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Changing face-to-face communication

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1 Introduction

You understand, what I tell you here is just a summary; for in the state of real life things are loaded with much more artifice: one day there is hope, the next day disconsolation.

João Guimarães Rosa¹

1.1 Communication and Learning in the Classroom

The classroom is a place for learning where students come together to be taught in a formal way. The classroom is primarily a communicative environment. Students' participation in the communicative practices in the classroom affects their achievement (Green, 1983). The view of what constitutes effective classroom communication has changed in the final decade of the 20th century (Cazden & Beck, 2003). Traditionally, classroom communication takes place between the teacher on the one hand and the students on the other, with the teacher as the pivot of the communicative activities. The teacher has the initiative and directs the flow of communication. Lectures are a good example of a teacher-centered communication pattern with their emphasis on the transfer of pre-structured knowledge from the teacher towards the student. In these cases, the teacher controls what is learned and how. Knowledge is objectified and learning consists of transferring that knowledge from outside to within the learner (Driscoll, 1994). It reflects a view that knowledge is simply to "be listened to" (Bruner, 1996).

Constructivist approaches have challenged the objectivist view towards knowledge and learning. These approaches do not see learners as passive recipients of knowledge. Rather, learners are actively involved in constructing their own understanding of things

¹ João Guimarães Rosa (1956), *The Devil to Pay in the Backlands*.

(Campbell, 2002). Learners construct useful and viable knowledge when they engage in meaningful experiences during which they have to draw upon their own concepts, judgments and actions to make sense of these experiences. A number of constructivist accounts introduce a particular view of knowledge that emphasizes its social nature. These Social-constructivist accounts stress the *construing* aspect of communication and state that knowledge constructions take place within everyday discourse between people in interaction (Burr, 1995). Learning from this perspective can be seen as a continuing effort to improve on existing knowledge through an engagement in a discourse that advances mutual understanding (Bereiter, Scardamalia, Cassells & Hewitt, 1997).

Social-constructivist learning methods have gained their place in the classroom. These methods take the interacting student as the starting point for learning with the aim to create learning environments that stimulate meaningful interactions, i.e. meaningful interactions between the learner and relevant learning resources like the teacher, fellow students or various kinds of learning materials. In this thesis, we describe how such a learning environment may look like for students who learn together in small groups.

New Learning

Quite recently, the Dutch education system went through an education reform that aimed to introduce new forms of learning that are based on a Social-constructivist epistemology. This educational reform is known as New Learning (Simons, van der Linden & Duffy, 2000) and can be described by the following characteristics (Teurlings, Wolput, Vermeulen, 2006, Bronneman-Helmers, 2007):

- autonomous learning,
- learning in meaningful and authentic settings,
- collaborative learning, and
- a different kind of relationship between the teacher and students.

New Learning already gained its acceptance in higher education where lectures are just one way to teach students, besides methods such as project work, problem-based learning and collaborative learning (CHEPS scenarios, 2004). More recently, these alternative learning methods have also been introduced in secondary education. It

seems that these methods gradually “dropped down” from higher education towards preparatory and vocational schools. These new forms of learning better prepare students for continuing education or the working practice. They provide the students with practical experience with everyday work situations where people are responsible for their own work and where they have to collaborate with others.

The new learning methods require different kinds of teaching and learning skills. The teachers is not only the expert who makes knowledge accessible for the students, the teacher is also an effective facilitator who creates meaningful learning experiences. For students the situation also changes. Students must have the skills and the motives to become learners who are largely responsible for their own learning processes. Furthermore, they should be effective collaborators who can learn with and from each other. For example, when students collaborate they must have the appropriate skills so that their communication becomes effective and conducive for learning (Sfard & Kieran, 2001). These changes require different kinds of learning environments, i.e. learning environments that fosters meaningful interactions between students.

1.2 Group Discussions in the Classroom

Social-constructivist approaches have a different view with regard to the communication patterns that can be associated with learning. Communication does not proceed in a one-way direction from an expert teacher towards a novice learner. Instead, students are seen as an important source for knowledge. Communication between students is a valuable vehicle for learning. *Active participation* in the communicative practice of the peer group makes the students aware of their own thinking in relation to what others say. Students may even be better able to address their fellow students' cognitive system because their concept of things is more closely related.

Collaborative learning explicitly exploits the interactions between students as a means for learning. Collaborative learning – as it is presented in this thesis – takes its form as a *problem-solving discussion* that is directed towards the exploration of a particular topic or the resolution of a problem. A problem-solving discussion consists of one or more meetings between a small group of students who communicate with each other, often face-to-face, in order to achieve one or more goals such as increased understanding, the coordination of an activity, or the solution of a shared problem (Galanes & Adams, 2007). In an educational setting the goal of solving a problem may

not come first, rather *increased understanding* is the main reason for introducing problem-solving discussions in the classroom. When students participate in a discussion, they develop authentic solutions for complex problems, and, while doing so, acquire useful knowledge of theories and concepts (Chernobilsky, Nagarajan and Hmelo-Silver, 2005). Through discussions, students generate and evaluate evidence to confirm or enhance their understanding (Hogan, Nastasi & Pressley, 2000).

A Constructive Dialogue

The group discussions that are the object of the research take place in the classroom where students are in physical proximity and interact directly with each other. Several small groups populate the classroom, which makes direct supervision by the teacher impracticable. As a consequence, the classroom communication shifts from mainly teacher-centered towards more diverse patterns of communication where the students often take the lead. From a Social-constructivist perspective, the communication should meet a number of requirements. Collaborative learning requires active and equal participation of all group members. However, active and equal participation is not sufficient. The communication between students must be coherent, meaningful and oriented at the construction of shared knowledge. We use the term *constructive dialogue* to indicate that students have to share their knowledge with the group and elaborate on what is shared. During a constructive dialogue, students collaboratively explore their mutual learning experiences. Differences in understanding give rise to further explorations with the aim to come to a shared understanding. During these collaborative explorations students communicate, defend, prove and justify their ideas (Twomey Fosnot, 1996). They explain their reasoning, listen to each other, learn from, and even argue with their peers (Cazden & Beck, 2003).

1.3 Research Problem

Bringing students together in small groups does not imply that they will actually engage in a constructive dialogue that promotes learning. Communication can be counter-productive; ineffective communication may prevent students to discuss a topic thoroughly with the risk that the group does not achieve the intended learning outcomes. When we look at these groups from a *functional perspective*, we can state that groups do not always enter into a constructive dialogue and that their performance varies. Several studies into collaborative learning observed that not all groups were able

to carry out a productive discussion (e.g. Gillies, 2004; Barron, 2003; Kneser & Ploetzner, 2001; Hogan, Nastasi & Pressley, 2000; Keefer, Zeitz & Resnick, 2000). These observations provide the rationale for the research that will be discussed in this thesis. It results in the following research problem:

groups who communicate face-to-face do not always display communication patterns that can be associated with a constructive dialogue; sometimes they perform less than expected and do not achieve their learning objectives.

The functional perspective states that the performance differences have to do with the communication patterns that can be observed during a group discussion. Collaborative learning requires particular kinds of *communication patterns*, which trigger learning mechanisms that lead to an increased understanding. It is however no guarantee that the expected patterns actually do occur (Dillenbourg, 1990).

Sfard and Kieran (2001) concluded that the merits of collaborative learning cannot be taken for granted due to *ineffective communication patterns*. These ineffective patterns inhibit the free expression of ideas and the further exploration of these ideas by the group. Interruptions are a good example of an ineffective communication pattern (Stein & Albro, 2001). Frequent interruptions by a dominant group member could hamper the process of collaboration and learning. Other group members have less opportunities to talk so that they cannot share their ideas freely with the group. It means that the group does not fully capitalize on the knowledge and skills available.

1.4 Research Objective

Information- and Communication Technologies (ICT) offer new opportunities for learning by providing easy access to information and better openings for communication. Learning that is supported by ICT is usually specified by its technological origin like e-learning, online learning or web-based learning. These terminologies describe ICT as the means to bring learning resources closer to the learner. These resources can be situated everywhere and learners can access them from different places. They include general information, teaching material, instructions, teachers or a community of learners.

E-learning, for example, refers to the use of technology to deliver content and instructions to individuals to aid their learning. Various technologies can be used for e-learning, like multimedia to display content that is brought to the individual through

the Internet or through storage devices as the compact disc. Online learning and web-based learning, in contrast, are confined to the Internet; the computer is the medium to access learning resources available on the World Wide Web.

We opt for the term *networked learning* because it contains a view on technology-enhanced learning that can be characterized by connectivity. The term connectivity refers to a general function of ICT that applies to a variety of learning situations. ICT can be used to *promote* connections: between one student and other students, between students and tutors, or between a learning community and its learning resources (Goodyear, Banks, Hodgson & McConnell, 2004). Networked learning stresses that new technologies enable learners to interact more fluently with the relevant resources in their surrounding.

Although different terminologies are used, there is a large degree of consensus about the role of the technology. Its main purpose is to overcome the time and space constraints associated with traditional learning situations like the classroom. These constraints have to do with the limited availability of information *and* people in relation to a particular place where learning takes place. Learning facilitated by ICT typically focuses on those situations where there is a perceived lack of face-to-face contact (Holmes & Gardner, 2006). The Internet gives the learner easy access to learning resources that are located elsewhere. There are no time zones; location and distance are no longer an issue (Anderson, 2008). Furthermore, learning is no longer confined to the classroom or the workplace; every place can be a place for learning, as long as there are computers or smart devices available. It is clear that these technologies have a direct added value because they broaden the scope of interactions so that a variety of learning resources becomes accessible that are difficult to reach otherwise. New learning environments emerge that could not exist without ICT and it seems that when the boundaries of time and space fade away, learning finally reaches its full growth.

Facilitating Face-to-Face Communication

In this thesis, we question the partial view that networked learning is all about crossing the physical and temporal boundaries of the learner. Networked learning, in our view, is not only about expanding interactions, it also applies to those situations where there is a need for *better* interaction. Not because more communication is needed but

because existing communication is not effective and may even hamper learning. From this perspective, networked learning suits a wide variety of situations – face-to-face and distance – as long as it improves connectivity. A networked-learning environment may have virtual properties, as is the case of online learning, but it could also be a real environment where people, tools and materials exist only in a particular location in time and space.

Computer Support for Collaborative Learning

Van Diggelen and Overdijk (2007) make a distinction between three types of computer support for collaborative learning, or more specific, for supporting group discussions (Figure 1.1). These situations take the face-to-face discussion as the point of reference.

The first situation (upper right corner of Figure 1.1) was already mentioned in the previous paragraph. It refers to collaborative learning situations where the computer connects students who are dispersed in time and/or space. The majority of networked-learning environments focuses on this kind of support where *all* the communication is mediated by a tool. For many researchers, this represents the archetypal networked-learning environment.

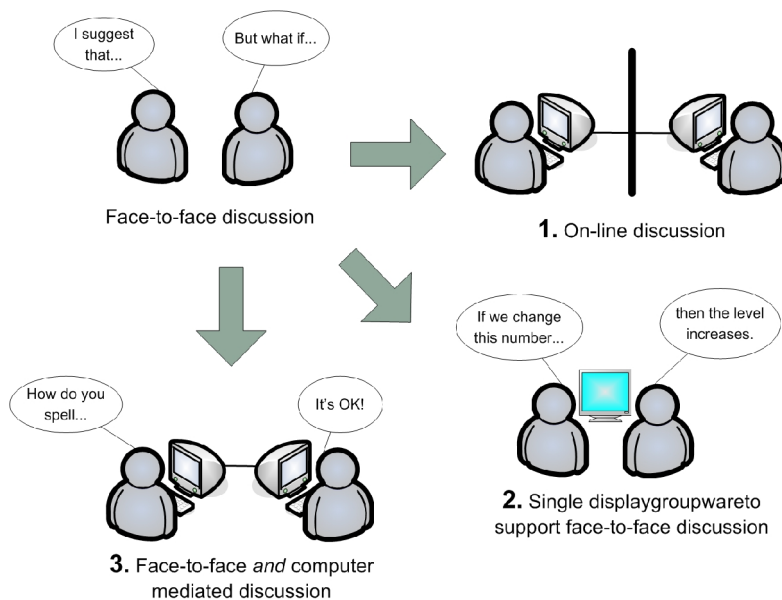


Figure 1.1: Three situations of computer support for group discussion.

Online learning usually reflects an attitude of “*more support is better*”. A rich information flow between the students is seen as a guarantee for collaboration and learning on a distance. Research into online learning indicates that it is extremely difficult to facilitate the full range of group interactions by collaborative technologies. Computer-mediated interactions are often restricted to those interactions that mirror the cognitive processes in a group (Kreijns, Kirschner and Jochems, 2003). An enrichment of the information flow may improve online collaborative learning; for example, students may use multiple tools simultaneously to enrich their communication, or they may use an awareness tool that gives detailed information about their performance. The aim of these tools is to broaden the range of interactions or to make the context of communication more meaningful. They try to reproduce the richness of face-to-face communication. Still, it remains unclear if online collaboration can *and* should mirror its face-to-face counterpart. Research into computer supported collaborative work seems to indicate otherwise (Olson & Olson, 2000; Kiesler & Cummings, 2002).

Computer Support for Face-to-face Collaboration

The other two situations of Figure 1.1 (situation 2 and 3) have a fundamentally different orientation. They take the existing face-to-face context as the starting point and support learning activities of students who are co-located. The two situations have two distinctive features: 1) the students are in the same room in close proximity, and 2) the students communicate face-to-face.

Computer support for face-to-face settings has already been applied, not so much to mediate communication, but more as an information source that could be used during a discussion (Stahl, Koschmann & Suthers, 2006). Computer support in the classroom mainly concerns: 1) “single-display groupware” (Stewart, Bederson & Druin, 1998) where students collaborate with the support of a single, shared computer screen, 2) communicative tools like hand-held devices that support the interaction between the tutor and the students (e.g. Ratto, Shapiro, Minh Truong & Griswold, 2003) but that do not support collaboration between students, 3) collaborative technologies that support the manipulations of visual objects or models in a shared workspace rather than the interactions between students (e.g. Sugimoto, Hosoi & Hashizume, 2004), or 4) the use of new technologies like interactive computer desks (e.g. Cheng, Chang, Deng and Chan, 2005).

A shift from online towards face-to-face collaborative learning brings along a shift in the kind of interactions that are mediated. The starting point for support differs: students can already communicate *without* the support of computers. This observation draws the attention to those interactions that can be facilitated by the collaborative technology *and* that improve learning. It seems that “*less but specific support*” is the leading principle.

Single-display groupware (situation 2, lower right corner of Figure 1.1) supports students by giving them feedback about certain actions that they perform with the use of the computer. It represents a situation where students are co-located and work with a stand-alone computer application. That application typically models a problem situation that the students have to investigate. Students can manipulate the model and receive feedback about their intervention by running a simulation. This feedback triggers a discussion between students about the consequence of their actions. This form of support has received some investment in terms of research (e.g. Roschelle & Teasley, 1995; Munneke, Amelvoort & Andriessen, 2003).

The *third situation* (lower left corner of Figure 1.1) represents a collaborative learning situation where students communicate orally *and* simultaneously use the computer to communicate. Their interactions will be distributed between the two modes of communication, i.e. an oral and a computer mediated part. The combination of verbal and computer-mediated communication is largely ignored by the educational community. It marks a shift in focus from feedback on actions as a means to advance learning like in the case of single-display groupware towards facilitating certain kinds of communication patterns that stimulate group learning.

Bringing Networked-learning to the Classroom

The research that is discussed in this thesis focuses on the third situation of Figure 1.1. It brings networked learning to the classroom to support a group of students who are co-located and interact face-to-face. We describe the development of a networked-learning environment that intervenes in the existing learning situation with the aim to improve collaboration and learning. This intervention has a rather technical character: a collaborative tool is introduced in the classroom that mediates part of the communication. However, the guidelines that form the basis of the intervention refer to the dynamics of small-groups who work together on a learning task.

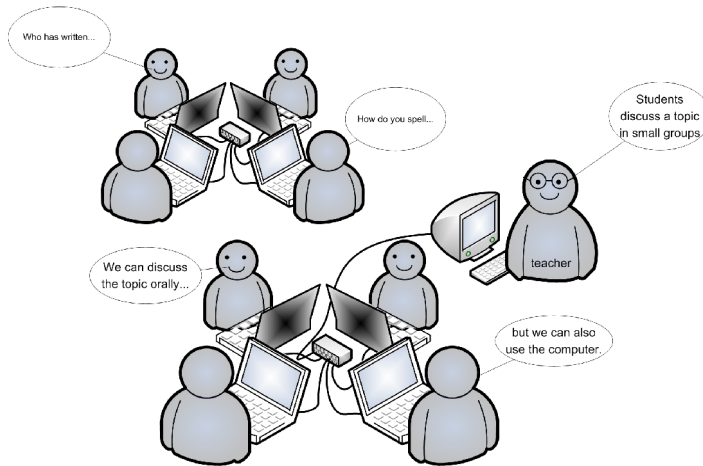


Figure 1.2: The envisioned networked-learning environment.

The objective of the research is to develop two collaborative tools that mediate part of the communication during a small-group discussion. These tools stimulate the occurrence of certain communication patterns that make the desired learning behaviors more likely. Students use – *in addition* to their verbal, face-to-face interaction – the computer to communicate (Figure 1.2). Intuitively, the situation that is displayed in Figure 1.2 seems an odd setting for learning. Why should the students use the computer to communicate when they can easily talk verbally? We expect that improvements do occur because the collaborative tool addresses some problems that can be traced back to verbal communication. The collaborative tool changes the nature of communication so that the groups are better able to carry out a constructive dialogue. The tool offers a number of additional *structural features* that guide the group towards the attainment of their learning goals.

1.5 Questions that Guide the Research

The objective of the research is to develop two collaborative tools that mediate part of the group communication with the aim to improve collaboration and learning. It is expected that the collaborative tools neutralize the *ineffective communication patterns* that can be observed during a small-group discussion. They offer the group an alternative medium to *organize* their communication. They do so by means of structural features that regulate the communicative exchanges in a way that better matches with the criteria of a *constructive dialogue*.

Ineffective Communication Patterns

A communication pattern can be regarded as a recurrent sequence of related communicative acts; it describes the regular flow of communication on a micro level. A pattern entails factors such as the distribution of acts among persons and over time, and the medium used (McGrath, 1984; McGrath, 1991). To improve group learning, we need to understand how the communication is patterned. The communication patterns must be compared to a standard for learning achievement. In our case, the standard is based on the criteria for a constructive dialogue. This brings us to the first research question:

Q1: What are the criteria for a constructive dialogue in terms of requisite patterns of communication?

To answer this question, we will examine research into collaborative learning that relates group communication to learning outcomes. The answer provides us with a set of criteria for understanding small-group discussions. These criteria will be formulated in “media-neutral” terms so that they can be used to study verbal as well as computer-mediated communication. This in accordance with Briggs (2004) suggestion that a theoretical model for the design of collaboration technology must be technology free.

The criteria for a constructive dialogue help us to the identify ineffective communication patterns that inhibit learning during a verbal face-to-face discussion. The second research question aims to identify these patterns:

Q2: Which communication patterns during a verbal face-to-face discussion prevent group members from carrying out a constructive dialogue?

Ineffective communication patterns refer to observable group activities. They can be considered as symptoms for problems that hamper group performance. The causes of these problems will be addressed by the following research question.

Structures that Organize the Communication

The communication patterns that can be observed on the level of the group are closely linked with individual behaviors. For example, interruptions as a dysfunctional communication pattern can be traced back to dominant behavior of a group member who wants to control the discussion. Dominant behavior is a manifestation of a person’s “dominance-submissiveness” trait (Cattell, 1965) that accounts for regularities

in behavior. This does not mean that a person who can be characterized as dominant always displays dominant behavior during a discussion. The actual manifestation of dominant behavior depends on the processes and structures that organize individual actions into group behavior. These processes and structures are situated outside the individual on the level of the group or the larger classroom environment. For example, if a classroom culture is oriented towards competition then the atmosphere will be hostile, while students in a cooperative classroom exhibit more friendly behavior (Johnson, 1980).

The manifestation of individual behaviors depends upon the way the groups couple individual actions into a sequence of collective behavior. Groups apply various structures to organize individual actions into a coherent and meaningful whole. These structures refer to the underlying patterns of stable relationships among group members and include components like roles, group norms or authority (Forsyth, 1983). In this thesis, we focus on structures that can be associated with a particular *medium for communication*. These features of a medium prescribe the content and sequence of communication (Cushman & Kovacic, 1994). They determine how the group members express their ideas and how they organize these individual communicative acts into a coherent and meaningful whole. Turn taking is a good example of a structural feature that can be associated with a specific medium. Turn taking is a type of sequential organization because it concerns the relative ordering of speakers (Schegloff, 2007). Interruptions, for example, are a deliberate violation of the turn-taking principle that states that only one participant talks at the same time. Interruptions that disturb the ongoing discussion are possible because verbal exchanges are organized according to the principle of turn-taking (Sacks, Schegloff & Jefferson, 1974). This example brings us to the third research question:

Q3: How do the structural features of the medium relate to the ineffective communication patterns?

Linking Computer-mediated Communication to Performance

In this thesis, we make a distinction between two kinds of media: 1) a human medium for verbal face-to-face communication, and 2) a digital medium to support computer-mediated communication. The former can be associated with the existing learning situation while the latter refers to the envisioned learning situation.

The collaborative tools provide the groups with an alternative medium that has different structural features to organize the communicative exchanges. It is expected that these alternative structures change the communication and improve the collaboration and learning of groups. The structures of the digital medium stimulate the occurrence of certain communication patterns that better match with the criteria for a constructive dialogue. The challenge for the research is to identify these structures and to implement them in the collaborative tool. It results in the fourth research question that lies at the basis of the design of the two collaborative tools:

Q4: How do the envisioned collaborative tools change the group communication for the better?

Briggs (2004) stated that theory-driven design of collaborative tools should be guided by two types of research questions: a scientific and an engineering one. The scientific questions address issues of group performance. The first three research questions (Q1, Q2, and Q3) fall into this category. The engineering research questions follow from the scientific research questions. Characteristic for these questions is their reference to the technology. Their aim of these questions is to find out how the use of a technology can improve group performance. The fourth research question (Q4) belongs to this category.

1.6 Background: The DUNES and the LEAD project

The research activities that are discussed in this thesis have been carried out within the context of two European funded projects: the DUNES project² and the LEAD project³. The DUNES project focused on argumentative discussions. The project delivered a software system – the Digalo – that enables groups to represent their arguments into a diagram. Initially, the DUNES project was about online learning. We introduced the software in the classroom to support small groups of students who met face-to-face. This shift in orientation laid the foundation for the LEAD project. The LEAD project explicitly focused on face-to-face learning situations where students are co-located and communicate directly with each other.

² The DUNES project (IST-2001-34153) was funded by the European Commission under the IST Programme of Framework V.

³ The LEAD project (IST-2005-028027) was funded by the European Commission under the IST Programme of Framework VI.

The starting point for the LEAD project was the observation that tomorrow's learning will still take place in schools where learners and teachers meet face-to-face (CHEPS scenarios, 2004). These face-to-face learning situations are largely ignored by much of the current research into computer-supported collaborative learning. The LEAD project focused on those collaborative learning situation where a group sits together to discuss a topic orally. The LEAD project assumed that these collaborative situations could be improved with the appropriate collaborative technologies (van Diggelen & Scarano, 2006; van Diggelen & Overdijk, 2006). The project delivered two software applications:

1. CoFFEE (Cooperative Face-to-Face Educational Environment), and
2. Tatiana (Trace Analysis Tool for Interactions Analysis).

CoFFEE

One of the objectives of the LEAD project was to develop and evaluate a networked-learning environment to support problem-solving discussions in the classroom. CoFFEE – the networked-learning environment that was delivered by the project – consists of various tools to support a range of collaborative learning activities. CoFFEE makes a distinction between four types of tools (van Diggelen, 2008):

1. *collaborative tools* to support a particular collaborative learning activity during a group discussion,
2. *shared tools* that enable students to share information relevant for the task or relevant for their performance as a group,
3. *personal tools* for private use, and
4. *communication tools* that allow teachers and students to communicate with each other.

In this thesis, we focus on the development of two collaborative tools that are part of the CoFFEE software system.

Tatiana

Students' ongoing actions within CoFFEE are recorded and stored in log files as interaction data. The software system "Tatiana" supports the researcher who have to

identify, analyze and represent meaningful patterns of interactions from these log files. We used Tatiana to analyze the data of students who worked together with the support of CoFFEE. However, the design of Tatiana is not a topic in this thesis.

1.7 Outline

The research activities that are discussed in this thesis can be situated at the interface between Educational sciences, Social Psychology, and Information Sciences. The object of the research – small-group discussions in the classroom – is a topic that has received a lot of attention in *educational research*. Research into collaborative learning provided us with valuable insights into small-group discussions and the kind of problems that students face. A further analysis of these communication problems relies on social psychological insights about group behavior. It tells us more about the functions of communication in terms of the needs, goals, problems and challenges that groups must satisfy or overcome to be effective (Poole, 1999). The results of that analysis serve as input for the design of two collaborative tools that regulate the communication so that certain learning behavior are more likely to occur. The design of the collaborative tools can be placed in a tradition of research – which has its origin in Information Sciences – that aims to develop and evaluate technologies for collaboration (Keen & Sol, 2008).

The multidisciplinary character of the research is visible in the various chapters: some have a strong educational flavor, while other chapters discuss group dynamics issues. A common theme throughout the thesis is *communication*. Communication is considered as essential for learning to occur in groups, communication processes and structures are a central topic for the study of groups, and communication is one of those human activities that is supported by ICT.

Methodology

The thesis starts with a methodological discussion that covers chapters 2 and 3. There is a need to justify the methodological choices that we made because we do not follow mainstream research where inferences are based on experimental manipulation and independent observations. Instead, we deliberately intervene in an existing real-life learning situation to *create* the phenomenon under study – networked learning – with the aim to generate new insights about the relationship between communication, collaboration and learning.

Chapter 2 presents the approach that guides the research activities. The research approach employs the design process as a means to generate scientific insights. An artifact – in our case a collaborative tool – will be intentionally designed to intervene in an existing learning situation with the aim to create specific outcomes. The design intervention is based on clear expectations of how the artifact changes the existing situation for the better. These expectations can be conceived as hypotheses that are made applicable for evaluation through the artifact.

We argue that a design-based research approach is related to a distinct social ontology, and hence with a particular practical theory. In *chapter 3*, we present that philosophical framework. Collaborative learning will be approached from a Systems perspective. This perspective opens up explanations of groups in terms of functions. A functional explanation differentiates between more and less successful groups. It provides us with an explanatory framework that matches with the design-based research approach, i.e. functionalists often design interventions that make desired patterns of communication more likely (Hollinghead, Wittenbaum, Paulus, Hirokawa, Ancona, Peterson, Jehn & Yoon, 2005).

Theory

The second part of the thesis defines small-group face-to-face discussions in the classroom. This part covers three chapters. It starts with a discussion about the communication patterns that are associated with a constructive dialogue. Next, the focus is on the learning environment of the classroom within which the research takes place. Finally, we discuss the design of the collaborative tools that are used in the classroom with the aim to create the proper conditions for a constructive dialogue.

Chapter 4 addresses the epistemological assumptions of Social-constructivist views that conceptualize group learning as a continuous process of collaborative knowledge construction. The co-construction of knowledge requires specific communication patterns. These communication patterns are presented by four criteria for a constructive dialogue. These criteria serve as a reference for the subsequent research activities.

Chapter 5 discusses the learning environment within which we carried out the research. The research that is described in this thesis deals with real-life problems and it aims to formulate authentic solutions for these problems. These solutions are, on its turn, implemented and evaluated in naturalistic learning setting. It means that we have

little opportunities to examine distinct relationships within a controlled environment. Instead, we need to deal with the situation as a whole or, to put it more formally, as a system. To understand the design interventions, it is therefore necessary to know the nature of the learning environment within which the research takes place.

In *chapter 6*, we discuss the design of the two collaborative tools. The criteria for a constructive dialogue that have been formulated in *chapter 4* served as a reference for the design. They will be used to identify the verbal communication patterns that inhibit learning. An analysis of these ineffective communication patterns focuses on the underlying structural features that organize the verbal exchanges into a coherent and meaningful whole. It acknowledges that a crucial aspect of collaborative learning is the way students manage to coordinate and adjust their actions (Erkens, 2004). The outcomes of the analysis serve as input for the formulation of the design guidelines.

Chapter 6 discusses eight design guidelines that lie at the basis of two collaborative tools. These guidelines contain clear expectations of how the tools mediate and regulate the communication so that certain learning behaviors are more likely to occur. The eight guidelines will be translated into a number of services that describe the behavior of the tool from an user's point of view. These descriptions serve as input for the software development process. It results in two collaborative tools that are presented at the end of *chapter 6*.

Research

The design guidelines that are discussed in *chapter 6* were developed during successive research cycles that lead to a number of adaptations of the initial tool design. The studies that are discussed in third part of the thesis reflect the iterative character of the research. In *chapter 7* and *8* we discuss two studies that aim to “strengthen” the tool design. The outcomes of these studies led to a number of adaptations of the design. These improvements had to do with the way the collaborative tools, as a medium for communication, organize individual actions into collective group behavior. They reflect an increased understanding of computer-mediated communication in face-to-face situations.

Chapter 7 presents a study that investigates the first basic property of the collaborative tools, i.e. parallel access as floor control mechanism. Parallel access allows users to access the shared digital workspace simultaneously. Users can put forward their contributions without any delay or interruptions. The study that is presented in

chapter 7 examines the communication problems that the groups experience when their interactions are based on parallel access. These problems had to do with the coordination of the joint actions in the digital workspace. Problems of this kind had to be solved before we could study the learning effects of the collaborative tools.

Chapter 8 elaborates on the second property of the collaborative tools: an orientation towards effective task-performances. It focuses on two distinct communication patterns – coherence and elaborations – that can be associated with effective task performance. The study that is discussed in chapter 8 analyzes the task-related interactions that can be observed in the shared digital workspace of the collaborative tool. The analysis makes a distinction between the content and the sequence of the computer-mediated actions and interactions.

Chapter 9 presents a large study that evaluates the two collaborative tools that are part of the newly developed CoFFEE software system. The aim of the study is to examine if the introduction of CoFFEE led to a more constructive dialogue. Chapter 9 starts with a discussion of the instructional strategy that makes the collaborative tool suitable for the specific context of use. The instructional strategy describes the sequence of learning activities, the expected outcomes, and the collaborative tools that the groups use. Next, we examine if the communication that is supported by the collaborative tools fulfills the minimal requirements of a group discussion. Finally, we compare the communication patterns of groups who only communicate verbally with groups who use CoFFEE in addition to their verbal communication.

Finally, in *chapter 10*, we draw some conclusions with regard to the research that has been described in this thesis. This chapter reflects the three-part structure of this thesis. We reflect on the design-based research approach, the design of the networked-learning environment and the effects of that environment on small-group group discussions in the classroom.