detected a problematic group, they more often acted upon this detection with an intervention focused at the problematic issue. Overall, no differences were found for the several categories for focus of interventions, neither were there any differences in the specificity of teacher interventions.

The last measure we investigated was cognitive load, as reported by the participants at the end of each of the three vignettes. No significant differences were found between the teachers who had access to the LA tools and those who did not. On average, cognitive load was perceived between 6 and 7 on a scale from 1 to 9, which means all participants indicated the task of regulating CSCL took a moderate amount of mental effort.

5.4.2 Implications

Together, these results seem to imply that although LA tools did not improve the ability to detect relevant events, they did stimulate teachers to act. Whereas in the control condition the detection of a problem often led to no action concerning this problem, in the experimental condition teachers acted more frequently. This is an important finding, because collaborating groups can only benefit from the teacher's presence when the teacher actually provides assistance. Even a few well-chosen interventions may have beneficial effects (Lin et al., in press). Also, teachers with the LA tools relatively more often intervened in the problematic groups, which could mean they were better able to direct their attention to the groups that needed it most. As simultaneous diagnosis of multiple groups is a demanding task (Schwarz & Asterhan, 2011), this is an important finding as well.

Our main hypothesis for the mechanism underlying these findings was that the LA tools would lower cognitive load because they give an overview of students' cognitive activities that is easy to interpret. This, in turn, would lead to increased availability of mental effort. However, we found that the experienced mental effort needed to regulate the collaboration between students was not reduced by the addition of learning analytics tools. Participants in both conditions used equal amounts of mental effort. This finding can be interpreted in multiple ways. First of all, it might be the case that the tools only lower cognitive load after longer periods of time or after a more extensive training in using the tools. None of the participants had much experience with CSCL, so besides getting used to the digital learning environment, effectively using the LA tools might require time as well (for the effect of training on teaching in online settings, see De Smet, Van Keer, De Wever, & Valcke, 2010a). Another interpretation could be that the cognitive load was lowered. After all, in the experimental condition, participants intervened more. Diagnosing and intervening both cost mental effort. So although the invested mental effort was the same, the way the effort was spent may have been different. In the control condition all effort went to diagnosing, whereas in the experimental condition there was effort left to spend on interventions. The measurement of cognitive load in this study in the form of a single score based on self-reports, which is a common method to measure cognitive load (Van Gog & Paas, 2012), does not enable us to confirm one of these explanations. We could have specified two questions so that participants would indicate the effort associated with diagnosing and intervening separately, but it is questionable whether participants would be able to judge this accurately (De Jong, 2010).

If lowered cognitive load did not account for the effects of the LA tools on the frequency of interventions, two other hypotheses can be offered. First of all, it might be the case that teachers with the learning analytics tools felt more confident about their diagnosis. After all, they had more 'evidence' to support their thoughts and more specific information to act on. However, the specificity of the interventions itself did not increase. Teachers could for example have used the concepts from the Concept Trail to provide students with more detailed feedback, which increases the intervention's effectiveness (Voerman et al., 2012).

Another explanation could be that besides summarizing students' cognitive activities, the mere presence of the LA tools steered the participants' focus more towards cognitive aspects, which led them to intervene more on the occurrence of problems concerning cognitive activities. This was evidenced by the finding that participants without the LA tools focused more on social activities in their diagnosis of the groups' discussions. It is important that teachers pay attention to both cognitive and social activities, especially in a collaborative setting (Asterhan, Schwarz, & Gil, 2011). In this study we explicitly wanted to examine the effect of tools showing visualizations of cognitive activities. Here we see the prescriptive function that learning analytics tools can serve (Duval, 2011): by choosing a particular tool as a researcher, implicitly this means there is an idea about what information is important. In class situations, tools could be offered to teachers concerning both cognitive and social activities, with the additional option for teachers to choose which tools are displayed or not, depending on the needs of the situation.

5.4.3 Limitations and directions for future research

Our study has some methodological limitations, which could be taken into account in future research. The first concerns our measurement of teachers' diagnosis. While teacher interventions during CSCL are always observable, the diagnoses preceding interventions are not, because it is a mental process that is usually not explicated. In this study, we asked teachers about their diagnosis after each vignette, so they gave an overall diagnosis, not a real-time one. This measure of 'detection' was rather crude and only consisted of two overall scores with short additional explanations. When participants scored a group low, they usually did so for both the problematic aspect as well as the non-problematic aspect. Although the vignettes were chosen so that the problematic group only showed deviating behavior on either concept coverage or task progress, in most cases the group that was judged lowest by the participants received low scores on both aspects. This might be a sign that the overall diagnosis was constructed after the vignettes instead of being a reflection of the actual, real-time diagnosis. An alternative explanation is the halo-effect, which means that a prior negative evaluation of a group of students biases the subsequent grading of the same students on a different aspect or task (Malouff, Emmerton, & Schutte, 2013). A challenge for future research is to come up with a method to also measure moment-to-moment diagnoses. A possibility would be to use stimulated interviews or thinking aloud methods (Schwarz & Asterhan, 2011). This would increase the possibility of adequately researching whether diagnoses becomes more specific with the addition of learning analytics tools.

As was said, the same critique applies to the way we measured cognitive load, because it was also measured as an overall score instead of a real-time one. One of our interpretations of the results was that teachers with access to LA tools may have felt more confident about their diagnoses. Therefore, instead of only asking about how difficult the task was, it might be more appropriate to also ask how confident teachers were about their choices. The difficulty of assessing both the cognitive load as well as the diagnosis itself in a real-time fashion is that interrupting the teacher to measure these constructs disrupts the completion of the task, which could hinder the validity of the results. For cognitive load, a solution could be to make use of physiological indicators that can unobtrusively be measured (such as stress levels) in addition to self-reports (Haapalainen, Kim, Forlizzi, & Dey, 2010).

The present experimental setup was used in a previous study (Van Leeuwen et al., 2014) to examine the effects of LA tools that show visualizations of students' social activities. Some of the expected effects that we did not currently find, were present in this previous study, for example that interventions were more specific in nature and that participants were better able to detect problems within groups when they had access to the LA tools. Of course, the vignettes and the types of problems that the groups of students experienced were different, which makes it hard to draw clear comparisons between the two studies. A result that was found in both studies was that the relative amount of interventions aimed at problematic groups was higher than those aimed at the neutral groups when the participants had access to the LA tools. This seems to indicate that at the level of moment-to-moment diagnosis and intervention, the tools do in some way help teachers to detect occurrence of problems and that they do influence teachers' choice to intervene. With additional measures described in the paragraphs above, we could study whether the tools help to make the diagnosis easier, or whether the tools have more effect after diagnosing in terms of giving teachers more confidence to act. In general, the employed experimental methodology has proven valuable because the use of vignettes makes it possible to research the effects of LA tools in a systematic way, while largely maintaining authenticity of the classroom situation. Because of the relatively small sample size of the present study, effect sizes of the found results are also relatively small. Future studies with the simulation software could be conducted with larger samples to replicate our findings.

5.4.4 Conclusion

To conclude, in the present study several effects of learning analytics tools were found on teacher regulation of CSCL. After diagnosis of problems concerning students' cognitive activities, teachers with access to learning analytics were more likely to offer assistance to the students concerning these problems. Two explanations for this finding were discussed, namely that the learning analytics steered the teachers' focus towards cognitive activities and that the tools increased the teachers' confidence of their diagnosis. Using an experimental set-up, we have therefore made first steps to uncovering the underlying mechanisms of how teachers are supported by learning analytics. In future studies hopefully these results can be expanded and applied in authentic educational settings.

Chapter 6: Discussion[5]

During computer-supported collaborative learning (CSCL), teachers have the opportunity to follow and diagnose all groups of students' activities as they are happening real-time. Furthermore, they can send messages to the whole class or specifically intervene in one or more collaborating groups as they see fit. CSCL settings therefore offer unique affordances for teacher regulation, but also makes teacher regulation a challenging task because of all the available information. The aim of this thesis is to answer the questions how teachers regulate CSCL in terms of diagnosing and intervening strategies, and what the influence of learning analytics (LA) on these strategies are.

This chapter starts with a summary of the four studies in this thesis, after which the two main research questions are answered. Then limitations of the presented studies are discussed as well as recommendations for future research. The chapter ends with a discussion of the results in a broader context, from which several implications are derived for the design and implementation of CSCL and LA.

6.1 Summary of the studies

6.1.1 Study 1: focus, means and temporality of teacher interventions

The first study (Chapter 2) explored teacher regulation of CSCL and summarized the way it has been studied by other researchers. Two aspects of teacher interventions have received considerable attention, namely the types of student activities that teachers regulate (focus) and with what type of intervention the teacher does so (means). However, these aspects have rarely been studied together. Furthermore, the aspect of time is not often taken into account in CSCL research, leading to aggregated teacher profiles. The goal of the first study was therefore to obtain a description of multiple aspects of teacher interventions during CSCL in combination with a temporal analysis. A case study of one history teacher and a 9th grade class (divided in seven groups that collaborated in a CSCL environment) in Dutch secondary education was presented detailing the interventions of the teacher over a period of 8 weeks. The focus and means of the teacher's interventions were analyzed and compared between lessons and between collaborating groups of students.

The results showed that the teacher displayed a wide range of types of interventions across time and between groups, both concerning focus as well as means of these interventions. The teacher's focus was often on cognitive and metacognitive activities, but the relative frequencies fluctuated for each lesson. The number of teacher interventions focusing on social and metasocial activities was much lower, reaching a maximum percentage within a lesson of about 15%. The means most often used were feedback, explaining and diagnosing

[5] Parts of this chapter are based on: Van Leeuwen, A. (under review). Learning analytics to support teachers during synchronous CSCL: balancing between overview and overload. Manuscript submitted for publication.

questions, again with variation between lessons. The early lessons elicited more explanations and direct instructions. After that, in the middle lessons the teacher used

more open forms of intervening such as hints and prompts to move students along with the assignment. The last stage, during which students completed the assignment, showed explanations again.

The framework of focus and means, derived from teacher regulation in face-to-face settings, was well suited to study the variation in teacher behavior in the present setting. Some of this variation in teacher interventions was to be expected, such as the peak of explanations and the focus on metacognitive activities at the start of the assignment, while others were highly group specific, such as metasocial interventions in order to end a fight between students. It was therefore found that teacher interventions could best be understood by explaining them as a reaction to the current situation, not as an expression of the teacher's style. These results concerning the variability between lessons and between groups led to the formulation of further research goals to study what strategies teachers employ when they regulate multiple collaborating groups, especially when they have more information available due to the computer-supported setting.

6.1.2 Study 2: diagnosing and intervening strategies of teachers regulating multiple collaborating groups

In study 2 (Chapter 3), teacher regulation of CSCL was further explored, this time focusing on the influence of multiple collaborating groups of students on strategies teachers employ. The previous study already showed that each group has its specific needs, which thus requires the teacher to continuously diagnose and adapt to multiple groups. As classes in secondary education are regularly composed of 25-30 students and group work is usually organized in groups of three to four students, teachers have to regulate in general five to seven groups at the same time. A multiple case study (N=2) was performed, leading to descriptions of the reported strategies and cognitions of two teachers each regulating seven groups of students. By means of teacher interviews both before, during and after the groups worked on an assignment, this study aimed to provide an initial exploration of the strategies teachers employ concerning diagnosing and intervening when regulating multiple collaborating groups in a CSCL environment.

The results showed that both teachers valued the affordance of the CSCL environment to monitor student progress real-time. Simultaneously, the teachers experienced high information load. The teachers put effort into detecting students' needs and offered support whenever they thought it was needed. Often, prior knowledge of students was used to decide on an intervention after diagnosis. The teachers' focus was mostly on students' metacognitive activities and they most often intervened at group or class level. While teachers could see all students' activity, students had no awareness of what the teacher was paying attention to at any given moment. Both teachers thought this was a challenge, because it gave them the impression that students were waiting for them to respond.

This study has given insights into the complexity associated with regulating the activities of multiple groups of students during CSCL. In particular, the nature and the type of data available about the collaborating groups offer challenges (information load, deciding when and how to intervene) as well as opportunities (monitoring group processes, ability to intervene at class and group level) for diagnosing groups' needs and for intervening.

6.1.3 Study 3: effects of learning analytics tools that focus on students' social activities

Together, studies 1 and 2 have shown how teachers regulating CSCL aim to offer adaptive support to each collaborating group, but simultaneously, how this goal can be hindered by the demands associated with diagnosing multiple groups at the same time. To lower the difficulty of keeping track of all available information, learning analytics (LA) tools could be added to CSCL environments. LA tools can take many shapes and can display different types of information.

In study 3 (Chapter 4), LA tools were investigated that visualize students' social activities. Information about student participation was given as statistics showing each group member's relative contribution. The Shared Space, integrated into the Chat-tool students use to communicate, showed the occurrence of agreement and disagreement within the group conversations. By means of an experiment, it was examined whether having access to these LA tools had an effect on teachers' way of diagnosing and intervening whilst regulating the activities of collaborating groups in a CSCL environment. Participants were asked to act as teachers and to regulate the activities of collaborating groups in interactive simulation vignettes, with either the presence (experimental condition) or absence (control condition) of LA tools. They could perform interventions and at the end of each vignette were asked to rate participation and discussion for each group.

The results showed that the teachers in the experimental condition gave significantly lower scores to the groups with a participatory problem in all four vignettes, whereas in the control condition this was only the case for two of the four vignettes. Concerning discussion problems, in the experimental condition teachers were not able to single out the groups that had a problem. In the control condition, teachers were able to do so in one of the four vignettes. Surprisingly, in the control condition the problematic group received higher scores instead of lower ones in one vignette. Additionally, the teachers with access to LA were better able to describe their diagnosis, as can be concluded by the higher level of specificity of the written comments accompanying the diagnosis scores. Furthermore, the focus of the teachers' written comments to explain their diagnoses in the experimental condition was more often on students' social activities. The mean number of interventions decreased in the experimental condition as time progressed. The interventions were relatively more often sent to problematic groups. The teachers in the experimental condition more often addressed individual students, possibly indicating diagnosis of a specific student's level of participation or role within the discussion.

To conclude, the results differed for the two types of social activities that the LA tools visualized. In general, however, it seems to be the case that LA tools help teachers to diagnose student activities and to more specifically intervene in groups experiencing problems.

6.1.4 Study 4: effects of learning analytics tools that focus on students' cognitive activities

As a follow up to the previous study, study 4 (Chapter 5) investigated the effects of two LA tools that visualize students' cognitive activities. Statistics were given about the task progress each group made. The Concept Trail, integrated in the Chat-tool students use to communicate, showed when students used a concept that was important to the task during the group discussion. An experimental setup similar to study 3 was used. Again, the effects of LA tools on teachers' diagnosis and interventions were examined. Teachers were asked to give a score to each group for the concept coverage in the discussion and the general task progress. In addition to these dependent variables, teachers were this time also asked to rate their experienced cognitive load on a scale from 1 to 9 after each vignette.

The results showed that teachers in both the experimental and the control condition were able to single out the problematic groups regarding both concept coverage and task progress. The mean frequency of interventions was significantly higher when teachers had access to LA, and those interventions were relatively more often directed at problematic groups than at non-problematic groups. A further effect of the LA was that when teachers detected a problematic group, they were more likely to act upon this detection with an intervention focused at the problematic issue than teachers in the control condition. There were no differences in the specificity of teacher interventions. Concerning cognitive load, no significant differences were found between the teachers who had access to LA and those who did not.

In this study, It was found that after diagnosis of problems concerning students' cognitive activities, teachers with access to LA were more likely to offer assistance to the students concerning these problems. No effects of LA tools were found on the ability to detect problematic groups nor on the experienced cognitive load associated with regulating CSCL.

6.2 Answers to main research questions

6.2.1 Exploration of teacher regulation of CSCL

The first main research question was: How do teachers regulate students' learning activities in multiple computer-supported collaborating groups, in terms of teachers' diagnosing and intervening strategies? In studies 1 and 2 in Part I of this thesis, the concepts *focus* and *means* were used to characterize teacher regulation of CSCL. It was investigated how teachers alternate their focus on different types of student activities, namely cognitive, metacognitive, social and metasocial activities and how teachers diagnosed those activities and regulated them by intervening using a particular means. To diagnose, teachers observed student activities or questioned students directly. Means for intervening included explaining, instructing and giving feedback.

Studies 1 and 2 illustrated how teachers diagnose student activities and how they explain the choice for a particular intervention in terms of a combination of a focus and a means. Instead of generalizing teacher behavior into a 'type' (cf. Mazzolini & Maddison, 2003), the detailed description in Part I led to a context-specific understanding of teacher regulation of CSCL. The context not only includes the activities students engage in and which the teacher responds to, but also the way the learning environment offers affordances for teachers to monitor those activities and the way teachers make sense of the information available to them. Teacher regulation of CSCL is thus an interactive process and increasingly, case studies are presented in the field of CSCL in which this interplay between teacher, student and technology is examined (e.g., Greiffenhagen, 2012; Chen, Looi, & Tan, 2010; Looi & Song, 2013; Onrubia & Engel, 2012; Schwarz & Asterhan, 2011; Song & Looi, 2012). The findings of Part I confirm and extend the existing research. We have shown how students' activities are the input for the teacher and how teachers in turn perceive their interventions to stimulate students (Song & Looi, 2012). Teachers continuously monitor and diagnose the students' activities, focusing their attention sometimes on the group level (by engaging in a conversation or observing a group's progress), and other times on the class level again to make an announcement or to see whether any group or student needs additional help (Greiffenhagen, 2012; Looi & Song, 2013). In other words, the teacher *orchestrates* the activities (Dillenbourg, Järvelä, & Fischer, 2009).

The affordances of CSCL can help the teacher during this process. There are three notable aspects concerning teacher-student interaction that are specific to the CSCL setting employed in our studies. The first is that the bigger amount of information that is available to the teacher offers opportunities for teaching strategies. Multiple groups can be observed simultaneously in order to compare their progress. When an issue is noticed that is relevant for the whole class, group announcements can be made. Simultaneously, issues that are specific to one group can be dealt with without disrupting the whole class (Schwarz & Asterhan, 2011). Also, both the teacher and students can use the logged history of the collaboration in subsequent lessons as a reminder of what each group has achieved so far (Chen et al., 2010). Thus, ideally, the CSCL setting makes it possible that the teacher is constantly aware of the activities students are engaged in, thereby ensuring that the teacher can adapt the given support towards each group both in a proactive and a reactive way (a difference employed by for example De Lievre, Depover, & Dillenbourg, 2006; Onrubia & Engel, 2012; Vlachopoulos & Cowan, 2010). Proactively, the teacher can initiate interaction with the students based on monitoring the students' activities real-time. Reactively, the teacher can use the logged history of the collaboration to adapt to the students' request for support.

The second aspect concerns the role of the teacher or the 'dynamic' between teacher and students. The image of the teacher as a figure with authority is less strong in online settings. As Park et al. (2015) note: "For a myriad of reasons, such as the absence of gestures and prosodic features that can intensify the power and influence of a teacher, or because the written medium gives saliency to participants' words, or because the floor can be accessed by more individuals at the same time when compared to oral settings, online discussions invite discourse that equalizes participation, distributing to teacher and students similar roles and functions" (p. 327). In Study 2 this was witnessed by the interactions that teachers had within each of the small groups. Because those conversations were not visible to the whole class, the teacher could interact with the students in a less formal way. Another factor that adds to this shifted dynamic is that the teacher is continuously engaged with students' activities, because the teacher can unobtrusively monitor students' activities in the background. In face-to-face situations, when the teacher walks around and stops at one of the groups, even when it is only to monitor what activities the group is engaged in, students expect the teacher to say something, for example to give an evaluation (Greiffenhagen, 2012). Because during CSCL the teacher is continuously present, there are no concentrated periods of contact (Vlachopoulos & Cowan, 2010) and there may be less pressure on the interaction between teacher and students.

The third aspect of teacher-student interaction that is caused by the technology is that the online setting means that both teacher and students can delay their response within a group conversation. That is, although the setting was synchronous (teacher and students were online at the same time), a message does not have to be answered immediately and teacher and students can both profit from 'thinking time' before responding (Vlachopoulos & Cowan, 2010). In face-to-face settings, when a student asks a question, the teacher cannot remain silent and as was noticed before, when students see that the teacher monitors their work, they expect a reaction. During CSCL teachers thus have the advantage that they can take time to monitor student activities and to consider whether or not to intervene. As Schwarz and Asterhan (2011) describe, the teacher in their study explicitly *pondered* about whether intervention was necessary and if so, what type of intervention: "We are far from the usual image of teachers overwhelmed by the complexity of classroom discussions without being able to consider and analyze the history of the discussion and its quality" (p. 434).

However, all the affordances associated with teacher regulation of CSCL mentioned above (adaptive teaching proactively and reactively, less formality in teacher-student interaction and the consideration whether or not to intervene) must be seen in light of the challenges that teachers face as well. In particular, the opportunity of being able to monitor the collaborative process in real-time also means there is a challenge to maintain an overview of all the available information. Such an overview could be called a prerequisite for the opportunities mentioned before. For example, we found that the teachers in study 2 experienced high information load and that their priority was to detect students' needs and offer support where needed, rather than the question whether it was better to let students work it out themselves before intervening. With too much information available, adaptive teaching is hindered (Schwarz & Asterhan, 2011). Mental capacity is needed in order to make informed decisions about interventions and about whether or not to intervene.

Based on the findings in Part I, several recommendations were given for supporting teacher regulation of CSCL by means of learning analytics (LA), and in Part II it was investigated whether LA tools could indeed help teachers to diagnose students' activities and to intervene adaptively.

6.2.2 Effects of learning analytics tools on teacher regulation of CSCL

The second main research question was: What are the effects of LA tools that visualize various types of students' activities on teacher regulation of CSCL, in terms of teacher diagnoses and teacher interventions? The studies in Part II of the thesis both examined the effects of LA; in study 3 LA showed information about students' social activities and in study 4 the LA showed information about students' cognitive activities. In the two studies, different effects of the LA were found. For example, in study 3, access to LA led to more frequent identification of the groups that experienced problems. In study 4, LA tools led to significantly more teacher interventions. As discussed in Chapter 1, the LA tools in studies 3 and 4 shared characteristics, such as the distinction between embedded and extracted tools and the common goal of supporting teachers. The results show that teachers were indeed supported, but in different ways. The difference in results may be explained by the differences in the types of problems that the groups of students in the two studies experienced. As appeared from these individual studies, teachers' interpretation of students' cognitive and social activities play a large role, as further discussed in Section 6.4.3 below.

A result found in both studies was that the relative amount of interventions aimed at problematic groups was higher than those aimed at the neutral groups when the teachers had access to the LA tools. This indicates that at the level of moment-to-moment diagnosis and intervention, the tools in some way helped teachers to detect occurrence of problems and, subsequently, helped or influenced the teachers' choice to intervene. By itself, this indicates that LA are a promising direction for supporting teachers during CSCL, given the complexity of this task as explored in Part I. In an attempt to explore the findings of both study 3 and 4, below three mechanisms are proposed of how LA support teachers that could account for the findings from these studies.

6.2.2.1 Aggregation of information to a manageable level

The first mechanism is that LA tools can aggregate information to a manageable level and thereby provide teachers with a quick overview of the situation. Evidence of this mechanism were that in study 3, teachers more often identified the groups that experienced problems, and that in both studies, groups with problems received more attention from the teacher. These are indications that on a general level, teachers had a better overview of the situation and thus could target their attention to the groups that needed it most. The LA tools, in line with this mechanism, act as a sort of indicator or marker, allowing teachers to at a glance discover which groups might need additional attention. The teachers in study 2 indeed used the tools this way: an uneven distribution of participation within a group led them to further investigate whether that group needed support. A recent study by Chounta and Avouris (2014) suggests that this mechanism is only beneficial to the teacher when the teacher experiences high load. If monitoring groups of students does not take up a lot of mental effort, for example when the number of groups is low, then the presence of LA tools can be perceived as a nuisance. The reason is that in this case, teachers already have an overview and the LA "mentally compelled [them] to re-evaluate the automatic evaluation results [by the LA] from their perspective" (p. 18). In other words, when there is no need for supporting LA tools, the LA only add to the workload.

We made a first attempt to examine in more detail the load teachers experience while regulating CSCL in study 2, in which teachers were interviewed about their strategies and the associated challenges, and in study 4, in which teachers were asked to rate their experienced cognitive load. It was not found that access to LA lowered cognitive load, but as discussed in study 4, this may have been due to the difficulty of assessing cognitive load in this situation. The measurement of cognitive load in study 4 took the form of a single score based on self-reports, which is a common method to measure cognitive load (Van Gog & Paas, 2012), but it did not enable us to distinguish between load associated with diagnosing and intervening. We could have specified two questions separately, but it is questionable whether participants would be able to judge this distinction accurately (De Jong, 2010). Section 6.3 further explores possibilities for future research, including measurement of diagnosing and associated cognitive load.

6.2.2.2 Steering of teacher attention

A second mechanism suggested by the data of how LA support teachers is that the presence of LA steers the teachers' attention. In both studies, the LA increased the teachers' attention for the aspect that the LA tools visualized, even when a collaborating group did not experience problems concerning this aspect. LA tools have a particular focus, which has an effect on the way the teacher perceives the students' activities. As a result, the activities visualized by the LA tools will receive more attention in general and make the teacher aware of this particular type of information. Awareness of information is indeed a commonly encountered goal of LA tools, both for supporting students (Janssen & Bodemer, 2013) as well as for supporting teachers (De Laat, Chamrada, & Wegerif, 2008).

6.2.2.3 Enhancement of teacher diagnosis

Thirdly, LA tools may play a role during teacher regulation because the information shown by the LA tools could provide additional evidence to enhance the teacher's diagnosis of the situation. In study 4, teachers in both conditions awarded the problematic groups with lower scores and thus diagnosed that these groups experienced problems, but the teachers with access to LA intervened significantly more often. Teachers continuously monitor students' activities and form impressions of the quality and the progress of those activities. Sufficient awareness of students' activities is needed to adequately adapt to the situation (Endsley, Bolte, & Jones, 2003; Schwarz & Asterhan, 2011; Van de Pol, Volman, & Boshuizen, 2010). Our findings indicate that the LA could have increased the accuracy of the teacher's diagnosis of the situation, which prompted the teachers with access to LA to react by means of an intervention. Another way in which the LA could have enhanced the diagnoses is by creating a theoretical construct to which the teacher's impressions could be related. As Sherin and Van Es (2005) explain, noticing important events involves "making connections between specific classroom interactions and principles of learning and teaching that they represent" (p. 477). For example, in study 4 teachers had access to the Concept Trail, which visualizes the concepts students use in the group conversations and thereby indicates the breadth of the discussions (see Baker, Andriessen, Lund, Van Amelsvoort & Quignard, 2007). This may have helped teachers to relate their impression of a problematic student discussion to the notion that the breadth of the discussion was lacking. Also, because especially the embedded tools (i.e., the Concept Trail and the Shared Space) provide process information about students' activities, the teacher is enabled to more specifically offer students assistance. For example, continuing the example above, the teacher can derive from the Concept Trail not only that the breadth of a discussion is small, but also which task-related concepts the students have paid less attention to. This information can be used when the teacher decides to intervene.

To summarize, LA tools can play a role during the earlier mentioned processes of proactive and reactive regulation of CSCL. When teachers proactively monitor students, LA can offer an overview of students' activities (mechanism 1), steer the teacher's focus towards particular aspects of student collaboration (mechanism 2), and when the teacher has formed an initial impression, the LA can serve as additional evidence (mechanism 3). When a teacher responds to a student question (and the focus is already determined by the student), LA can quickly update the teacher about the situation within the small group (mechanism 1), and provide additional information that may be used in choosing the appropriate intervention (mechanism 3). To conclude, it thus seems that LA tools can have an influence on teacher regulation of CSCL in various ways.

6.3 Limitations and recommendations for future research

The strengths and weaknesses of the individual studies in this thesis were already discussed in the corresponding chapters. In this section, some overarching limitations and opportunities for future research are described.

6.3.1 Supporting teachers and students

A first comment that applies to the entire thesis is that our focus has been on exploring teacher regulation of CSCL and subsequently, on supporting teachers in doing so. The underlying assumption was that supporting teachers by means of LA tools could lead to more efficient and possibly more accurate diagnoses and thus to more appropriate interventions. In turn, this could lead to improvements in the way groups of students collaborate and the quality of the task products they work on. Although we investigated whether LA tools influenced teacher diagnoses and interventions, the effect of those interventions on collaboration between students and on learning outcomes was not examined. We have assumed that adaptive teaching is beneficial for student learning, for which some evidence exists (De Kleijn, Meijer, Brekelmans, & Pilot, 2014; Kyriakides, Creemers, & Antoniou, 2009), but the relation between teacher diagnoses, teacher interventions and subsequent student behavior is complex. Teachers are not always capable to adequately respond when they diagnose a problem (Seifried & Wuttke, 2010) and if they do, interventions can lead to different results concerning how students process the teacher's intervention (Yin et al., 2008). Gabelica et al. (2014) found that after providing feedback, students need to be prompted to actively process this feedback in order for the feedback to have an effect. Thus, while we have focused on teacher diagnoses and interventions, student uptake of the teacher's support should not be automatically assumed.

A related question is why we have chosen to provide *teachers* with LA tools, and not the students, or both. A rich field of research exists concerning LA aimed at supporting students (Janssen & Bodemer, 2013), which shows that LA provided to students can have a positive influence on for example usage of task-related concepts (Fischer, Bruhn, Gra, & Mandl, 2002) and group participation (Janssen, Erkens, Kanselaar, & Jaspers, 2007). Nonetheless, LA provided to students do not always improve collaboration or learning outcomes, and collaborative problems may still occur. Support such as LA provided to students can also be combined with the presence of a teacher. Pea (2004) hypothesized about a situation in which "people and machines join together in helping someone learn something" (p. 444) and called this design a "mixed initiative". Tabak (2004) uses the term "distributed scaffolding" in a more general way to denote designs in which student support is provided in multiple ways. In this type of setting, where students are supported both by the presence of a teacher as well as by the learning environment in the form of for example LA, it could be argued that the learning environment is more suited to regulate activities such as maintaining an overview of the sub tasks that need to be completed, and the teacher is more suited to regulate activities such as the integration of task-related concepts (Ertmer & Glazewski, 2015; Saye & Brush, 2002). We therefore believe providing students with LA does not preclude the need for the presence of a teacher to regulate collaboration among students, and this thesis has been about supporting the teacher while doing so.

The choice between using LA to support students or teachers will depend on the intended goal, as students and teachers will most likely benefit from them in different ways. For example, LA tools such as the Participation Statistics help the teacher to maintain an overview of the participation rates within each of the groups. Shown to the students, such an overview creates opportunities for social comparison, which might motivate students to set higher standards for themselves (Janssen et al., 2007; Michinov & Primois, 2005). An interesting direction for future research is to investigate the results of using LA tools to support students and teachers simultaneously, compared to a situation in which only the teacher has access to these tools. In this case, there is "distributed scaffolding" (Tabak, 2004) because the LA tools partly regulate students' activities. When LA tools provide feedback to students, the pressure on teachers to regulate students' activities can be relieved. As Ertmer and Glazewski (2015) note, some "scaffolds may serve as intermediate structures that support teachers in the task of […] scaffolding by *creating time for reflection before their response is required*" (p. 100, emphasis added). This relates directly to the time for "pondering" that is needed to choose the appropriate intervention (Schwarz & Asterhan, 2011) that was discussed earlier in Section 6.2.1. For example, the statistics that show progress on the task (see Chapter 5) could inform groups of their progress and help them to regulate their activities if they notice they are falling behind. The teacher can, where needed, further support them to resolve their difficulties. Further research needs to point out the best way to support students and teachers during CSCL by means of LA.

6.3.2 Novice versus expert teachers

Another aspect related to teacher regulation of CSCL that was not examined in this thesis is teaching experience, which could play a role for various reasons. First of all, some researchers have compared regulation of collaborative learning by novice and experienced teachers in online settings. From these studies, it appeared for example that novice teachers experience more challenges and felt uncertain about their skills as regulator (De Laat, 2006; De Smet, Van Keer, De Wever, & Valcke, 2010b). Also, novice and experienced teachers differed in the importance they ascribed to the different types of student learning activities (Kopp, Matteucci, & Tomassio, 2012), and differed in the average number of interventions they perform, with novice teachers intervening less than experienced ones (Goold, Coldwell, & Craig, 2010). Chen, Looi and Chen (2009) offer a description of how teachers make use of the affordances offered by technology over time. Interestingly, once teachers had aligned their practices with the technology this did not mean that they remained in this state; in some cases they continued to struggle.

A complicating factor is that it is not evident whether experience with regulation of collaborative learning in online settings can be directly compared to such experience in face-to-face settings. In the studies mentioned above, it is not always explicated whether the experienced teachers only have experience in online settings, or in face-to-face settings as well. On the one hand, both settings have similarities such as the presence of multiple groups and teachers thus face the same challenges to a certain degree (see Section 6.4). However, from Part I of this thesis, it has become clear that as a result of the difference in the type of available data concerning students' activities, teachers' diagnosing and intervening strategies are also different in various respects. As a consequence, teaching in these two settings involves differences concerning for example the character of teacher-student interaction (Park et al., 2015; see Section 6.2.1). It is thus an interesting question whether experience in face-to-face settings is transferable to online settings, and vice versa. Little research is performed into systematically comparing online to face-to-face teaching (cf. Solimeno, Mebane, Tomai, & Francescato, 2008).

There is a large body of research in face-to-face education comparing novice to experienced teachers, which shows experienced teachers create so called schemas of classroom situations. These schemas allow them to process chunks of information with less mental effort (Feldon, 2007). Experienced teachers have learned which elements of the classroom are important to monitor, how particular student activities should be diagnosed, and how best to intervene based on these diagnoses (Colestock & Sherin, 2009; Peterson & Comeaux, 1987; Van den Bogert, van Bruggen, Kostons, & Jochems, 2014). They thus have different knowledge that influences their diagnosing and intervening strategies. The question is whether these mechanisms are the same in online settings and thus whether the most appropriate type of LA tools differs for novice and experienced teachers. One of the intended goals of the LA tools in the presented studies was to lower the mental effort needed to monitor and diagnose all student activities. More experienced teachers may have less need for these types of tools if they are already able to chunk the available information and instead may wish to have more choice in what type of data is visualized by the LA tools (see also the discussion in Section 6.4.3).

Thus, there are reasons to assume that teaching experience (in both online and face-to-face settings) influences teacher regulation of CSCL. In the experimental studies presented in this thesis, teaching experience did not account for any of the found differences between teachers with and without access to LA tools, so that the found effects of LA tools could not be ascribed to this factor. More research with larger samples is needed to study whether teachers with different amounts of experience benefit from different types of LA. This is therefore an important direction for future research.

6.3.3 Co-located setting and online communication

The communication between teacher and students in the presented classroom studies occurred synchronously and online through a Chat-tool, in a co-located setting. There were various reasons for choosing this set-up, for example that online communication offers more opportunities for students to participate that are usually more silent (Asterhan & Eisenmann, 2011), the concise style of communication that is associated with online communication (Newlands, Anderson, & Mullin, 2003), and the fact that all discussion is logged and serves as a joint workspace (Chen et al., 2010), which is especially beneficial when students work on ill-defined tasks (Tutty & Klein, 2007). For the teacher, it meant all group discussions were available for real-time monitoring. Given that the classroom studies occurred in a co-located setting (i.e., teachers and students were present in the same classroom), face-to-face communication between teachers and students would have been possible as well. In study 2, the teachers indicated they sometimes made use of this opportunity because of the directness and non-verbal aspects of face-to-face contact, which allowed them to quickly establish common ground with the whole class. This need for face-to-face contact was partly based on the finding that whereas the teacher knew what each group was doing, the groups themselves did not know the teacher's activities. Students were unable to physically see which group is receiving help at a given moment, or if for example the teacher is reading students' texts. As discussed in study 2, tools could be added to CSCL environments to solve this issue.

Currently there is much interest in blended learning, the integration of face-to-face learning experiences with online learning experiences (Garrison & Kanuka, 2004). When implemented adequately, blended learning can combine the advantages of both settings. At the moment, new technologies are being developed for use during face-to-face collaborative learning in classroom settings to support teachers to diagnose students' activities. For example, tables with interactive touch screens (Martinez-Maldonado, Clayphan, Yacef, & Kay, 2014) capture all students' activities and can provide teachers with analyses and visualizations. Another example are so called Lanterns (Alavi & Dillenbourg, 2002), which are interactive lamps that display each group's status in terms of which exercise they are working on, whether they have called for help and if so, when. There are also studies that combine online and face-to-face communication simultaneously, so that students both have a shared digital workspace and can directly speak to each other if they wish to (Chen et al., 2010; Van Diggelen, 2011). Technologies like these all aim to increase the effectivity and efficiency of teacher-student interaction. Of course, in the case of distance education, there often is no opportunity for face-to-face contact. Some studies have demonstrated that in face-to-face and online communication the same learning goals can be achieved (Barile & Durso, 2002) and also, that the teacher can realize the social presence associated with face-to-face contact in online settings dependent on the use of the technological affordances and the employed teaching strategies (Nagel & Cotzé, 2010; Wengrowicz, 2014).

6.3.4 The use of simulation vignettes as a research methodology

Lastly, some observations can be made regarding the employed methodology of the experimental studies, in which simulation vignettes were used to examine the effects of the LA tools. Besides the analysis of teacher interventions, which occurred during the vignettes, the collected data primarily consisted of measurements at the end of each vignette. Given the focus of this thesis on real-time teacher regulation of CSCL, it is a challenge for future research to find a methodology that allows for investigation of process properties of teacher regulation. For example, finding a way to map the continuous monitoring and diagnosing of student activities could shed light on which data sources teachers use exactly to diagnose, and how they decide whether or not to intervene. The difficulty is that interrupting the teacher to measure these constructs disrupts the completion of the task, which could hinder the validity of the results. Related to this is the fact that in contrast to the extracted tools (i.e., the two types of Statistics, see Table 1.1), we did not have data about how often the embedded LA tools were used. Teachers did not have to click on these tools for them to appear like they had to for the extracted ones. Again, the main reason for this choice was ease of use for the teachers. As noted in the sections above, teachers could directly make use of the embedded tools while they monitored the group discussions. Having to click a button first might have disrupted this situation and might have made using the tools more complex. For the studies reported in Chapters 4 and 5, the ideal research set-up would have been to use a 2×2 design with the presence of each tool as an independent variable so that the effect of each tool separately was investigated instead of two at the same time. A more general remark concerning the simulation vignettes relates to the fact that the independent variable in Chapters 4 and 5 was the presence or absence of LA tools. It is important to keep in mind that by comparison to other factors that could influence teacher regulation of CSCL, the addition of LA tools to the learning environment is a relatively unobtrusive intervention. This is partly because the use of the tools is often not coerced, i.e. users can usually decide for themselves whether they want to use the tool or not (Janssen & Bodemer, 2013). This means that expected effects (e.g., in terms of effect sizes, such as Cohen's *d*) of such interventions will likely be relatively small in comparison to other interventions such as intensive training of teachers (cf. Asterhan, Schwarz, & Gil, 2012; De Smet et al., 2010a). On the other hand, these elaborate interventions require considerable more time to implement.

A suggestion to widen the collected data and to resolve some of the limitations mentioned above is to make use of physiological indicators that can unobtrusively be measured in addition to self-reports. This would be a suitable approach to measures constructs such as cognitive load (by measuring stress levels, cf. Haapalainen, Kim, Forlizzi, & Dey, 2010), and possibly for diagnosing processes (by combining eye tracking with stimulated recall, Persaud & Eliot, 2014; Van Gog, Paas, Van Merriënboer, & Witte, 2005), including the usage of each of the separate tools.

In general, we believe the set-up with simulation vignettes is a promising one as it allowed for a controlled way (i.e., presenting the same pedagogical situations to all teachers) to test the effects of the LA tools while largely maintaining authenticity of the classroom situation. In contrast to what might have been expected, participants did not regard the task of regulating students' activities during the vignettes as unnatural. The participants found the set-up clear, and continued to send messages in subsequent vignettes even though students could not respond. The simulation software could be combined with other methods such as eye tracking or thinking out loud to capture and understand teaching processes in more detail (Van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009).

6.4 Implications of findings for (CS)CL research and practice

Based on the answers to the main research questions, in this section, the central themes of this thesis are discussed in a broader context. This section begins with an evaluation of the extent to which the theoretical framework and findings from this thesis can be used more generally in settings in which collaborative learning is used. Next, some aspects related to teacher regulation of CSCL are described that could be considered during the implementation of CSCL and the use and design of LA. Concerning CSCL, the importance of social activities is described. Concerning LA, the role of teacher beliefs and teachers' technical skills are discussed.

6.4.1 Diagnosing student activities

Although the research in this thesis was undertaken in a computer-supported setting, the employed theoretical framework leads to considerations for collaborative learning in a broader context. Teacher regulation of collaborative learning was conceptualized by defining teaching and learning activities (see Chapter 1). Teachers are expected to observe and diagnose students' activities and to intervene when students need assistance. By doing so, the teacher regulates various types of students' activities. This characterization of teaching and learning activities does not solely apply to CSCL, but can be used for collaborative learning in general (Kaendler, Wiedmann, Rummel, & Spada, 2014). The teacher's task during collaborative learning is the same, independent of the specific setting. In all cases, there are collaborating groups that need to be monitored (Strijbos, 2011). The specific setting has consequences for the strategies teaches can use to fulfill this task, but the goal is the same: continuously diagnose the current state of each group and provide adapted support.

Concerning diagnosing, we have discussed a number of types of activities that students engage in, both cognitive and social and have tried to support the teacher to diagnose these activities by providing teachers with LA tools. The information displayed by the LA tools are based on general markers of learning that are of importance during collaborative learning. As a result, Kaendler, Wiedmann, Rummel, Leuders and Spada (2013) argue that LA tools may indirectly also be useful in face-to-face settings, because the underlying indicators for student activities that these tools represent are also relevant during face-to-face collaboration. They explain that LA tools can be translated into a 'checklist' that teachers can go through while observing student interaction, which thereby serves as a kind of observational instrument or as rating criteria for teachers to use. For example, in case of the Concept Trail the observational checklist would include the criterion that the groups of students make use of various task-related concepts during their discussion. The teacher can keep this in mind while walking around the classroom and observing the various groups. In face-to-face settings, teachers indeed seem to struggle with regulating collaborative learning. Gillies and Boyle (2010) describe that teachers for example find it hard to deal with off-task behavior during collaborative learning and how to assess whether learning occurred within the groups.

Even when using a checklist, however, the teacher can never monitor the group during the *whole* discussion, as there are multiple groups to tend to. Because in a CSCL environment the discussion is logged, the LA tools have the unique affordance to display the entire history of the discussion concerning for example the use of task-related concepts. When these data are not available, teachers are dependent on their own (limited) observations and the reports of students about their progress. The problem with student reports is that students sometimes lack accurate self-knowledge (Pintrich, 2002). For example, when students are not aware they have misunderstood something, they will probably not ask for help. So, in some situations, the affordances offered by technology could be a reason to prefer CSCL, under the condition that teachers are adequately prepared to use the technology (see Section 6.4.3).

6.4.2 Social activities, number of groups and group size

As stressed throughout this thesis, collaborative learning (CL) is an essential part of 'CSCL' (Stahl et al., 2006). It could be said that social activities are the prerequisite for the occurrence of learning, for example because students are only encouraged to express and explain their ideas when group members engage in constructive and safe discussion in which ideas are challenged (Kreijns, Kirschner, & Vermeulen, 2013; Mercer, 2000). Despite this importance, in the four presented studies the teachers' focus was generally more on students' cognitive and metacognitive activities than on social and metasocial ones, except in Study 3, in which it is likely that the LA tools and the questions in between vignettes increased the teachers' focus on social and metasocial activities. It is known that the role of the teacher is different while regulating collaborative learning than during individual learning (Salinas, 2008). Social aspects of the collaboration require additional regulation (Kreijns, Kirschner, & Jochems, 2003), but teachers are not always aware of the importance of these processes during online discussions (De Smet, Van Keer, & Valcke, 2008), as our findings confirm.

Kopp, Matteuzzi and Tomasetto (2012) found that more experienced teachers ascribed more importance to students' social activities and intervened more often concerning these activities, which points to the role of teaching experience. Another possible explanation for the lack of attention of the teacher for social activities is that students generally do not automatically engage in these activities simply because they form a group; they need guidance for engaging in collaborative activities (Kreijns et al., 2003). If students foremost engage in metacognitive and cognitive activities, then it is not surprising that the teacher also for a large part concentrated on these activities, because the teacher's focus is partly steered by the students' activities (Kaendler et al., 2014; Vermunt & Verloop, 1999). It is then the teacher's task to stress the importance of social processes during collaboration given their importance for learning (Kreijns et al., 2014). A recommendation for the implementation of CSCL is therefore to at least make teachers aware of the importance of students' social activities. LA tools that analyze and report on social activities, such as the Participation Statistics and the Shared Space, could help teachers become aware of social activities (see Mechanism 2 in section 6.2.2.2) and help them diagnose whether groups of students experience problems regarding social activities.

As students work on tasks in small groups, a further consideration to keep in mind is the size of the class and the possible division of students among groups in terms of the number of collaborating groups and the size of each group (Blatchford, Baines, Kutnick, & Martin, 2001; Qiu, Hewitt, & Brett, 2014). As explored in Study 2, a high number of collaborating groups can lead to high information load, thereby making teacher regulation of CSCL more complex. Simply lowering the number of groups is not a solution, however, because this inevitably means the number of students per group will increase. Increasing group size, in turn, may lead to additional collaborative problems: the risk of free-riders and the formation of "islands" within the group will be more likely (Kreijns et al., 2003; Strijbos & De Laat, 2010). As a teacher, it is important to be aware of the possible consequences of number of groups and chosen group size.

6.4.3 Learning analytics, teacher beliefs and teacher training

In the presented studies concerning LA, several effects were found on teacher regulation of CSCL. It became clear that at the level of individual teachers information from the LA tools could be interpreted in different ways. For example, the Shared Space visualizes whether groups are in agreement or disagreement by coding their messages in the Chat-tool. Sometimes, a group was in constant agreement and this led to two different types of responses by the teachers. Some indicated that this was problematic, because it showed that the group lacked critical discussion, whereas others were satisfied that the group showed a positive group atmosphere. Thus, when LA tools are designed and eventually used, it is important to keep in mind that the information depicted by the LA tools is not necessarily interpreted in one particular way, because it depends upon the knowledge and beliefs of the user. It is known that teachers' pedagogical beliefs influence how they interpret classroom situations, and that these beliefs also influence what type of information teachers look for when they diagnose a situation (Clark & Peterson, 1986; Endsley et al., 2003; Song & Looi, 2012).

It can be argued that the consequences and importance of this relation between the teacher's beliefs and the way LA are interpreted depend upon the intended goal. LA tools can be placed on a continuum of how much control is left to the teacher (Jermann, Soller, & Muehlenbrock, 2005). On the one end of the continuum are tools that are solely aimed at supporting the teacher in the phase of diagnosis, and the interpretation of the information shown by the tools remains the teacher's task. In this case, it is to be expected that different teachers will come to different interpretations. Further on the other end of the continuum are LA that are used in scripted scenarios in which tools automatically give alerts or even connect intervening actions to signaled problems (see for example Borges & Baranauskas, 2003; Casamayor et al., 2009; Chen, 2006; Van Geel & Visser, 2013). In this case, it is important that teachers are aware of how the LA are constructed and which characteristics of student activities are used to determine whether a situation is problematic. A combination between these two approaches is to provide teachers with the option to determine the 'threshold' for alerts (Marcos-García et al., 2009). For example, in the Signals project (Tanes, Arnold, King, & Remnet, 2011), the teacher can enter a value for the grades that he or she finds problematic, so that an alert is sent to the teacher when students drop below this grade. The amount of control left to the teacher or to the LA system can thus vary. It is hard to imitate or translate a teacher's judgment by means of LA (Bravo, van Joolingen, & de Jong, 2009) and there is an ongoing discussion in the CSCL community about which point on the continuum of LA tools is most effective (Roschelle, Dimitriadis, & Hoppe, 2013).

Following this line of reasoning, another implication is that LA may not be helpful to teachers in some situations. If the information shown by the LA tools is not considered important by the teacher, the LA tools might be disregarded and the LA tools become superfluous (Zinn & Scheuer, 2006). The presence of superfluous information will typically increase the mental effort needed to complete a task (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Thus, when LA tools are not aligned with the beliefs or goals of the teacher who uses them, LA tools might increase instead of decrease information load in working memory. The intended effect is then not realized. In our studies, none of the teachers ever indicated they did not find the tools useful, but the considerations mentioned above show that independent of the type of LA, the teacher is the agent: it is the teacher who makes use of the technology and decides how and when to use it (Looi & Song, 2013). Therefore, when designing or implementing LA tools in classroom situations it is recommended to align them with the intended users, and to invest in training teachers to use the LA tools and to make teachers aware of how information shown by the LA may be interpreted. Aligning the technological affordances with teachers' knowledge and intentions may prevent problems during the implementation phase of technology (Chen, Looi, & Chen, 2009) and can help to achieve successful teaching with technology (Voogt, Fisser, Pareja Roblin, Tondeur, & Van Braak, 2013).

6.5 Concluding remarks

The focus of this thesis has been teacher regulation of CSCL. Starting from the assumption that teachers can fulfill an important role during collaborative learning, we have explored the complexity of teacher regulation of CSCL and the supporting role that LA could play. Central concepts during this investigation were synchronicity and adaptivity, which means that teachers during CSCL try to tailor their support to the characteristics and needs of multiple collaborating groups that all engage in multiple types of activities. In the first part of the thesis we have given a description of the strategies teachers use to try to accomplish this goal. In the second part, we have examined three mechanisms by which LA could support teachers. As Greiffenhagen (2012) stated: "It may be time to renew our interest in the work of teachers in the analysis of collaborative learning activities […] Rather than only asking how technologies can help pupils to learn, we should perhaps also ask how technologies can help teachers to help pupils to learn" (p. 39). In this thesis, we have tried to answer precisely this question, and the results of this thesis are a promising indication that LA can indeed support teachers in multiple ways. Further research needs to validate the proposed mechanisms by which LA can support teacher regulation of CSCL and needs to address questions such as how these mechanisms interact, which teacher characteristics must be taken into account, and how the balance between overview and overload of information can be preserved.

The specific synchronous setting of the presented research has allowed us to reflect on the findings in a broader perspective, thereby contributing to insights into teacher regulation of learning processes in a more general sense, including the key aspect of how teachers continuously diagnose student activities as related to synchronicity and adaptivity described earlier. Hopefully, the theoretical, methodological and practical considerations presented in this thesis concerning teacher regulation of collaborative learning and the role of LA will lead to more empirical research in this field, which could pave the way for a better understanding and more support of moment-to-moment teacher regulation of learning processes in authentic educational settings.

Samenvatting

Probleemstelling

Computerondersteund samenwerkend leren (*computer-supported collaborative learning*, CSCL) is de verzamelnaam voor onderwijssituaties waarin groepjes leerlingen samen aan een opdracht werken en daarbij ondersteund worden door computers (Stahl, Koschmann, & Suthers, 2006). Computerondersteuning bij samenwerkend leren biedt zowel leerlingen als docenten voordelen (Stahl et al., 2006). De digitale leeromgeving biedt groepjes leerlingen namelijk een communicatieplatform voor overleg en tools voor het werken aan gemeenschappelijke taken (bijvoorbeeld een gedeelde tekstverwerker). Daarnaast worden alle activiteiten en tussentijdse taakproducten automatisch opgeslagen en zijn door zowel de leerlingen als de docent in te zien.

Adequate docentbegeleiding is noodzakelijk om de beoogde doelen van samenwerkend leren te bereiken (Gillies, Ashman, & Terwel, 2008). De docent volgt en diagnosticeert de voortgang van de groepen en intervenieert waar nodig, een proces dat in het vervolg *docentregulatie* wordt genoemd. Door de samenwerking digitaal te laten verlopen, kan de docent alle groepsactiviteiten dus *real-time* volgen. Doordat de docent meerdere groepen tegelijk in de gaten houdt, kan de hoeveelheid beschikbare informatie echter overweldigend worden. Daardoor is het voor de docent een uitdaging om alle activiteiten te volgen en eventuele interventies af te stemmen op de voortgang van de groepen (Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder, 2012).

Deze dissertatie bestaat uit twee delen. In Deel I werden verschillende aspecten van docentregulatie van CSCL bestudeerd, en in Deel II werd onderzocht in hoeverre visualisaties van groepsactiviteiten, een vorm van *learning analytics*, docentregulatie van CSCL kunnen ondersteunen. In **Hoofdstuk 1** werd de achtergrond van deze twee delen uiteengezet.

Achtergrond van de studies en onderzoeksvragen

Achtergrond Deel 1: exploratie van docentregulatie van CSCL

Tijdens CSCL is de voornaamste taak van de docent het reguleren van de samenwerking door betekenisvolle interactie tussen leerlingen te stimuleren en hulp te bieden wanneer samenwerkende groepen die nodig hebben (Kaendler, Wiedmann, Rummel, & Spada, 2014). Om dat te bereiken, observeert en diagnosticeert de docent de groepsactiviteiten en intervenieert de docent wanneer nodig. Groepsactiviteiten werden in deze dissertatie in vier typen ingedeeld (Janssen, Erkens, & Kanselaar, 2007; Kaendler et al., 2014), te weten cognitieve activiteiten (gerelateerd aan de taakinhoud, bijvoorbeeld het stellen van vragen over taakmaterialen of het delen van informatie met groepsleden), sociale activiteiten (gerelateerd aan sociale en communicatieve aspecten van samenwerking, zoals constructieve discussie en gedeelde verantwoordelijkheid over de taak), metacognitieve activiteiten (het coördineren van cognitieve activiteiten, zoals het bedenken van een taakstrategie) en metasociale activiteiten (het coördineren van sociale activiteiten, zoals het verdelen van taken). De docent reguleert deze typen activiteiten.

Er is in onderwijskundig onderzoek tot nu toe weinig aandacht geweest voor de manier waarop docenten groepsactiviteiten volgen en diagnosticeren. Dit is verrassend gezien de mogelijkheid tot het real-time diagnosticeren van die activiteiten binnen CSCL leeromgevingen. De mogelijkheid tot diagnosticeren tijdens CSCL zou het kiezen van de passende interventie makkelijker kunnen maken omdat docenten een gedetailleerder beeld kunnen vormen van de groepsactiviteiten. Daarom is het belangrijk om verder te onderzoeken hoe de interactie tussen docent, leerling, en technologie eruitziet (De Laat & Lally, 2003).

Het doel van Deel I van de dissertatie was om twee aspecten van docentregulatie van CSCL te onderzoeken. Allereerst was het doel om een analyse van verschillende aspecten van docentinterventies te integreren, namelijk de *focus* (welke groepsactiviteiten worden gereguleerd, bijvoorbeeld cognitieve of sociale activiteiten), de *means* (welk middel gebruikt de docent om te interveniëren, bijvoorbeeld een instructie of een suggestie) en *tijd* (in hoeverre variëren docentinterventies over een langere periode). Het tweede doel was om de strategieën en beslissingen te achterhalen die docenten gebruiken tijdens het reguleren van samenwerkende groepen. Deze doelen leidden tot de eerste onderzoeksvraag: Hoe reguleren docenten de activiteiten van meerdere samenwerkende groepen tijdens CSCL in termen van diagnose- en interventiestrategieën?

Achtergrond Deel 2: effecten van learning analytics op docentregulatie van CSCL

Tijdens het continue volgen van groepsactiviteiten kan het de docent moeite kosten om alle groepsactiviteiten bij te houden waardoor het voordeel van het kunnen *overzien* van die activiteiten om kan slaan naar een *overbelasting* van de docent (Dyckhoff et al., 2012). Dit heeft mogelijk tot gevolg dat docenten groepsactiviteiten niet nauwkeurig diagnosticeren en dat interventies niet aangepast zijn aan de specifieke leerling of groep op een specifiek moment (Feldon, 2007). Een verdere moeilijkheid tijdens het diagnosticeren is dat sommige aspecten van samenwerking zich niet beperken tot één gebeurtenis maar zich afspelen over een langere periode, bijvoorbeeld de mate waarin ieder groepslid bijdraagt aan het oplossen van de taak. Deze aspecten vereisen dat de docent op meerdere momenten de groepsactiviteiten evalueert om tot een adequate diagnose te komen (Tabak, 2004).

Learning analytics (LA) is de verzamelterm voor “het meten, verzamelen, analyseren en rapporteren van gegevens over leerlingen en hun context, met het oog op het begrijpen en optimaliseren van het leren en de omgevingen waarin het leren zich voordoet” (Siemens & Gasevic, 2012, p. 1). LA kunnen ingezet worden om de real-time diagnose door docenten te ondersteunen, bijvoorbeeld door de informatie over groepen samen te vatten en overzichtelijk weer te geven (Schwarz & Asterhan, 2011). In Deel II van deze dissertatie werden de effecten van vier LA toepassingen op docentregulatie van CSCL onderzocht. De LA toepassingen visualiseerden activiteiten die belangrijk zijn tijdens samenwerkend leren. De eerste twee LA toepassingen betroffen sociale aspecten van samenwerking. Daarnaast werden er twee LA toepassingen onderzocht die betrekking hadden op cognitieve activiteiten. De volgende vraag werd in Deel II beantwoord: Wat zijn de effecten van learning analytics die verschillende typen groepsactiviteiten visualiseren op docentregulatie van CSCL, in termen van diagnose- en interventiestrategieën?

Resultaten van afzonderlijke studies

Studie 1: analyse van verschillende aspecten van docentinterventies

In de eerste studie (**Hoofdstuk 2**) werd docentregulatie van CSCL verkend en werd samengevat hoe bestaand onderzoek docentregulatie van CSCL heeft geanalyseerd. Wat betreft docentinterventies hebben twee aspecten met name aandacht gekregen, namelijk de typen groepsactiviteiten die docenten reguleren (de *focus*) en het type interventie dat de docent daarbij gebruikt (de *means*). Deze twee dimensies worden zelden tezamen bestudeerd. Bovendien wordt de invloed van tijd niet vaak in beschouwing genomen, wat heeft geleid tot het benoemen van algemene docentstijlen waarin niet altijd recht wordt gedaan aan de verscheidenheid van docentgedrag. Het doel van deze eerste studie was het beschrijven van meerdere aspecten van docentinterventies. In Hoofdstuk 2 stond de casus centraal van een geschiedenisdocent en een klas leerlingen binnen het voortgezet onderwijs die samenwerkten middels een digitale leeromgeving, waarin de interventies van de docent gedurende een periode van 8 weken werden geanalyseerd. De focus en means werden geanalyseerd alsmede de verschillen tussen de lessen en tussen de verschillende groepjes leerlingen.

De docent initieerde een verscheidenheid aan typen interventies afhankelijk van de les en de groep zowel wat betreft focus als means. De focus lag vaak op cognitieve en metacognitieve activiteiten, maar de frequenties varieerden sterk per les. Het aantal interventies gericht op sociale en metasociale activiteiten was lager, met een maximum percentage per les van ongeveer 15%. De meest gebruikte means waren het geven van feedback, het geven van uitleg, en het stellen van diagnosticerende vragen, opnieuw met grote variatie tussen lessen. In de eerste lessen werd veel gebruik gemaakt van uitleg geven en directe instructies. In de daaropvolgende lessen kwamen open vormen van interventie, zoals hints en suggesties, vaker voor. In de laatste fase van het werken aan de opdracht werd er opnieuw relatief veel uitleg gegeven door de docent.

Het onderscheid tussen focus en means, afkomstig uit literatuur over face-to-face onderwijs, bleek een geschikte methode om de variatie in docentgedrag tijdens CSCL te bestuderen. Een deel van de gevonden variatie in docentinterventies was naar verwachting, zoals het veelvuldig voorkomen van het geven van uitleg en de focus op metacognitieve activiteiten tijdens de eerste lessen. Andere bevindingen konden verklaard worden vanuit de activiteiten binnen de verschillende groepen, zoals de interventies met focus op metasociale activiteiten om een ruzie te beëindigen. De conclusie was dan ook dat docentinterventies het beste begrepen kunnen worden door ze te beschouwen als een reactie op de huidige situatie, en niet zozeer als een uiting van een vaste doceerstijl. Het relatief vaak voorkomen van diagnosevragen duidde erop dat de docent mogelijk moeite had met het volgen van alle groepsactiviteiten. Ook de gevonden variatie tussen lessen en binnen groepen leidde tot de formulering van doelen voor vervolgonderzoek met betrekking tot de strategieën die docenten gebruiken om meerdere groepen tegelijkertijd te reguleren in een digitale leeromgeving, waarin zij meer informatie over groepen leerlingen tot hun beschikking hebben.

Studie 2: diagnose- en interventiestrategieën bij het reguleren van meerdere samenwerkende groepen

In studie 2 (**Hoofdstuk 3**) werd docentregulatie van CSCL verder geëxploreerd, waarbij ditmaal de invloed van een relatief groot aantal samenwerkende groepen op de regulatiestrategieën die docenten toepassen centraal stond. Studie 1 (Hoofdstuk 2) toonde reeds aan dat elke groep specifieke hulpbehoeften heeft, met de consequentie dat een docent continu de voortgang van elke groep moet diagnosticeren om de geboden hulp aan de behoeften van elke groep aan te kunnen passen. Samenwerkend leren betekent in een klas van gemiddelde omvang dat een docent al gauw vijf tot zeven groepen reguleert. In een CSCL omgeving is over elk van deze groepen informatie beschikbaar over de activiteiten die de groepen ondernemen. In studie 2 werd onderzocht hoe docenten deze groepen volgen en reguleren middels een casus van twee docenten met ieder een klas bestaande uit zeven groepjes leerlingen. Het resultaat was een beschrijving van de strategieën en cognities van deze twee docenten. De docenten werden zowel vooraf, tijdens, als na afloop van het reguleren van samenwerkend leren geïnterviewd.

De resultaten lieten zien dat beide docenten positief waren over de door de digitale leeromgeving geboden mogelijkheid om groepsactiviteiten *real-time* te volgen. Tegelijkertijd ervoeren de docenten een hoge druk door alle beschikbare informatie. De docenten stopten veel moeite in het achterhalen van de behoeften van elke groep, en boden meteen hulp als zij dachten dat dit nodig was. Daarbij maakten zij vaak gebruik van hun kennis over de leerlingen. De focus van de docenten lag voornamelijk op metacognitieve activiteiten, en interventies waren vaak gericht op groeps- en klasniveau. Hoewel de docenten alle groepsactiviteiten in de gaten konden houden, hadden de leerlingen geen besef van de activiteiten van de docent. Beide docenten ervoeren dit als een nadeel omdat zij daardoor het idee hadden dat groepen op hun reactie zaten te wachten.

Deze studie heeft inzicht geboden in de complexiteit die gepaard gaat met het reguleren van meerdere groepen samenwerkende leerlingen tijdens CSCL. Met name de kansen (het monitoren van groepen en het kunnen interveniëren op verschillende niveaus) en de moeilijkheden (de hoge druk en de beslissing om wel of niet te interveniëren) ten gevolge van de beschikbare informatie over de groepen ten aanzien van de regulatiestrategieën die docenten gebruikten, werden verduidelijkt.

Studie 3: effecten van learning analytics die gericht zijn op sociale activiteiten

Tezamen toonden studies 1 en 2 (Hoofdstuk 2 en 3) aan op welke manier docenten die CSCL reguleren adaptieve begeleiding proberen te bereiken, en tegelijkertijd hoe dit doel in het gedrang komt door de complexiteit van het diagnosticeren van meerdere groepen tegelijkertijd. Om het houden van overzicht te vergemakkelijken, zouden *learning analytics* (LA) toegevoegd kunnen worden aan CSCL omgevingen. LA toepassingen bestaan in vele vormen en kunnen verschillende typen informatie weergeven.

In studie 3 (**Hoofdstuk 4**) werden toepassingen van LA onderzocht die *sociale* groepsactiviteiten visualiseren. Informatie over leerlingparticipatie werd gegeven in de vorm van statistieken over de relatieve contributie aan het groepswerk van elke leerling. De tweede toepassing van LA was de Shared Space, die werd geïntegreerd in het Chat-venster waarbinnen groepsleden met elkaar en met de docent communiceren. De Shared Space laat zien of er overeenstemming of discussie is binnen een groep. Door middel van een experimentele opzet werd onderzocht of beschikking tot de LA effect had op de manier waarop docenten diagnosticeerden en intervenieerden tijdens CSCL. Docenten werd gevraagd om de activiteiten van samenwerkende groepen te reguleren in vier interactieve simulatievignettes, waarin de LA aanwezig (experimentele conditie, N = 14) of afwezig (controleconditie, N = 14) waren. De docenten konden interventies plegen en werden na afloop van elk vignette gevraagd naar hun diagnose van de participatie en discussie binnen elke groep.

De resultaten lieten zien dat de participanten in de experimentele conditie significant lagere scores gaven aan de groepen met een probleem betreffende participatie in alle vignettes, in vergelijking tot twee vignettes in de controleconditie. Met betrekking tot de scores voor discussie werd in de experimentele conditie geen enkele problematische groep lager beoordeeld. In de controleconditie gebeurde dat in één van de vier vignettes. In één geval kreeg de problematische groep daarentegen juist een hogere score. Een ander resultaat was dat de participanten die beschikking hadden over LA hun diagnoses nauwkeuriger konden beschrijven, zoals bleek uit de opmerkingen die zij konden geven bij de scores na ieder vignette. De focus van deze opmerkingen lag in de experimentele conditie vaker op sociale activiteiten. Het gemiddeld aantal interventies nam in de experimentele conditie af naarmate de tijd vorderde en waren relatief vaker gericht op problematische groepen. De participanten in de experimentele conditie spraken vaker individuele leerlingen aan, wat er mogelijk op duidt dat zij een specifieke diagnose hadden gevormd over de rol van die leerling binnen de groep.

Kortom, de gevonden resultaten verschilden voor de twee LA toepassingen die onderzocht werden. Over het algemeen bleek echter dat de LA docenten ondersteunden bij het diagnosticeren van groepsactiviteiten en het specifiek interveniëren binnen groepen die problemen ervoeren.

Studie 4: effecten van learning analytics die gericht zijn op cognitieve activiteiten

Studie 4 (**Hoofdstuk 5**) was een vervolgstudie op studie 3 (Hoofdstuk 4) en onderzocht het effect van twee LA toepassingen die *cognitieve* activiteiten visualiseren. Informatie over taakvoortgang werd gegeven in de vorm van statistieken. De tweede toepassing van LA was de Concept Trail, die werd geïntegreerd in het Chat-venster waarbinnen groepsleden met elkaar en met de docent communiceren. De Concept Trail laat zien wanneer de groepsleden een taakrelevant concept gebruiken tijdens hun discussie. Er werd eenzelfde experimentele opzet gebruikt als in studie 3 (Hoofdstuk 4). Opnieuw werd het effect van LA toepassingen op docentdiagnoses en docentinterventies onderzocht. Docenten (N = 20 in zowel de controle- als de experimentele conditie) werden gevraagd een score te geven aan elke groep voor de taakvoortgang en voor de mate waarin relevante concepten werden gebruikt. Naast deze afhankelijke variabelen werden docenten in deze studie na afloop van elk vignette tevens gevraagd een score te geven voor de ervaren cognitieve belasting op een schaal van 1 tot 9.

De resultaten lieten zien dat docenten in zowel de experimentele als de controleconditie in staat waren om de problematische groepen op te merken. De gemiddelde frequentie van interventies was significant hoger wanneer docenten beschikking hadden over LA en de interventies waren relatief vaker gericht op de problematische groepen dan op de niet-problematische groepen. Een ander effect van de aanwezigheid van LA was dat wanneer docenten een problematische groep lager beoordeelden, zij vaker dan in de controleconditie een actie verbonden aan deze diagnose door de betreffende groep aan te spreken over het probleem. Er werden geen verschillen gevonden wat betreft de specificiteit van de docentinterventies. Ook wat betreft de ervaren cognitieve belasting waren er geen significant verschillen tussen de docenten in de twee condities.

Algemene discussie

In **Hoofdstuk 6** werden de twee algemene onderzoeksvragen beantwoord. Daarnaast werden de beperkingen van het onderzoek en mogelijke richtingen voor vervolgonderzoek besproken. Als laatste werd ingegaan op de implicaties van de resultaten voor onderzoek naar en implementatie van (computerondersteund) samenwerkend leren.

Antwoorden op onderzoeksvragen

Als antwoord op onderzoeksvraag 1 werd in Hoofdstukken 2 en 3 beschreven hoe docenten tijdens CSCL de activiteiten van groepen diagnosticeerden en hoe zij hun keuzes voor een bepaalde interventie verklaarden. Het interactieve karakter van docentregulatie van CSCL werd belicht en het werd duidelijk hoe docenten de interventies afstemden op de context, daarbij wisselend tussen verschillende foci en zowel gebruikmakend van communicatie op klas- en groepsniveau als op het niveau van de individuele leerling.

De rol van de digitale leeromgeving werd op drie aspecten duidelijk. Allereerst bood het feit dat de docent alle groepsactiviteiten real-time kon monitoren de kans om zowel pro- als reactief op een adaptieve manier te reguleren. De docent kan een gesprek met een groep zelf initiëren op basis van de geobserveerde activiteiten, en de docent kan als een leerling iets vraagt de opgeslagen activiteiten van de betreffende groep gebruiken om het antwoord aan te passen aan het begrip van de leerling. Het tweede aspect betreft de dynamiek van de interactie tussen docenten en groepen leerlingen in digitale leeromgevingen. De docent is meer deelgenoot van de samenwerkende groepen en minder een autoritair figuur omdat de docent op een onopvallende manier bij de activiteiten van elk groepje betrokken blijft (Park et al., 2015). Er ligt daardoor minder druk op de interactie. Het laatste aspect dat specifiek is voor de onderzochte setting is dat zowel de docent als de leerlingen het beantwoorden van een vraag kunnen uitstellen en daardoor kunnen profiteren van ‘bedenktijd’ alvorens aan een groepsgesprek bij te dragen (Schwarz & Asterhan, 2011).

Al deze aspecten moeten echter wel worden bezien in het licht van de complexiteit van de taak van de docent en de bijbehorende moeilijkheden die docenten kunnen ervaren, met name het bijhouden en verwerken van alle informatie die over groepen beschikbaar is. Onderzoeksvraag 2 richtte zich daarom op de ondersteuning die LA mogelijk aan docenten zouden kunnen bieden. In Hoofdstukken 4 en 5 werden de effecten van LA op docentregulatie van CSCL onderzocht. Op basis van de resultaten konden drie mechanismen onderscheiden worden. Mechanisme 1 houdt in dat LA informatie over groepen kunnen samenvatten en daarmee de beschikbare informatie tot een beheersbaar geheel reduceren. Docenten kunnen deze samenvattingen gebruiken als indicatoren voor waar mogelijk problemen spelen. Mechanisme 2 is dat LA de focus van de docent kunnen sturen en de docent daarmee bewust kunnen maken van bepaalde typen informatie. Mechanisme 3, ten slotte, houdt in dat LA de diagnose die de docent vormt over groepsactiviteiten kunnen uitbreiden of versterken. Hoe gedetailleerder de diagnose van de docent is, hoe beter de interventie daarop aangepast kan worden. Ook kan een meer complete diagnose de docent helpen besluiten om wel of niet te interveniëren. Samengevat werden er dus aanwijzingen gevonden voor verschillende manieren waarop LA docenten kunnen ondersteunen.

Beperkingen en richtingen voor vervolgonderzoek

Het beschreven onderzoek kent een aantal beperkingen. Allereerst kan opgemerkt worden dat deze dissertatie gericht was op bestudering en ondersteuning van docenten. Hoewel het onderliggende doel hiervan was om leerlingen te ondersteunen, hebben we de stap tussen ondersteuning van de docent en het effect van het daaropvolgende docentgedrag op leerlingen, niet onderzocht. Gerelateerd hieraan is de vraag waarom we docenten van LA hebben voorzien, en niet de groepen leerlingen, of allebei. Het antwoord daarop is dat wij van mening zijn dat LA voor beide partijen verschillende doelen kunnen vervullen. Vervolgonderzoek zou zich wel op de vraag kunnen richten in hoeverre de complexiteit van docentregulatie van CSCL verminderd wordt indien groepen al voor een deel van feedback worden voorzien in de vorm van LA (Ertmer & Glazewski, 2015).

Een tweede beperking is dat er in de uitgevoerde studies geen aandacht is geweest voor de rol van doceerervaring. Uit verschillende studies blijkt dat ervaren begeleiders van digitale onderwijsvormen anders handelen dan beginnende begeleiders (zie bijvoorbeeld Kopp, Matteucci, & Tomassio, 2012). Uit de literatuur rondom face-to-face onderwijs is bekend dat doceerervaring ertoe leidt dat docenten zogenoemde schema's ontwikkelen van onderwijssituaties, die hen in staat stelt om informatie op een efficiënte manier te verwerken (Feldon, 2007). Mogelijkerwijs hebben meer ervaren docenten dus minder behoefte aan de ondersteuning van LA, met name op het gebied van Mechanisme 1 (zie boven). Ook dit is een interessante richting voor vervolgonderzoek.

Gegeven dat het uitgevoerde onderzoek plaatsvond in een synchrone setting waarbij de docent en de groepjes leerlingen in dezelfde ruimte aanwezig waren, was face-to-face communicatie mogelijk geweest. De docenten gaven zelf aan dat zij dit face-to-face contact af en toe nodig hadden. De gekozen online leersituatie biedt echter ook veel voordelen, waaronder het feit dat alle activiteiten opgeslagen blijven. Vervolgonderzoek zou zich wel kunnen richten op de combinatie van online en face-to-face onderwijs, een richting die onder de naam 'Blended Learning' op het moment veel aandacht krijgt (Garrison & Kanuka, 2004).

Een laatste beperking heeft betrekking op de methodologie van de experimentele studies uit Hoofdstukken 4 en 5 waarin gebruik werd gemaakt van simulatie-vignettes. De diagnoses en de ervaren cognitieve belasting van docenten werden met name na afloop van de vignettes gemeten. Het is een uitdaging voor vervolgonderzoek om deze constructen in kaart te brengen *tijdens* docentregulatie als een continue maat in plaats van enkel gebaseerd op reflecties achteraf (zie bijvoorbeeld Van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009). Een verdere beperking is dat de effecten van LA steeds per tweetal toepassingen zijn onderzocht (bijvoorbeeld de Statistieken tezamen met de Shared Space) in plaats van per losse toepassing (bijvoorbeeld enkel de Statistieken). Omdat de toevoeging van LA aan de leeromgeving een relatief bescheiden interventie is in vergelijking met andere interventies zoals het trainen van docenten, moet er in het algemeen rekening mee worden gehouden dat er kleine effecten worden verwacht bij de inzet van LA.

Desalniettemin zijn we van mening dat de gebruikte experimentele set-up een veelbelovende manier is om docentregulatie te onderzoeken omdat het een combinatie bood tussen gestandaardiseerde items en authentieke situaties. Door vignettes te gebruiken konden alle deelnemende docenten dezelfde situaties bekijken en beoordelen.

Implicaties van de resultaten voor onderzoek naar en implementatie van (computerondersteund) samenwerkend leren

Op basis van de antwoorden op de algemene onderzoeksvragen werden de centrale thema's van de dissertatie in de algemene context van samenwerkend leren besproken. De theoretische uitgangspunten van de dissertatie zijn namelijk breder toepasbaar (Kaendler et al., 2014): ongeacht de setting wordt tijdens samenwerkend leren van de docent verwacht dat hij of zij meerdere groepen leerlingen monitort en adaptieve hulp biedt. In deel II van de dissertatie werd getracht docenten te ondersteunen met LA, die gebaseerd waren op algemene markers van leerprocessen. LA zouden daarom indirect ook in face-to-face settingen nuttig kunnen zijn omdat deze markers hier ook van toepassing zijn. De LA zouden bijvoorbeeld omgezet kunnen worden in een 'checklist' die de docent kan gebruiken tijdens het rondlopen in de klas (Kaendler, Wiedmann, Rummel, Leuders, & Spada, 2013). Het blijft echter het geval dat de docent nooit *alle* groepsactiviteiten in de gaten kan houden en dat de activiteiten niet 'teruggekeken' kunnen worden. Dit zou een reden temeer kunnen zijn om in bepaalde situaties CSCL te verkiezen boven face-to-face samenwerking.

Een andere bevinding die van breder belang kan zijn is dat docenten hun focus relatief weinig legden op sociale en metasociale activiteiten, ondanks het belang dat aan deze activiteiten wordt toegedicht (Kreijns, Kirschner, & Vermeulen, 2013). Het is daarom aan te bevelen om docenten hierop te wijzen. LA zouden hier een rol in kunnen spelen omdat deze de focus van docenten kunnen sturen (Mechanisme 2 zoals eerder besproken). De gekozen indeling van de klas, in termen van het aantal samenwerkende groepen en de grootte van elk groepje, speelt bij sociale activiteiten ook een rol. Grotere groepen kunnen sneller problemen ervaren met zaken als meeliftgedrag, maar een te groot aantal groepen levert meer complexiteit op voor de docent. Het is dus zaak om hier een goede balans in te vinden.

Mocht er gekozen worden voor het gebruiken van LA ter ondersteuning van docenten dan is het van belang om de LA af te stemmen met de docenten. De informatie die door de LA weergegeven wordt kan namelijk op meerdere manieren geïnterpreteerd worden afhankelijk van de pedagogische en didactische kennis en ervaringen van de docent (Song & Looi, 2012). Indien de docent de door de LA getoonde informatie niet belangrijk acht, kan de cognitieve belasting van de docent zelfs verhogen (Paas, Tuovinen, Tabbers, & Van Gerven, 2003) en het handelen van de docent belemmeren. Investeren in docenttraining bij het gebruik van LA wordt daarom aanbevolen, zodat de implementatie van deze technologie soepel verloopt (Chen, Looi, & Chen, 2009; Voogt, Fisser, Pareja Roblin, Tondeur, & Van Braak, 2013).

Conclusie

In deze dissertatie stond docentregulatie van CSCL centraal. In Deel I werd beschreven welke strategieën docenten toepassen om de activiteiten van groepen leerlingen te volgen en op welke manier zij beslissen of en welke interventie nodig is. In Deel II werden aanwijzingen gevonden dat LA docenten hierbij kunnen ondersteunen. Meer onderzoek is nodig om de voorgestelde mechanismen waarop LA docenten kunnen ondersteunen, verder te bestuderen. Ook kan gekeken worden naar de manier waarop deze mechanismen elkaar beïnvloeden en welke docenteigenschappen hierbij een rol spelen. Hopelijk leiden de theoretische, methodologische, en praktische overwegingen die in deze dissertatie besproken zijn tot meer empirisch onderzoek op dit gebied. Dit zou kunnen leiden tot meer inzicht in en ondersteuning van de manier waarop docenten de leerprocessen van leerlingen reguleren.

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List of publications

Peer-reviewed publications

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2013). Teacher interventions in a synchronous, co-located CSCL setting: Analyzing focus, means, and temporality. *Computers in Human Behavior*, *29*(4), 1377-1386. doi:10.1016/j.chb.2013.01.028

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Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (in press). Teacher regulation of multiple computer-supported collaborating groups. *Computers in Human Behavior.*

Submitted articles

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (under review). Teacher regulation of cognitive activities during student collaboration: effects of learning analytics.

Van Leeuwen, A. (under review). Learning analytics to support teachers during synchronous CSCL: balancing between overview and overload.

Other publications

Van Leeuwen, A., Janssen, J., & Erkens, G. (2014). Effecten van learning analytics bij computerondersteund samenwerkend leren. *4W: Weten wat werkt en waarom*, *4*, 14-21. http://4w.kennisnet.nl/artikelen/2014/12/10/effecten-van-learning-analytics-bij-computer-onder/

Conference Posters

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2011). Intenties en acties van docenten tijdens computerondersteund samenwerkend leren. Poster presented at the Onderwijs Research Dagen (ORD) 2011, Maastricht, the Netherlands.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2012). De effecten van awareness tools op het scaffolding gedrag van docenten in een CSCL omgeving. Poster presented at the Onderwijs Research Dagen (ORD) 2012, Wageningen, the Netherlands. (*Best poster nomination.*)

Van Leeuwen, A., & Buis, S. (2013). Effects of computer supported diagnostic tools on assessment, intervention and self-regulation in collaborative learning. Poster presented at the Learning Analytics and Knowledge (LAK) conference, Leuven, Belgium.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2015). Learning analytics to support teachers: theoretical and empirical findings. Poster presented at the international conference on CSCL 2015, Gothenburg, Sweden.

Conference Papers

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2012). Teacher's Scaffolding Behavior in CSCL - A Case Study. Paper presented at the 4th International Conference on Computer Supported Education, Porto, Portugal.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2012). Combining behavioral and cognitive data to study teachers' scaffolding process in a computer-supported collaborative learning environment. Paper presented at the SIG17 meeting of the European Association of Research on Learning and Instruction (EARLI), Deventer, the Netherlands.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2012). Teachers' scaffolding in CSCL: towards understanding and support. Paper presented as part of the symposium "Supporting interaction in CSCL: effects on assessment, teacher scaffolding, and intercultural communication" at the Onderwijs Research Dagen (ORD) 2012, Wageningen, the Netherlands.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2013). Focus, Means, and Task Influence on Teacher Regulation of Computer-Supported Collaborative Learning. Paper presented at the American Educational research Association (AERA) conference 2013, San Francisco, USA.

Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2013). Multidimensional teacher behavior in CSCL. Paper presented at the international conference on CSCL 2013, Madison, USA.

Janssen, J., Kirschner, F., Van Leeuwen, A., Erkens, G., & Brekelmans, M. (2015). Shared Workspaces and Multimedia for Regulating Learning in CSCL. Paper presented as part of the symposium "Regulated Learning in CSCL - Theoretical Progress for Learning Success" at the international conference on CSCL 2015, Gothenburg, Sweden.

Curriculum Vitae

Anouschka van Leeuwen was born on June 3, 1988, in Voorburg (the Netherlands). She completed her secondary education in 2005 at the Erasmus College in Zoetermeer. In September 2005, Anouschka started studying Cognitive Artificial Intelligence in Utrecht, resulting in a Bachelor degree (*cum laude*) in 2008 and a Master degree in 2010. During her Master's, she was also enrolled in several courses in Educational Sciences. These two study interests were combined at the end of 2010 when she started her PhD project concerning teacher regulation of computer-supported collaborative learning. During this time she also gained teaching experience as a research supervisor and lecturer. Starting 2010, Anouschka has also been a member of several educational committees and has been involved in organizing workshops and symposia. After finishing her PhD project, she has continued her work in Utrecht as post-doc researcher and lecturer.

ICO Dissertation Series

In the ICO Dissertation Series the dissertations of graduate students from faculties and institutes on educational research within the ICO Partner Universities are published: Eindhoven University of Technology, Leiden University, Maastricht University, Open University of the Netherlands, University of Amsterdam, University of Twente, Utrecht University, VU University Amsterdam, and Wageningen University, and formerly University of Groningen (until 2006), Radboud University Nijmegen (until 2004), and Tilburg University (until 2002). The University of Groningen, University of Antwerp, University of Ghent, and the Erasmus University Rotterdam have been 'ICO 'Network partner' in 2010 and 2011. From 2012 onwards, these ICO Network partners are full ICO partners, and from that period their dissertations will be added to this dissertation series.

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299. Gabelica, C. (04-12-2014). *Moving Teams Forward. Effects of feedback and team reflexivity on team performance.* Maastricht: Maastricht University.
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