Minds in Teams

The influence of social and cognitive factors on team learning

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Thank you. Wim Gijselaers, for fostering potency in the light of great ideas. Mien Segers, for an apprentice-master relationship that delivers an optimal (learning) environment. Paul Kirschner and Els Boshuizen, for creating opportunities. PJ Beers, for joining me in this adventure. Sanne Akkerman and her partners in crime, Robert-Jan Simons and Wilfried Admiraal, for looking for a shared mind. Geert Woltjer and Nanine van Gennip, for contributing valuable knowledge and even more important: catching enthusiasm. Henny Dankers and the student-assistants for the bits and pieces. David, Emily, Filip, Gerard, Siesel, my colleagues at the department of educational research and development, my Ridley, and not to forget my parents and family. For creating the right atmosphere that nurtured this dissertation and the researcher behind it.

This book provides evidence for the idea that great teams spring from diversity combined with a fundamental common ground. Els, this is just some other proof of what we knew all along. Thanks for teaming up!

Piet Van den Bossche
Antwerp, 2006

Content

Chapter 1

INTRODUCTION

"The properties of groups of minds in interaction with each other (...) are frequently at the heart of intelligent human performance"
(Hutchins, 1993, p. 62)

Organizations increasingly turn to team-based working to contend with the growing complexity of the environment in which they operate (e.g., Cohen & Bailey, 1997; Salas, Sims & Burke, 2005). It is argued that teams have the potential to offer greater adaptability, productivity and creativity than any one individual can offer and provide more complex, innovative and comprehensive solutions to organizational problems (e.g., Beers, 2005; Salas et al.). Teams can bring together people who have a variety of backgrounds, points of view, education, and/or expertise. Therefore, it is assumed that such teams can bring multiple perspectives to bear on a problem, which allows for the rich problem conceptualization required to solve complex problems (Beers; Vennix, 1996). However, both experiences and empirical research demonstrate that teams are not easily implemented and that the creation of a team of skilled members does not ensure success; teamwork does not just happen (e.g., Hackman, 1989; Salas et al.).

'Office Design Incorporated', a manufacturer of office furniture, implemented teams to promote employee participation and cross-functional elaboration.
However, results are questionable if we hear some of the experiences of the team members:

> *"people try to figure out what [the team leader] wants to hear before saying what they think"* (member of a management team)
>
> *"people speak openly in team meetings, [whereas in other teams] they wait until the meeting is over and speak privately in the hall about their frustrations"* (member of a cross-functional product development team)

(Taken from Edmondson, 1999)

Collaboration with others is also being capitalized upon in educational settings. It is argued that learning is facilitated by interaction with peers on the subject matter. New learning arrangements with a group-/team-work component, such as problem-based learning, project-based learning or team-based learning, are implemented. It is assumed that this will lead to deeper elaboration of the subject matter and facilitate a sense of agency through the tangible accomplishments that can result from collaborative work on interesting problems (Barron, 2000).

Next to comprehension of the subject matter, collaborative learning environments are used as a tool for the development of teamwork skills (Druskat & Kayes, 2000). Since teamwork skills are a prerequisite for graduates (Dowd & Liedtka, 1994), schools have increased the use of team projects as part of their curriculum (Druskat & Kayes), intending to give their students the opportunity to gain experiences in what it takes to deliver good and effective teamwork. However, also in school settings experiences suggest that participation in teams often creates more frustration and dislike of teamwork than appreciation for the diversity of perspectives and improved learning and performance that it makes possible (Druskat & Kayes; Salomon & Globerson, 1989). Research has revealed cases in which large variation in group-work interaction and performance is encountered between teams that seem not to differ in composition and assigned task (Barron, 2000).

Sixth grade triads are confronted with a problem-solving adventure. Significant differences emerge between groups in what they accomplish, the insights that individuals generate and the amount of task-related talk they engage in, despite the equivalence of prior knowledge of group members. Barron made the following observations in trying to grasp the reasons for these differences:

> *"In some of the less successful teams, problematic relational issues did arise. Attention to partners' contributions and the sharing of ownership over the work was lacking. In less successful triads exchanges were oriented toward dominating the problem solving and this may have stemmed from a need to protect one's identity as a competent problem solver, resulting in failures to solve the problem."*

(Taken from Barron, 2003)

The fact that teamwork does not always reach the potential, begs the need for further understanding of the factors that drive the success of a team. This dissertation argues that, fundamentally, both the working teams in organizations and the learning groups in schools are confronted with the same issues; "they are faced with challenges of establishing common frames of reference, resolving discrepancies in understanding, negotiating issues of individual and collective action, and coming to joint understanding" (Barron, 2000, p. 403-404; Roschelle, 1992). Effective collaboration implies a process of building and maintaining a shared conception of a problem (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Roschelle, 1992), which we will define as a shared mental model of the task. This is important, since neglecting certain perspectives on the problem can lead to detrimental effects on constructing appropriate solutions (Vennix, 1996). This dissertation questions which factors and processes influence the construction of a shared mental model of the task at hand, and if this construction leads to increased team effectiveness.

Teams have been the focus of research efforts across the social and behavioral sciences scattered around different disciplines, tackling the subject from different perspectives (Poole, Hollingshead, McGrath, Moreland & Rohrbaugh, 2004). The present dissertation takes a multidisciplinary approach, based on aspects of cognitive, social and organizational research, to grasp the mechanisms that underlie the ability of a team to successfully deal with these challenges. This dissertation aims to add to the growing body of knowledge on teamwork, by integrating cognitive and social perspectives in an effort to understand teamwork.

Integrating perspectives towards a team effectiveness framework

Conceptually, team researchers have converged on a view of teams as complex, adaptive, dynamic systems (Arrow, McGrath & Berdahl, 2000). They exist in larger systemic contexts of people, tasks, technologies and settings (Ilgen, Hoolenbeck, Johnson & Jundt, 2005). For this dissertation we have chosen to rely on a definition of teams that is applicable to both an organizational and an educational setting. The definition is provided by Cohen & Bailey (1997, p. 241): "*A team is a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems*".

Arrow et al. (2000) argue that no sharp line distinguishes interacting teams from uncoordinated collections of individuals. The elements of a team-definition can therefore better be used as criteria to determine how "team-like" a given system of relations is (Arrow et al.). In this light, a well-developed team effectiveness framework can maybe provide a better guideline to determine if real 'teamwork' is established.

Defining a team effectiveness framework

Much empirical research on teams has been guided by practical issues; searching for answers to the generic question of what makes some teams more effective or more viable than others. It addressed input variables such as composition, structures, or reward allocations. More recently, attention was directed to mediating processes that explain why certain inputs affect team outputs (e.g., Dillenbourg et al., 1996; Ilgen et al., 2005).

The input-process-output model has been the foundational conceptual framework for a great deal of empirical studies on team performance (Hackman, 1983). Inputs include knowledge, skills and abilities of group members; composition of the team; and aspects of organizational context such as the task and associated objectives, reward systems, information systems and training resources. Process refers to the interactions among group members, information exchange, patterns of participation in decision making, and social support and sanctions for group-related behavior. Outputs include the products of the group's performance but may also include group viability and the well-being, growth and satisfaction of team members (West & Anderson, 1996).

However, it is argued that a conceptualization in terms of an input-process-output model is at least in one way insufficient; many of the mediating variables that intervene and transmit the influence of inputs to outcomes are not processes (Cohen & Bailey, 1997; Ilgen et al., 2005; Marks, Mathieu & Zaccaro, 2001). For example, variables such as potency (i.e., the belief that the group can be effective) and cohesion (i.e., the resultant of

all the forces acting on the members to remain in the group) have frequently been used to represent processes. It can be stated that these types of constructs do not denote interaction processes, but instead, tap qualities of a team that represent member attitudes, values, cognitions and motivations. Therefore, these types of variables are sometimes called "emergent states", constructs that characterize *properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes and outcomes* (Marks et al., p. 357). The point is that emergent states are not processes in and of themselves because they do not describe the nature of member interaction (Marks et al.). This distinction is important because indices of emergent states are often intermingled with interactional process indicators. Emergent states do not represent team interaction, rather they are products of team experiences and become (new) inputs to (subsequent) processes and outcomes (Marks et al.). Cohen and Bailey made a similar point by stressing the importance of 'psychosocial traits', next to team processes.

This dissertation presents a comprehensive conceptual framework identifying mediating variables influencing team effectiveness. It acknowledges that fundamentally teams are faced with the challenge of establishing a shared conception of a problem, which will be defined as shared mental models. Now, the challenge of creating a shared mental model is foremost a learning endeavor: In order for teams to achieve a shared mental representation of the key elements of the task environment, changes in the knowledge of team members occur. And as such, team learning, defined as the development, modification and reinforcement of mental models through processes of group interaction, plays a central role (Mohammed & Dumville, 2001).
This dissertation adds to the existing literature by developing a learning perspective on the issue of building shared mental models. For this purpose, it integrates insights from different perspectives, drawing from different research strands such as cognitive psychology, social psychology, educational sciences and organizational sciences, to develop a comprehensive account of this perspective.
The foundational conceptual framework of this dissertation is shaped by an extension of the traditional input-process-output model by mediating factors, c.q. emergent states. Concerning the input, the diversity in composition of the team is looked at. Learning behaviors grasp essential socio-cognitive processes. The construction of a shared mental model and the achievement of a beneficial interpersonal context are defined as emergent states and crucial mediating factors, respectively cognitive and social by nature, in teamwork. For output, a broad approach regarding team effectiveness including performance, viability and learning is taken. The following paragraphs take a closer look at the elements of the conceptual framework.

Input

It was argued that the potential of teams is for a large part determined by the people that are brought together, having a variety of backgrounds, points of view, education, and/or expertise. Given this potential, teams can bring multiple perspectives to bear on a problem, which allows for the rich problem conceptualization required to solve complex problems (Vennix, 1996; Beers, 2005). The research on work-group diversity focuses on

dimensions of diversity in team composition and related aspects of group processes and their relation with performance. In this line, this dissertation examines how the structural composition of the team (informational and social category diversity) sets the stage for these processes.

Shared mental model

The idea of shared mental models is proposed as a central issue in understanding (effective) group work (Cannon-Bowers & Salas, 2001; Klimoski & Mohammed, 1994). As such, the aggregation of individuals' knowledge structures creates a context for efficient group decision-making (Cannon-Bowers, Salas & Converse, 1993; Klimoski & Mohammed, 1994). The shared mental model integrates and coordinates the perspectives of the team members. Shared mental models assure that all team members are solving the same problem and help exploit the cognitive capabilities of the entire team (Orasanu, 1990 in Klimoski & Mohammed). This enables the team to have a complex and rich understanding of the task environment (Nosek & McNeese, 1997).

Team learning behaviors

Given the importance of shared mental models, the question then is how these shared mental models develop; and thus, how learning is taking place. In order for teams to achieve a shared mental representation of the key elements of the task environment, changes in the knowledge of team members need to occur (Mohammed & Dumville, 2001). Barron (2003) points out that understanding the development of shared mental models entails an articulation of how characteristics of the interaction (discourse practices) interact with knowledge building processes that lead to shared mental models. This implies that a socio-cognitive perspective is relevant to study team learning. Therefore we build on research in the learning sciences as well as branches of linguistic research on models of conversation, discourse or dialogue. These two disciplines provide a framework on interactions constituting team learning. This dissertation operationalizes the interactions processes as the construction and co-construction of shared mental models. Also, the crucial role of constructive conflict is stressed.

Interpersonal context

The identification of the social conditions under which teams make the effort to reach shared knowledge is an essential prerequisite for developing enhanced understanding of successful teamwork. Viewing collaborative learning as reaching mutually shared cognition, and thus as fundamentally social, stresses the need to take into account the social factors. Therefore, this dissertation focuses on emerging team-level beliefs about the relations between the team members; in other words beliefs about the interpersonal context. We identify a number of powerful group-level beliefs which potentially affect the learning behavior in teams: psychological safety, cohesion, potency and interdependence. It is hypothesized that teams will engage in learning behavior when specific social conditions are realized; first, there has to be a shared commitment towards the task at hand (task commitment), further they have to believe that they need each other for dealing with this task (interdependence), third, they believe they will not be rejected for proposing ideas (team psychological safety), and they believe that the team is

capable of using this new information to generate useful results (team potency).

Output

A broad approach to effectiveness is taken to grasp the effects of the mediators on team effectiveness. Hackman (1989) conceptualized the multiplicity of outcomes that matter in organizational settings in three ways. Not only is the degree to which the team output meets the standard of quality (performance) of importance, but also the degree to which the process of carrying out the work enhances the capability of members to work together in the future (viability). Next, the degree to which the team work contributes to the professional growth of the team members (learning) need to be taken into consideration. These three dimensions are also of crucial importance from an educational perspective. Education aims to support students in their individual development (growth as an output measure); to deliver graduates who are able to solve the professional problems they encounter (performance) and who can contribute to enduring teamwork environments (viability).

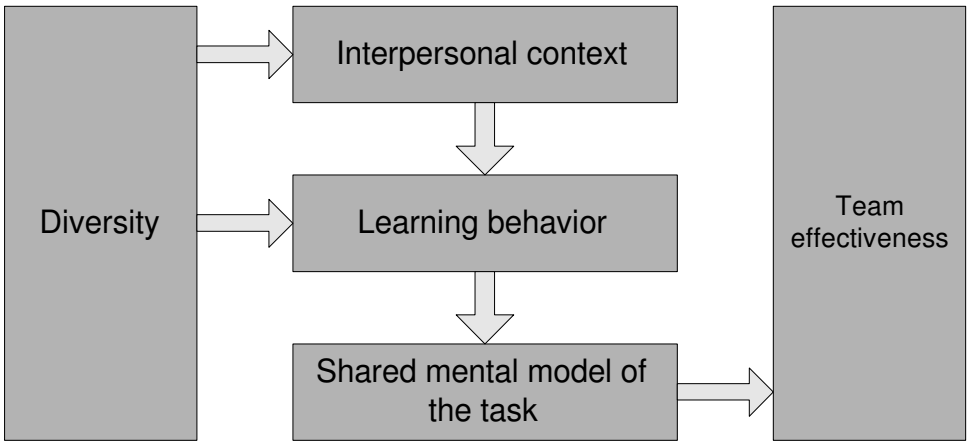

Figure 1: Team-effectiveness framework

Figure 1 depicts the team-effectiveness framework which forms the basis of the studies presented in this dissertation. It includes the identified mediators, and also aspects of the input and outcome are considered. The model states that beliefs about the interpersonal context shape the willingness to engage in learning behavior. And that learning behavior gives rise to shared mental model of the task, leading to higher team effectiveness. Furthermore, it indicates that the structural composition of the team sets the stage for these mediating factors and processes.

Overview of the studies

In this dissertation four studies will be presented which elaborate and question, each in their own way, aspects of the framework as it is presented in this introduction.

A comment regarding terminology
Shared mental model is one of the central constructs in this dissertation. Some comments need to be made to clarify the terms that are used in this dissertation to denote the construct. In the review (chapter 2) we use the term group cognition as a general term to grasp all potential conceptualizations of the construct. So, shared mental model can be considered as a specific conceptualization of the construct 'group cognition'.
In the first empirical study we use 'mutually shared cognition' to denote a specific conceptualization of 'group cognition'. The definition of mutually shared cognition in that study is similar to the definition of shared mental model used in the following studies. However, the methodology is fundamentally different in the first empirical study. In this first study we base our methodology on the perception of the team members, where in the in the other studies we try to grasp shared mental models by using cognitive mapping techniques. Since we argue in the review (chapter 2) that conceptualization and methodology go hand in hand, it seemed appropriate to use different terms to stress the difference.

1) A review on the literature considering group cognition.

The review tackles the fundamental problem of conceptualizing 'group cognition' from which shared mental models is an instantiation. The purpose of the review is to compare conceptualizations of group cognition; that is, to assess differences and similarities in how 'group cognition' is conceptualized in the empirical literature in educational and psychological sciences. A framework is presented on which we will rely to highlight the important dimensions on which these conceptualizations differ. This framework draws on two socio-genetic views, representing two different perspectives on the social nature of cognition. The results of this literature review guide us in the conceptualization and choice of methodology in the empirical studies.

2) Social and cognitive factors driving teamwork in collaborative learning environments.

This study specifies and elaborates the social and cognitive mediators of the framework. More specifically, this study explores the relations between the interpersonal context emerging in the team and the learning behaviors that take place. Furthermore, the influence on the construction of mutually shared cognitions in the team (i.e., the shared mental model as perceived by the team members) is questioned. The model that is explored can be presented as in figure 2.

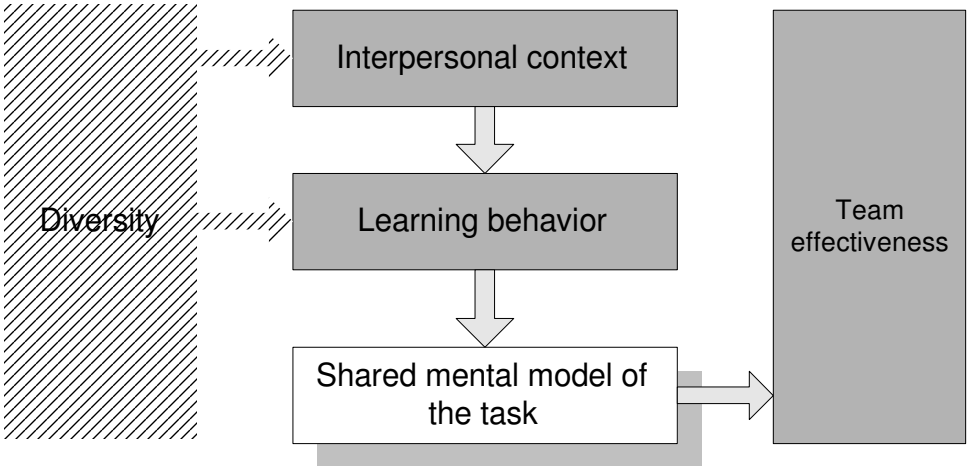

Figure 2: Model first empirical study

3) A study on team learning and its effect on shared mental models

The second empirical study wants to research in-depth some aspects of the model that was validated in the first empirical study. To gain insight in the social processes that lead to shared mental models, this chapter questions which team learning behaviors lead to the construction of a shared mental model. Differentiation is made between different kinds of team learning behaviors: construction, co-construction and constructive conflict. Additionally, it explores how the development of shared mental models mediates the relation between team learning behaviors and team effectiveness. Extensive attention is also paid to the difficult issue of measurement of shared mental models in teams. The underlying model of this study can be pictured as in Figure 3.

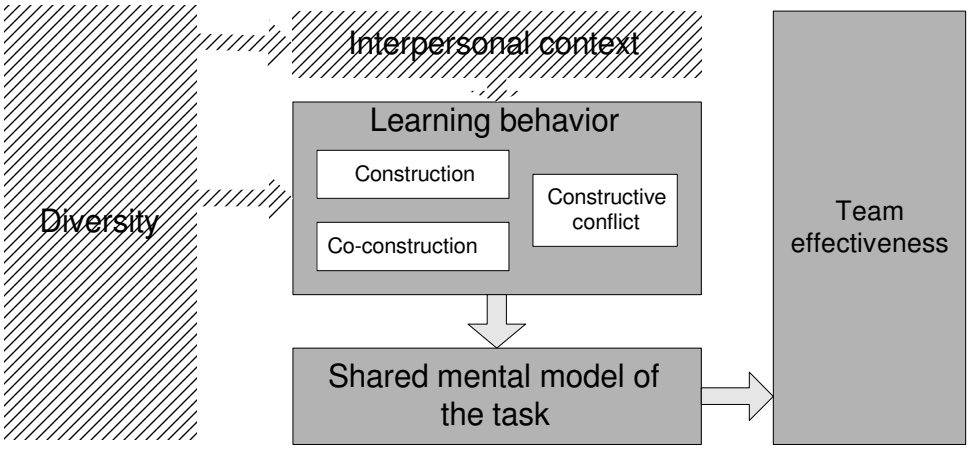

Figure 3: Model second empirical study

4) Diversity in teams

The last study in this dissertation questions the mechanisms underlying diverse teams affecting team performance. It does so by connecting the findings of the previous studies to the findings of the research-on-diversity literature. The focus is on dimensions of diversity in team composition and related aspects of group processes. The information/decision-making perspective in this line of research looks primarily at disagreements on task-issues in teams, so-called task conflicts, as a key process linking

team composition with performance (van Knippenberg, De Dreu, & Homan, 2004). This perspective is supplemented with insights from the other studies presented in this dissertation; the importance of learning behaviors as constructive conflict and the role of interpersonal factors to explain effectiveness. Again, we examine whether the development of shared mental models is a crucial mechanism in explaining team effectiveness. The model underlying this study is presented in figure 4.

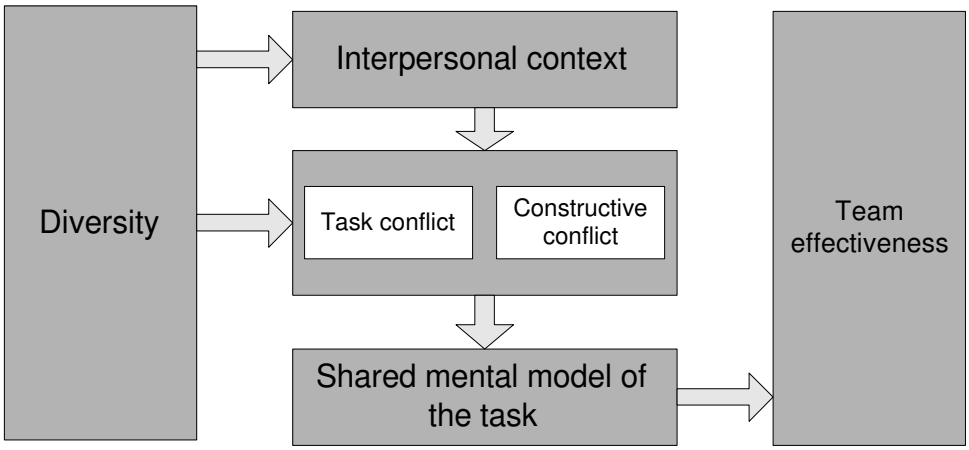

Figure 4: Model third empirical study

The final chapter reviews the major insights of the different studies. Furthermore it discusses challenges and future directions for the research related to the social and cognitive factors facilitating effective teamwork.

Note

This dissertation is not a book in the traditional sense but a collection of highly related articles. Since every chapter is written to be read on its own, repetitions and overlap across chapters are inevitable.

References

Arrow, H., McGrath, J. E., & Berdahl, J. L. (2000). *Small groups as complex systems. Formation, coordination, development and adaptation*. Thousand Oaks, California: Sage Publications, Inc.

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

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

Beers, P. J. (2005). *Negotiating common ground: Tools for multidisciplinary teams.* Unpublished doctoral dissertation. Open Universiteit Nederland, Heerlen.

Cannon-Bowers, J. A., & Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behavior, 22*, 195-202.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed.), *Individual and group decision making: Current issues*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, S. G., & Bailey, D. E. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management, 23*, 239-290.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in humans and machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford, UK: Elsevier.

Dowd, K. O., & Liedtka, J. (1994). What corporations seek in MBA hires: A survey. *The Magazine of the Graduate Management Admission Council*, 2.

Druskat, V. U., & Kayes, D. C. (2000). Learning versus performance in short-term project teams. *Small Group Research, 31*, 328-353.

Edmondson, A. C. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350-383.

Hackman, J. R. (Ed.). (1989). *Groups that work (and those that don't). Creating conditions for effective teamwork.* San Francisco, CA: Jossey-Bass.

Ilgen, D. R., Hollenbeck, J. R., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output models to IMOI models. *Annual Review of Psychology, 56*, 517-543.

Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management, 20*, 403-437.

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26*, 356-376.

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*, 89-106.

Nosek, J. T., & McNeese, M. D. (1997, March). *Issues for knowledge management from experiences in supporting group knowledge elicitation & creation in ill-defined, emerging situations.* Paper presented at the AAAI Spring Symposium Artificial intelligence in knowledge Management, Stanford University.

Poole, M. S., Hollingshead, A. B., McGrath, J. E., Moreland, R. L., & RohrBaugh, J. (2004). Interdisciplinary perspectives on small groups. *Small Group Research, 35*, 3-16.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*, 235-276.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "Big Five" in teamwork? *Small Group Research, 36*, 555-599.

Salomon, G. & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research, 13*, 89-99.

Van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*, 1008-1022.

Vennix, J. A. M. (1996). *Group model building. Facilitating team learning using system dynamics*. Chichester: Hohn Wiley & Sons.

West, M. A., & Anderson, N. R. (1996). Innovation in top management teams. *Journal of Applied Psychology*, 81, 680-693.

Chapter 2

Reconsidering Group Cognition: From Conceptual Confusion to a Boundary Area between Cognitive and Socio-cultural Perspectives?*

Various strands of research in educational and organizational psychology focus on structures of collectively created meaning that emerge in and coordinate activities of groups. Despite expanding, this field still lacks a lack of conceptual clarity, enhanced by the multitude of terms used, such as common ground, shared understanding, collective mind, team mental models, and distributed cognition.
We conducted a review of the conceptual frameworks being used in empirical studies. To understand the premises of the conceptualizations, we connected these conceptualizations to either cognitive or socio-cultural perspectives on the social nature of cognition. Some studies are identified as representing initial ways of boundary crossing between these perspectives. To conclude, we explore ways for boundary crossing and suggestions are made to foster more conceptual clarity and cross-fertilization in future research.

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* Based on:

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., Simons, R.-J., & Kirschner, P.A. (submitted). Reconsidering group cognition: From conceptual confusion to a boundary area between cognitive and socio-cultural perspectives? (first two authors must both be considered as first authors).

There is a growing attention for collaboration between people. Group work has become a cornerstone of organizational life and it is increasingly being capitalized on in educational settings. Organizations rely on teams to deal with the increasingly high-demands of the environment. This is most obvious in the multi-disciplinary/-functional teams that are brought into action to deal with complex problems (Derry, DuRussel, & O'Donnel, 1998; Hall, Stevens, & Torralba, 2002). Fundamentally, both the working teams in organizations as the learning groups in schools are confronted with the same issues; "they are faced with challenges of establishing common frames of reference, resolving discrepancies in understanding, negotiating issues of individual and collective action, and coming to joint understanding" (Barron, 2000, pp. 403-404). Collaboration is hereby a process of building and maintaining a shared conception of a problem (Dillenbourg, Traum, & Schneider, 1996; Roschelle, 1992). Concomitantly, studying groups and group collaboration has become an important area of research (Cohen & Bailey, 1997). Both in educational and psychological literature there is an identification of the need to study group learning as truly collaborative (Crook, 1998). Researchers became convinced that an individual approach will not fully grasp the phenomenon of group-work and group-learning (Thompson & Fine, 1999). Several cognitive constructs, such as mental models, which have traditionally been considered at the individual-level of analysis, now become recognized as group-level phenomena (Klimoski & Mohammed, 1994). In trying to grasp and understand this collaborative effort, new research interests focus on the ways groups are creating meaning and are acting upon collectively developed cognition (Thompson, 1998).

The growing interest in this group cognition can be recognized by a multitude of terms that can be found in the literature, such as common ground, team mental models, shared understanding, distributed cognition and collective mind. These terms all do refer in some way to structures of collective meaning that emerge in and coordinate the activities of a group. The idea of group cognition is proposed as a central issue in understanding (effective) group work. Group cognition is argued to provide a basis for the coordination of individual actions as well as for future communication and activity of the group (Clark & Brennan, 1991; Hutchins, 1995). In the learning sciences it is pointed out that the development of group cognition is related to the learning potential of groups (Roschelle, 1992; Webb & Palincsar, 1996). The development of group cognition is a process of negotiating and interrelating diverse views of group members. This process enables group members to learn from others' preferences and viewpoints by facing different viewpoints and by accepting the existence of them as legitimate (Engeström, Engeström, & Kärkkäinen, 1995). Moreover, this process is argued to lead to rich argumentations and creative problem solutions (Homan, 2001; Matusov, 1996), as well as to the members experiencing ownership of the activity and of group products (Fiol, 1994; Mohammed & Ringseis, 2001). The recognition of these merits made it a worthwhile endeavor for many researchers to study the processes in and through which group cognition is actually developing, potentially leading to new ways of improving group practice and group learning (Cannon-Bowers & Salas, 2001b).

Although the research on group cognition attracts a great deal of interest and is considered to be valuable, it is confronted with some difficulties (Cannon-Bowers & Salas, 2001b; Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994; Matusov, 1996). In the past, some articles were published which tried to combine the conceptual developments and empirical results in fields that are concerned with the idea of group cognition (Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994; Thompson & Fine, 1999). These reviews acknowledge the usefulness and potential of the construct, and recognize that this is a promising line of research, but at the same time they also stress the need for more fundamental theoretical work before this potential can be realized. More specifically, they urge for theoretical integration:

> (...) we have established that despite the popularity of the concept, many authors have been very casual in its application. Most disconcerting, many writers do not really define what they mean by a shared or team mental model. There is a surprising lack of definitional or conceptual clarity. Also problematic, when attempts at definition have been made, different authors have defined things in alternative (usually in incomplete) ways. In our view, part of the problem is that writers in a particular area often do not cite the literature in other areas that may be referring to the same concept of interest (albeit with a different name). To put it another way, heretofore there have not been much "cross-fertilization". Various writers seem to be "re-inventing the wheel" (Klimoski & Mohammed, 1994, pp. 426-427).

Cannon-Bowers and Salas (2001b) have tried to describe the issues and problems the field is confronted with, and the issues on which conceptual clarity is lacking. Primarily, the literature is neither consistent in labeling nor defining concepts of group cognition. Therefore it becomes unclear what is referred to by group cognition. We already noted that different authors use multiple terms to indicate group cognition. There are also substantial differences in the meaning of the concept. This can be illustrated by comparing the following three studies. Carley (1997) examined the "team mental model" by looking at the similarity of declarative and procedural knowledge about the task. A different study is that of Levesque, Wilson and Wholey (2001), who examined under the label "shared mental model" the similarity of cognition about the team processes and expertise in the team. Yet another study of Yoo and Kanawarranachai (2001) focused on the 'collective mind' of groups, hereby referring to the social cognitive system in which individuals heedfully interrelate their actions. Besides the use of different terms and meanings, sometimes the same terms are used with different meanings. For example, Matusov (1996) argues that traditionally "intersubjectivity" is studied with a focus on processes of unification of the participants' subjectivities, while he pleads for a focus on how participants coordinate their contributions in the joint activity. A different definition of intersubjectivity lies behind these various approaches.

Cannon-Bowers and Salas (2001b) warn that clear statements of what group cognition is and how it operates become impossible as long as there is conceptual confusion. One of the problems emerging from this is the usage of very distinct measurement approaches in different studies. For example, whereas Levesque et al. (2001) and Carley (1997) measure mental models of individuals and try to compute some kind of similarity as

indicator for group cognition, Yoo and Kanawarranachai (2001) ask the team to evaluate the interrelations of the actions in the team as a whole and use this as an indicator.

The lack of clarity encountered in this area of research, makes it difficult to make use of and build forward on the various empirical studies, since it is unclear how the empirical studies relate to each other as they use many different concepts as well as different, but often implicit, understandings of group cognition. Both the research on group cognition and the practice of groups and group learning, or the optimization of this practice, would benefit from an awareness of the different conceptualizations being used. This would encourage future research to build upon previous results and could deliver guidelines for both conceptualizing the object of study and choosing research methodologies. It opens the possibility to compare the evidence gathered, potentially leading to more general conclusions, and building a ground for new questions and approaches.

The purpose of this review is to compare conceptualizations of group cognition; that is, to assess differences and similarities in how "group cognition" is conceptualized in the empirical literature in educational and psychological sciences. The various conceptualizations will be framed in order to lay the ground for conceptual clarity that enables to build on each others work. This conceptual review is not intended to provide a complete and final overview of empirical studies on group cognition nor present the specific findings. Rather, the review is meant to cover and structure the broad range of conceptualizations. We will present a framework on which we will rely to highlight the important dimensions on which these conceptualizations differ from each other. This framework draws on two socio-genetic views, representing two different ideas about the social nature of cognition. How one understands the social nature of cognition is fundamental for conceptualizing group cognition. Therefore this framework is considered to be of value to map the types of conceptualizations of group cognition that are found in the empirical literature.

The plan for this review is as follows. In the next section, we will first elaborate on the framework in which we distinguish cognitive and socio-cultural perspectives. This will be followed by a method-section in which we describe how we used this framework to analyze the differences in conceptualizations that are present in the empirical literature. Next, we will present the results of this analysis. We found that the studies on group cognition can be categorized into three types of conceptualizations of group cognition. Hence, in the results section these three groups of studies are discussed, respectively illustrating understandings of group cognition according to cognitive perspectives, socio-cultural perspectives, and those that seem to be on the boundary between these perspectives. We will characterize each group of studies by showing how the concepts referring to group cognition are being treated, both conceptually and operationally. We will end up by arguing how these different types of conceptualizations complement each other, and we will also explore how to reach more conceptual clarity and cross-fertilization in future research.

Two socio-genetic views: Cognitive and socio-cultural perspectives

To address the question of how to frame the diversity of conceptualizations of group cognition, this chapter draws on two socio-genetic views, underlying cognitive versus

socio-cultural perspectives, which are distinguished by Valsiner and Van der Veer (2000). In doing so, it also questions the value and the possibilities of an initial reconciliation between these perspectives. The reason for turning to socio-genetic views is that they entail basic ideas about the social nature of cognition. The socio-genetic views raise fundamental questions for conceptualizing group cognition. Therefore we will elaborate on these views, resulting in a framework that helps to grasp the differences in conceptualizations of group cognition. Although departing from the socio-genetic views presented by Valsiner and Van der Veer, we will also consider the literature on this issue in general educational and psychological theorizing, specifically on the controversy between the socio-genetic views.

In educational and psychological theorizing an individualistic approach towards the human mind was, and perhaps still is, dominant. This approach has been questioned for its lack of providing a meaningful account of social interactions (Thompson, 1998). At present, most social scientists seem to acknowledge that human psychological functions stand in close relationship with the social environment in which they are situated (Valsiner & Van der Veer, 2000). As such, individual learning and development is studied as involving social aspects (Salomon & Perkins, 1998). Through acknowledging the importance of the social practices in which the individual is engaged, the dispute is no longer about the appropriateness of the individual versus the social collective as unit of analysis (Cobb & Bowers, 1999). Rather, there is confusion about how the actual relation between the person and the social should be conceptualized. Valsiner and Van der Veer distinguished two socio-genetic views that theorize this relation differently. They state "there is the axiomatic preference for fusion (of person and the social environment) or inclusive separation (i.e., the person is viewed as distinguished from the environment, yet interdependent with it) bases for socio-genetic models" (p. 6). Whereas the former socio-genetic view perceives the person and the social environment as one whole and relies on terms like participation and adaptation, the latter socio-genetic view perceives the person and the social environment as separate units that are related to each other and uses terms such as internalization and externalization. Sfard (1998) notes a similar distinction of perspectives when she describes two different learning metaphors. The first, more traditional metaphor being used is the acquisition metaphor, wherein learning is seen as acquiring knowledge. The subject of learning is the individual who acquires knowledge about the world surrounding him/her. A learning theory that is based on this metaphor is cognitivism. The second metaphor is the participation metaphor, wherein learning is seen as a process of becoming participant in a community. The learner is then also seen as a participant, and knowledge is rather an aspect of discourse and activity. Knowledge is preferably referred to as "knowing". This metaphor is said to be related to socio-cultural views of learning. Additionally, Salomon and Perkins (1998) noted that the different ways of understanding social contributions to learning are the result from different ideas about where information processes lie (within the individual mind versus within social interaction) and about what entity these processes serve (the individual or a social entity). It is the first dimension, where information processes lie, that distinguishes the two socio-genetic views. Combining

these distinctions, the one view on socio-genesis is the "inclusive separation" view, which is related to the "acquisition metaphor" and connected to "learning within the mind". The other view on socio-genesis is the "fusion" view, which is related to the "participation metaphor" and connected to "learning within social interaction".
These two socio-genetic views also lay behind a previous discussion between researchers from the cognitive perspective and those from the situated perspectives as found in psychological theories (Anderson, Reder, & Simon, 1996, 1997; Cobb & Bowers, 1999; Greeno, 1997). Also, several attempts have been made to create initial bridges between the two perspectives (Billet, 1996; Gauvain, 2004; Glick, 2004; Greeno, 1998; Saxe & Simonde, 2004). In order to arrive at a framework for our review, we have scrutinized how these authors characterized and positioned the socio-genetic views, and determined what distinctive conceptual dimensions are associated with them. The results are summarized in Table 1.

Table 1
Socio-genetic views: Cognitive and socio-cultural perspectives

Distinctive conceptual dimensions	COGNITIVE PERSPECTIVES "Inclusive separation" socio-genesis (Valsiner & Van der Veer, 2000)	SOCIO-CULTURAL PERSPECTIVES "Fusion" socio-genesis (Valsiner & Van der Veer, 2000)
The individual	Individual as autonomous; promotes individuality	Individual as participant; absorbs the individual in social practices
The social world	Contexts of performance	Evolving systems of socially organized discourse and activity
Individual-social	Individual actions can be independent of social structures or interactions	All individual activity involves socially organized activity
Cognition	Individually constructed structures in memory consisting of conceptual and procedural knowledge	Dispositions to agree with certain propositions being culturally shaped and patterned by social and cultural circumstances
Learner	(Re-)constructor	Peripheral participant, apprentice
Learning	Entails gaining possession over some commodity	Entails contribution to an individual's identity as valuable participant in social practices
Knowledge	is considered a structure in the person's mind, and as such a property, possession, or commodity of the individual	is considered as knowing, and as such an aspect of discourse and activity
Key terms	knowledge, concepts, meaning, schema, representation, reception, acquisition, construction, internalisation, transmission	knowing, practice, activity, discourse, communication, social mediation, participation, belonging, situatedness, contextuality, cultural embeddedness

In this chapter, we have chosen to use the general term "cognitive perspectives" which is associated to the inclusive separation view of socio-genesis and in a general sense the term "socio-cultural perspectives" to refer to the fusion view of socio-genesis.
As pointed out in Table 1, an essential difference between the two socio-genetic views is encapsulated in the understanding of the individual. In the one view, underlying cognitive perspectives, the individual is seen as an autonomous agent, an active person who constructs personal understanding of the world surrounding him or her. This understanding is reflected in a mental network of internal constructs of meaning stored in memory. The social world surrounding the individual is seen as a set of social contexts in which the person acts. These contexts are considered important and although complex, they can be analyzed through its components. The individual moves through these contexts, responds to them and is affected by them. These notions indicate that the social is certainly not denied by these perspectives, but that the social is understood through its residence in the mind of the individual.
In the fusion view of socio-genesis, underlying the socio-cultural perspectives, the individual is seen as a participant in social practices, in which he/she is interacting with others and with material and representational systems. Participating in social and cultural practices contributes to the construction of the participants' dispositions to agree with certain propositions or routine practices, and as such to his or her identity. The socio-cultural perspectives do not deny the existence of an individuals' mind, nor its agency, but they understand this mind as situated in the participation processes in systems of socially organized activity that are themselves evolving.
Research on group cognition can be identified that seems to be starting from either a cognitive or a socio-cultural perspective. However, although representing two fundamentally different socio-genetic views, this is rarely made explicit. As these socio-genetic views both convey a specific understanding of the social nature of cognition, they both can be considered relevant for conceptualizing group cognition. To understand the concept of group cognition, one has to deal with what is meant by *cognition* as well as what is meant by cognition at *a group-level*. This entails defining cognition (where does it reside?) and defining cognition in terms of individual and social dimensions (how are they related?). For that reason, we will use the framework presented in Table 1 to outline the important dimensions on which the conceptualizations of group cognition in empirical studies differ. Hereby, we reach beyond the definition given by authors and try to disclose their premises regarding socio-genetic views.

Method

Literature search

The goal of the literature search was to gather a representative sample of the multiplicity of conceptualizations of group cognition. Hereto, the search was based on a variety of terms that refer to group cognition. Based on our first readings of studies, we composed a list of synonyms, looking initially at all combinations of:

- Words implying cognition: capital, cognition, frame of reference, framework, ground, intersubjectivity, meaning, mental model, mind, perspective, position, representation, thinking, understanding, view, vision, voice;
- Words referring to the aspect of group: collective, common, distributed, group, joint, mutual, shared, social, team.

In the search, these terms were always combined with the search terms "group" or "team"[1]. Two major computerized databases were screened: The Educational Resources Information Centre (ERIC) catalogue and PsycLIT. These databases give access to materials from the educational and psychological sciences, but also from related disciplines such as organizational behavior, medicine, social work, law and criminology.
A first selection of the studies was based on the abstracts; in a next step also the complete articles were screened. Those studies were selected which had group cognition as a central object of study (we were not interested in studies that only marginally touched upon the idea) and they had to study this idea at the group level (some studies consider this idea at for example organizational level). Furthermore, we were primarily interested in empirical studies on group cognition (a lot of studies mention group cognition terms but do not study it as such). The reason for focusing on empirical studies was that we wanted to reach an in-depth understanding of how the author conceptualized the idea of group cognition. Therefore, we did not only focus on the explicit meaning attributed to the concept of group cognition by the author as shown in the theoretical background and definitions of the concept, but also on the meaning-as-used by the author. The latter is best shown in the research methodology being used to measure the concept in the empirical part of the studies. Although non-empirical work was taken into account for the development of the theoretical framework, this work was not included in the analysis. This resulted in 22 studies.

Analyzing the literature

Using conceptual literature as a guide (e.g., Cannon-Bowers & Salas, 2001b; Klimoski & Mohammed, 1994) we summarized the studies we selected based on a range of characteristics (study aim, theoretical assumptions, concept used for and definition of group cognition, study design, group characteristics, task of the group, time, method of analysis, measurement of group cognition, antecedents and consequences of group cognition and the subsequent analysis, conclusions of the study). This resulted in a table of review used as a tool for further analysis.
Our analysis aimed to question in what respects these conceptualizations differ, using the socio-genetic views as framework. First, studies were categorized as representing a cognitive or a socio-cultural view on group cognition. This categorization was as a result of the conceptual dimensions in Table 1, and determined holistically whether the theoretical framework of the study represented more the cognitive or the socio-cultural perspectives. The first two authors of this paper were concerned with categorizing the

1 Some combinations already included the term group or team, for example 'group cognition' or 'team mental models'. In the other combinations it was necessary to limit the search to those studies that were looking at group level.

studies. In most cases, both authors came to the same categorization. The few cases of doubt were resolved after discussion. This resulted in 11 studies representing a cognitive perspective, 5 studies representing a socio-cultural perspective, and 4 studies having characteristics of both socio-genetic perspectives. These latter studies were classified as "boundary crossing studies". Two studies were found that neither related to the cognitive nor to the socio-cultural perspectives (Hare & O'Neill, 2000; Mulder, Swaak, & Kessels, 2002). The two studies defined the construct of group cognition in a general way and therefore added minor insight in the conceptualizations in the study. In the theoretical introductions we found no more implicit understandings of the concept than is expressed by these definitions. Subsequently, in their analysis they used the method of self assessment, asking group members for their perceptions of the development of group cognition in the group in which they participated. They did not analyze group cognition itself. Because the conceptualizations could be derived from these studies, they were excluded from further analysis.

After categorizing the studies, we analyzed them and focused on the socio-genetic issues "where cognition resides" (how is *cognition* conceptualized), and "how the individual and the social relate" (how is cognition conceptualized *at group-level*). We will discuss how the different studies in the discerned groups of cognitive perspectives, socio-cultural perspectives and boundary crossing studies dealt with these two questions. In addition to this categorized description, the appendix provides a short overview of each individual study (i.e. the conceptualization and analysis of the group cognition-construct).

Overview of the empirical studies on group cognition

Cognition

First, we explicitly looked at the diverse *interpretations* of cognition, referring not only to the kind of asset or quality that group cognition entails, but simultaneously where this particular asset or quality is considered to be localized. Second, we describe how the groups of studies *analyzed* cognition. We will respectively discuss studies reflecting cognitive perspectives, socio-cultural perspectives and those that reflect both perspectives (the boundary crossing studies).

Cognitive perspectives

As for the conceptualization of cognition, the studies connected to the cognitive perspectives refer to the knowledge of the individual team members. More specifically, these studies rely mostly on the construct of mental models (Klimoski & Mohammed, 1994). This construct assumes that individual people organize knowledge into structured, meaningful patterns and store them in their memory (Johnson-Laird, 1983; Rouse & Morris, 1986). Some of the authors (Druskat & Pescosolido, 2002; Edelson, 2000; Levesque et al., 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Peterson, Mitchell, Thompson, & Burr, 2000) point out how these mental model function, hereby showing the crucial importance of this construct for understanding (team) performance. Reference is often made to the definition offered by Rouse and Morris (1986): "mechanisms whereby humans generate descriptions of system purpose and form,

explanations of system functioning and observed system states, and predictions of future system states" (p. 360). Mental models enable team members to form accurate explanations of and expectations for their environment (Levesque et al., 2001), and in turn allow them to coordinate their actions and adapt their behavior to demands of the environment (Cannon-Bowers, Salas, & Converse, 1993).

There are several types of mental models, containing different kinds of content. Each of these different types of models is considered to be relevant for the functioning of teams (Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994; Mathieu et al., 2000; Rentsch & Hall, 1994). The most elaborated categorization of the types of mental models and their knowledge content is proposed by Cannon-Bowers et al. (1993). They discern four *types of mental models* that can be shared in teams:

- Task model (e.g., group cognition regarding task strategies, environmental constraints);
- Team interaction model (e.g., group cognition regarding interactions patterns, roles/responsibilities);
- Team model (e.g., group cognition in terms of awareness of team-mates' knowledge, skills);
- Equipment model (e.g., group cognition regarding a shared idea about equipment functioning, operating procedures).

As indicated in Table 2, the studies reviewed primarily focus on task and/or team interaction as the type of mental model. Only Levesque et al. (2001) did also study the mental models of team members about each other's expertise (team model). None of the studies considered the equipment model.
The analysis of the studies from a methodological perspective indicates that two different aspects of the mental models as a knowledge structure are considered: (1) the content aspect or the possession of certain knowledge, and (2) the structural aspects or the specific way the knowledge base is structured. Therefore, in trying to understand the individual mental model, the literature (e.g., Langan-Fox, Code, & Langfield-Smith, 2000; Mohammed & Dumville, 2001) claims that two issues need to be taken into consideration. One is elicitation; a procedure used to ascertain the content of the mental model. The other issue is representation; a procedure used to determine the relation between the content elements or the structure of the mental model.

Table 2
Characteristics of the Studies in Cognitive Perspectives

Studies in cognitive perspectives	Interpretations of cognition: (type of model:)	Analyzing cognition by: (measurement techniques of the individual mental models:)
Mathieu et al. (2000)	Task model Team interaction model	Relatedness ratings (elicitation + representation)
Peterson et al. (2000)	Task model Team interaction model	Likert-scale questionnaires (elicitation)
Ensley & Pearce (2001)	Task model	Likert-scale questionnaires (elicitation)
Carley (1997)	Task model	Idiosyncratic information (elicitation + representation)
Marks et al. (2002)	Task model	Relatedness ratings, Concept mapping (elicitation + representation)
Stout et al. (1999)	Task model	Relatedness ratings (elicitation + representation)
Mohammed & Ringseis (2001)	Team interaction model	Likert-scale questionnaires (elicitation)
Levesque et al. (2001)	Team interaction model Team model	Likert-scale questionnaires (elicitation)
Langan-Fox et al. (2001)	Team interaction model	Relatedness ratings (elicitation + representation)
O'Neill et al.(1999)	Task model	Group discourse and activity
Edelson (2000)	Team interaction model	Likert-scale questionnaires (elicitation)

A part of the analyzed studies (see Table 2) elicit the mental model content using Likert-scale questionnaires (Edelson, 2000; Ensley & Pearce, 2001; Levesque et al., 2001; Mohammed & Ringseis, 2001; Peterson et al., 2000;). Hereby, these studies did not look at the representation or structure of the mental models. The other studies look at both elicitation as well as representation of the mental models, using three different kinds of techniques. One technique being used is relatedness ratings (Marks, Burke, Sabella, & Zaccaro, 2002; Mathieu et al., 2000; Langan-Fox, Wirth, Code, Langfield-Smith, & Wirth, 2001; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). In this technique individual team members are asked to judge the relatedness of concepts provided by the researcher. This information is then used by most authors (except for Langan-Fox et al., 2001) as input for the analysis, using programs as Pathfinder and UCINET. This allows for generating each group member's mental model. Concepts that are highly related to one another are more closely linked within the structure (Kraiger, Salas, & Cannon-Bowers, 1993). A second technique used is concept mapping (Marks et al., 2002), in which participants are asked to choose from a range of concepts and place them in a pre-specified hierarchical structure. A third technique, used in one of the studies (Carley, 1997), is that of using idiosyncratic information of the team members. In this particular

study the participants responded essay questions. The resultant texts are supposed to contain a portion of the author's mental model at the time the text was created (Kaufer & Carley, 1993). An automated approach of the cognitive mapping technique was used to extract the concepts and the relations between these concepts out of these texts. This resulted in a map, a network of concepts that was considered as an elicitation and representation of the individual's mental models (Carley, 1997). The difficulty of the first two techniques is that the concepts relevant to the team or task are specified in advance by the researcher (based on other sources such as task analysis, experts, existing scales, etc.), which may not match the participants' knowledge structures (Mohammed, Klimoski, & Rentsch, 2000). This drawback can be countered by the third technique of capturing the idiosyncratic content of an individual's knowledge structure. However, in this latter technique it can be difficult to compare different individual mental models (Mohammed et al., 2000).

Unlike the other studies, O'Neill, Johnson and Johnson (1999) did not rely on a direct measurement of the "internal private model", but state that "the evidence that is available (…) on which that inference may be based is the verbal and nonverbal communications that [is presented] through their interaction" (p. 69). This shows how they infer the mental model of the individuals based on the verbal and non-verbal communications.

Social-cultural perspectives

As for the conceptualization of mind, the studies related to the socio-cultural perspective refer to contributions in the activity, focusing on the actions that the group participants undertake during the group work (see Table 3). All five studies related to the socio-cultural perspective were concerned with the question how the group participants acted on, and thereby defined the specific domain or object of activity. In other words, this domain is what motivates the people to work together, and through working together they define concretely this particular domain. The process of defining the domain or object of the work can be regarded as a continuous process of creating, what in cognitive perspectives would be called "task models". In these studies, defining the object of activity, or creating a task model, is considered to be important for the purpose of understanding a certain problem or question, coordinating actions, and ultimately achieving the goal of the activity. For example, Granados (2000) studied the group understanding of the design space or conceptual structure that is build by a group of students, by analyzing the commands in performing the task and the kinds of marks (clarifying statements and questions) that are made within the group. De Haan (2001) was concerned not only with how pairs defined the object of activity (the task model), but also with the so-called "team interaction model" that the pairs were using, by looking at the way teacher-pupil and parent-child pairs divided roles and responsibilities in solving a particular task. In these five studies, "mind" is closely related to how one participates in or contributes to the immediate joint activity (Matusov, 1996), in this case the specific task at hand. Additionally, the studies were concerned with cultural dimensions of cognition. Some studies (Auer-Rizzi & Berry, 2000; De Haan, 2001; Hall, Stevens, & Torralba, 2002) addressed how participants coming from similar national

cultures, disciplines or professions, use also similar ways of talking and express their own way of understanding the situation at hand. But this cultural dimension of cognition is also salient in how these studies do look at joint activity itself, since they focus on how the specific ways of talking and understanding of the diverse participants contribute to the development of a group culture.

In line with conceptualizing 'cognition' as situated in the activity of the group, the five studies focus their analysis on group discourse and activity (see Table 3). Four studies (Auer-Rizzi & Berry, 2000; De Haan, 2001; Hall et al., 2002; Granados, 2000) focused not only on the content of what is being discussed in groups (about the object), but also on the way the group interacts. For example, De Haan conducted first a qualitative analysis of the organizational structure of the interactions and of the role divisions that were set up, using a checklist of open questions. Secondly, she studied the specific pattern of participation structures and control strategies by a task analysis of subtasks scoring video's of the activity on: who is taking the initiative, to whom is it directed, who performs, and what is the involvement of the non-performing partner. These four studies all argued that the framing of expressions also indicates how one understands the task or object. Only Fiol (1994) did not directly analyze the group discourse, but followed the two year collaboration process of a new-venture team by analyzing the written reports made by the team. In several studies coding techniques were used with codes based on either theory (Fiol, 1994) or preliminary analysis (Granados, 2000; De Haan, 2001). In analyzing the discourse and activity of the group, the studies were not focused on determining the individual cognitions of each group member. Rather, they focused on group cognition, as implied by the whole of contributions that the group participants made during the interactions and actions.

Table 3
Characteristics of the Studies in Socio-cultural Perspective

Studies in socio-cultural perspectives	Interpretations of cognition:	Analyzing cognition by:
Auer-Rizzi & Berry (2000)	Defining the object of activity (=task model)	Qualitative analysis of group discourse and activity
Granados (2000)	Defining the object of activity	Qualitative analysis of group discourse and activity
Fiol (1994)	Defining the object of activity	Qualitative analysis of group's reports
Hall, Stevens, & Torralba (2002)	Defining the object of activity	Qualitative analysis of group discourse and activity
De Haan (2001)	Defining the object of activity Defining the roles and responsibilities (=team interaction model)	Qualitative analysis of group discourse and activity

Boundary crossing

We found three studies (Derry et al., 1998; Banks & Millward, 2000; Yoo & Kanawattanachai, 2001) that we consider to be boundary crossing literature, because they

were able to pursue a mixed discourse of both cognitive as well as socio-cultural perspectives on mind throughout the whole study (see Table 4). These three studies focus both on a stable cognitive map (or memory structure representing information and form), and on dynamic, situated cognitions representing coordination of information and actions. Derry et al. distinguished the individual long-term memories and the thoughts shared by the individuals during the group work. Similarly, Banks and Millward (2000) made a distinction between on the one hand a mental model form, representing a map of elements and their relations and on the other hand mental model states, representing the dynamic configuration of the aspects of the model that can be changed when running the model. Yoo and Kanawattanachai (2001) distinguished transactive memory, referring to information that is encoded, stored, and retrieved from the memory of the individual members and the individual minds at work during group activity. These three studies were all concerned with the ideas and information in the teams relevant for conducting the task, or task models, and how these were created in the teams.

The three studies used different methodologies (see Table 4). Derry et al. (1998) used discourse analysis of the interactions, to determine if the list of ideas resulting from the meeting represented cognitions that have been more or less processed by group discussions. Banks and Millward (2000) coded all the communication used and the actions taken with respect to mental model forms and mental model states. For example, one of the categories used is "offers"; these kinds of communications provide information about the model form. Yoo and Kanawattanachai (2001) used self-assessment, asking the group participants to fill in a questionnaire with items referring to the amount of transactive memory and of collective mind. This questionnaire asked for the perception of behavioral attributes of the team. Based on these, inference is made regarding the cognitive constructs of transactive memory and collective mind.

Table 4

Characteristics of the studies that cross the boundary between the perspectives

Boundary crossing studies	Interpretations of cognition: (type of model)	Analyzing cognition by:
Derry et al. (1998)	Task model	Qualitative analysis of group discourse and activity
Banks & Millward (2000)	Task model	Qualitative analysis of group discourse and activity
Yoo & Kanawattanachai (2001)	Task model	Self-assessment through questionnaire

The fourth study of Rutkowski and Smits (2001) that was initially classified as boundary crossing seemingly connected to both perspectives, and mixed the two socio-genetic views in discussing group cognition. However, close examination of the study revealed that it did not enlighten the issue of boundary crossing. Rutkowski and Smits claim to look at two schools of thought, constructivist and constructionist schools, similar to what we have termed respectively the cognitive and socio-cultural perspectives. But, because of the separate "treatment" of the two theoretical schools, we do not regard this study as

a boundary crossing study, even though they explicitly mention and discuss the two schools of thought related to the concept of shared meaning.

'Group' cognition

We have described how the studies considered cognition, that is, how they defined and analyzed it. We will now turn to the conceptualizations of cognition *at the group-level* in these three groups of studies (studies reflecting cognitive perspectives, socio-cultural perspectives and studies that reflect both). We first elaborate on the diverse *interpretations* of the meaning of cognition at group-level in the studies. Second, we describe how the groups of studies *measured* cognition at group-level. Therefore, according to Mohammed, Klimoski, and Rentsch (2000), we distinguish between two ways for measuring group-level cognitive structures. Individual measures can be aggregated to create higher level measures (aggregated measurement), or the collectivity can speak for itself (global measurement) (Axelrod, 1976; Schneider & Angelmar, 1993). Third, we describe how the groups of studies perceived *the role of group cognition in relation to group processes and outcomes*.

Cognitive perspectives

Cannon-Bowers and Salas (2001b) provide an overview of *interpretations* that are outlined in the literature pertaining to the cognitive perspective (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Mohammed & Dumville, 2001; Cannon-Bowers et al., 1993) in four categories. The first category refers to "overlap" of the individual cognitions: team members have a part of their knowledge base that is communal. In the second category, the authors interpret group cognition as 'similar' or 'identical' between the team members: they hold identical knowledge. In the third category group cognition is considered as 'complementary': knowledge or team-members does not need to be identical, but leads to the same expectations for the task at hand. In the fourth category group cognition is conceptualized in terms of 'distributed': the knowledge necessary for the task is dispersed among the different members of the group.

As indicated in Table 5, in the first column, all studies conceptualize group cognition as a similarity or overlap between individual mental structures. They are interested in the communality of the cognitions between team members. Cannon-Bowers and Salas (2001a) refer to this group of studies as literature on shared cognition and define them as follows: "They all encompass the notion that team members hold some knowledge that is similar or overlapping" (p. 87). The idea of group cognition is conceptualized as a group-level construct, but therefore they rely heavily on the individual as entity. To share becomes nothing more than a cross-section of those individual entities. And 'what' they share reflects organized knowledge; individuals store concepts and relations between these concepts. Group cognition is defined in terms of similarity in these concepts and relations. What underlies this conceptualization is that cognition is housed in the mind, as an individual possession. This is also reflected in the use of concepts that are derived from cognitive psychology conceptualizing individual cognition.

Most studies use the phrase 'similarity' in their definition of group cognition. For example Mohammed and Ringseis (2001) define the idea of group cognition as similarity

among group members regarding how key matters are conceptualized. Others rely on other terms like convergence or overlap; for example Mathieu et al. (2000) define shared mental models as the convergence of individual mental models. Nevertheless, the methodology in all studies shows a focus on similarity, with the underlying hypothesis that the more similarity in the identified knowledge structures of the individuals, the better the team functions. Also Mathieu et al. compute a correlation between matrices of individual ratings and relate this to better team processes and performance.

Table 5
Characteristics of the studies in cognitive perspectives

Studies in cognitive perspectives	Interpretations of cognition at group-level: -Similarity -Overlap -Complementary -Distributed	Measurement of cognition at group-level: -Aggregation measurement -Global measurement	Role of group cognition in relation to group processes and outcomes: -input -process -output
Mathieu et al. (2000)	Similarity	Aggregation measurement	Input
Peterson et al. (2000)	Similarity	Aggregation measurement	Process
Ensley & Pearce (2001)	Similarity	Aggregation measurement	Process
Carley (1997)	Similarity	Aggregation measurement	Process
Marks et al. (2002)	Similarity	Aggregation measurement	Input
Stout et al. (1999).	Similarity	Aggregation measurement	Input
Mohammed & Ringseis (2001)	Similarity	Aggregation measurement	Process
Levesque et al. (2001)	Similarity	Aggregation measurement	Output
Langan-Fox et al. (2001)	Similarity	Aggregation measurement	Output
O'Neill et al. (1999)	Similarity	Global measurement	Output
Edelson (2000)	Similarity	Aggregation measurement	Process

Following this line, almost all studies rely on aggregated data to represent this group-level construct (see Table 5). This aggregation is measured by calculating either the variance or the similarity of individual measures (comparing individual questionnaire answers or individuals' cognitive maps). For example, some calculated the average of pair wise comparisons between members (Peterson et al., 2000; Edelson, 2000). Carley (1997) relied on the individual idiosyncratic cognitive maps to determine the team

mental model. Hereby, a thesaurus is used to decide if the content of individual mental models is similar or not. Only the study of O'Neill et al. (1999) does not make use of data aggregation. They use, what Mohammed et al. (2000) call, a global measurement technique; the researcher does not integrate the cognitive structures, but instead the group cognition is elicited from a key informant, observing group interaction or examining group products. O'Neill et al. used representations of the group members, video records of participants, and insights gained from the author's involvement as a participant-observer and from interviews and conversations.

Although all studies show a similar conceptualization of group cognition in terms of what is meant by "shared", they use different hypotheses about *the role of group cognition in relation to group processes and outcomes* (see Table 5). First, one can look at group cognition as input for teams to start working (input), as mediating for team performance (process), or as result in itself (*output*). Most of the studies study the role of group cognition as a result of team processes. The studies of Langan-Fox et al. (2001), Levesque et al. (2001) and O'Neill et al. (1999) are focused on the development of group cognition as a result in itself (output). Langan-Fox et al. (2001) and Levesque et al. argue that the development of group cognition is important because it supports a group to work, as it enables individuals to adapt their behavior to the task and other team members. A range of other studies also picture group cognition as a result of group processes, but in addition study whether group cognition is related to a) the successfulness of the group (Carley, 1997; Edelson, 2000; Peterson et al., 2000), b) the perception of implementation success (Mohammed & Ringseis, 2001), or c) the performance of the firm (Ensley & Pearce, 2001) (*process*). For example, Ensley and Pearce study, among several other relations, whether the extent to which mental models on strategy are shared between teams, is related to the success of the firm in terms of sales growth.

In contrast to these studies, three studies (Marks et. al., 2002; Mathieu et al., 2000; Stout et al., 1999) examined the influence of group cognition on subsequent group processes (*input*). Hereby they depicted the role of group cognition as an input variable. Stout et al. and Mathieu et al. delivered training to their participants, by way of establishing group cognition as a starting condition for the real teamwork. Marks et al. did not use a training period in their design, but allowed a planning period in a kind of pre-performance period. In these three studies, group cognition is treated as an input variable for further group-work.

Socio-cultural perspectives

As indicated before, the studies in the socio-cultural perspectives defined cognition in terms of contributions to joint activity. Furthermore, these studies consider *group* cognition as constituted by the way in which those contributions have a central orientation towards defining the object of activity. If a group shows a particular pattern in defining the task at hand, then that pattern is indicative for the group cognition. The studies of the cognitive perspectives showed diverse *interpretations* of group cognition. Unlike the cognitive perspectives, the socio-cultural perspectives do not interpret cognition at the group-level in terms of similarity, overlap, complementarity, or distribution. All these four interpretations imply some sort of comparison between

separate individual minds. The socio-cultural perspective rather perceives group cognition as something constituted by the group as an entity in itself. As such, cognition resides in the active mind, as a phenomenon situated in the group interaction. The concept group cognition is then defined as a process of coordination of participants' contributions in joint activity (Matusov, 1996).

Table 6
Characteristics of the studies in socio-cultural perspective

Studies in socio-cultural perspective	Interpretations of cognition at group-level: constituted by the group within social interaction	Measurement of cognition at group-level: -Aggregation measurement -Global measurement	Role of group cognition in relation to group processes and outcomes: - common ground - common engagement - updated common ground
Auer-Rizzi & Berry (2000)	Constituted by the group	Global measurement	Common ground
Granados (2000)	Constituted by the group	Global measurement	Common engagement
Fiol (1994)	Constituted by the group	Global measurement	Common engagement
Hall et al. (2002)	Constituted by the group	Global measurement	Common ground Common engagement Updated common ground
De Haan (2001)	Constituted by the group	Global measurement	Common engagement

Despite different contexts, the studies all define group cognition as a process phenomenon that is situated in group collaboration and that allows for coordinated action (see Table 6). Similar to this focus on coordinated action is the concept of collective mind as described by Weick and Roberts (1993). They described and illustrated collective mind in organizations as a pattern of heedful interrelations of actions in a social system. In such a pattern, actions are conscientiously, critically and carefully (i.e., heedful) constructed. Moreover, when actions are constructed, the acting subject envisages the social system of joint actions, and subordinates his or her actions to this system (interrelate). Additionally, Matusov notes how a "participatory notion of intersubjectivity" (cfr. socio-cultural perspective on group cognition) moves beyond individual intentionality, since the direction of the activity is not foreseen by any of the participants. In these studies, "shared" refers to the degree of coordination that is seen in this social action. When contributions in the group have a central orientation, it is possible to coordinate the actions, even though the participants may have diverse views or even disagreements. For example, Granados (2000) talks about how the group, working on a design problem, develops a design space, which is an "open and negotiated conceptual structure that contains the ongoing collective specifications

relevant to the design activity" (p. 505). Moreover, using similar modes of thinking is argued to lead to reproductive processes, with the danger of group think narrowness, while disruptions resulting from different views of participants and socio-cultural subgroups are perceived as offering potential for productive, creative processes and group development (Homan, 2001; Matusov, 1996).

The five studies *measure* group cognition by looking what patterns are revealed in their analysis of the group interaction and work (see Table 6). Thereby they used "global measurement". The patterns within the group's interaction and work show how the participants coordinate their actions and arrive at a decision or solution to the problem. So far as these studies do look at individual cognitions and compare them, these studies always focus on cognition as it appears during social interaction. However, the focus is not on a set of individual minds, but on the mind that is established by the whole group or by socio-cultural subgroups, as directly implied by the patterns in the interaction. For example, Hall et al. (2002) analyze how disciplinary groups put their difference in understanding and in using objects into coordinated action and when these differences lead to conflict.

Similar to the studies showing cognitive perspectives, these five studies also have different understandings of *the role of group cognition in relation to group processes and outcomes* (see Table 6). However, whereas the studies in the cognitive perspectives differed in conceptualizing group cognition as either input, process of output variable, the model of input-process-output variables does not apply to these five studies. The five studies are concerned with group cognition as developing within the process, in terms of emerging patterns in the conversations and actions. Group cognition is as such always process-like and situated within group work. They imply that it is not possible to "measure" it as a given state, or as an end state. Although group cognition in socio-cultural perspectives is not measurable separate from a certain process of activity, studies do differ in referring to group cognition concepts in three sequential moments (Matusov, 1996). According to Matusov (1996), group cognition can be perceived as a *common ground* (a shared background) between the group members that is activated in the group collaboration, as *common engagement* (shared activity), or as *updated common ground* (a shared experience) that is built during the collaboration. Considering these, the five studies also differed in their perceptions of the role of group cognition. Auer-Rizzi and Berry (2000) group participants that shared a business or a cultural background and looked how these backgrounds offered a common ground or frame of reference for those participants to collaborate more easily. Three studies (De Haan, 2001; Fiol, 1994; Granados, 2000) focused on the creation of group cognition as a common engagement among the participants who are directly involved in the joint activity, or, as Stone (1993, as cited in De Haan, 2001) wrote: "a continuous evolving mutual perspective on how to conceive the situation at hand." Hall et al. (2002) make it even more complicated by referring to group cognition in all three sequential moments, that is, to group cognition as common ground, as common engagement, and as updated common ground. They argue that group participants from different disciplines understand and use objects in strikingly different ways (*sharing a disciplinary background provides common ground*). The

differences between participants can either go unnoticed or be put into coordinated use (*common engagement*) without explicit, group cognition. By studying a multi-disciplinary group working on a design problem, Hall et al. found that differences become remarkable either when a design proposal runs counter to deeply held disciplinary objectives or threatens to destabilize a wider network of tools and concepts (or representational infrastructure) used in that particular discipline. In such cases differences may disrupt or change the representational infrastructures that a disciplinary group relies on (*updated common ground*).

Boundary crossing

We have come to the conclusion that the three boundary crossing studies conceptualized cognition in terms of both stable mental model forms with information stored in memory and mental model states that are active and situated in the group collaboration. Accordingly, in the three boundary crossing studies the authors *interpret* the concept of shared in terms of "distributed": the knowledge necessary for the task is dispersed among the different members of the group (see Table 7). Derry et al. (1998) noted that a group distributed working memory would represent those thoughts from distributed long-term memory that becomes active within any individual's attention during the group discussion. Connecting this to the notion of group cognition, they write: "Obviously, only ideas that are shared (discussed) by one individual (and attended to by others) have the potential to modify a group collective long-term memory" (p. 30). Similar to this, Banks and Millward (2000) define the central group cognition concept, shared mental model, as "a distributed system which runs a model collectively through the propagation of representational states across representational media". By that definition they point on the one hand to the stable form of mental models. As an example they refer to a mental model of a bath that will have a certain size and therefore maximum volume. These aspects refer to model form, and will not change. On the other hand they point to the dynamic configuration of the aspects of the model that can be changed when running the model. In the example this can be seen as the plug being in or not or as the amount of water actually in the bath at any point in time. These aspects refer to states, and are dynamic and depending on the specific situation.

Table 7

Elements of the socio-genetic perspectives that are integrated in the boundary crossing studies

Boundary crossing literature	Elements of cognitive perspectives	Elements of socio-cultural perspectives	Combined in a notion of:
Derry et al. (1998)	Information-processing (collective) long-term memory	Situated cognition distributed working memory	Distributed cognition
Banks & Millward (2000)	Shared mental models mental model form	Situated cognition mental model state	Distributed cognition
Yoo & Kanawattanachai (2001)	Transactive memory	Collective mind	Socially shared distributed cognition

The third boundary crossing study (Yoo & Kanawattanachai, 2001) uses the concepts of transactive memory and collective mind to combine cognitive and socio-cultural perspectives on group cognition. With transactive memory, following Wegner, Erber, and Raymond (1991), they imply a "shared system for encoding, storing, and retrieving information". With collective mind they, following Weick and Roberts (1993), refer to a social cognitive system in which individuals heedfully interrelate their actions. Whereas transactive memory reflects the cognitive perspectives on group cognition, the concept collective mind reflects the socio-cultural perspectives on group cognition. The former refers to cognition within the minds of the group members, the latter points to cognition within group interaction. They draw upon these two concepts to examine how teams coordinate and interrelate their knowledge and actions in order to perform their tasks. In short, all three studies integrated elements of the cognitive perspectives (concepts like information processing, long-term memory, mental model form, transactive memory) and elements of the socio-cultural perspective (concepts such as situated cognition, distributed working memory, mental model state, collective mind) into an integrated approach centralized around the term distributed cognition. We summarize the integrated elements in these three studies in Table 7.

To *measure* group cognition, two of the studies used global measurement (see Table 8). They looked at the characteristics of the group as an entity (Banks & Millward, 2000; Derry et al., 1998), through analysis of the group discourse and activity. The third study (Yoo & Kanawattanachai, 2001) used questionnaires to ask each group member about the extent of group cognition in the group, with statements such as "Our team members had a global perspective that includes each other's decisions and the relationships among them." Since these perception measures formed the only basis for their analysis of the group cognition of the group, they recommended in their discussion that in future studies the contents of the communication interactions should also be examined.

With respect to the role of group cognition in relation to group processes and outcomes, the input-process-output model best represents the way the three studies dealt with group cognition (see Table 8). All three studies theoretically introduced group cognition partly as input for groups to work and partly as a process variable, developing during group working. Yoo and Kanawattanachai (2001) hypothesized that group cognition in terms of transactive memory of the group (input variable) had an influence on the group cognition in terms of the interrelation of actions during the group work (process variable). This latter was hypothesized as mediating the team performance. Derry et al. (1998) also noted group cognition of the group as input variable for the group to work in terms of overlap of prior knowledge, but their analysis focused only on the group cognition as a process variable (ideas shared during the interaction) which may influence the nature of the final group products. Banks and Millward (2000) studied group cognition as input in terms of the influence of shared and diverse information known to the team members, and group cognition as process variable in terms of the information that was shared during the group interaction.

Table 8
Characteristics of the studies that cross the boundary between the perspectives

Boundary crossing studies	Interpretations of cognition at group-level: -Similarity -Overlap -Complementary -Distributed	Measurement of cognition at group-level: -Aggregation measurement -Global measurement	Role of group cognition in relation to group processes and outcomes: -input -process -outcome
Derry et al. (1998)	Distributed	Global measurement	Process
Banks & Millward (2000)	Distributed	Global measurement	Input Process
Yoo & Kanawattanachai (2001)	Distributed	Global measurement (through individual assessments)	Input Process

Comparing different conceptualizations of group cognition

The purpose of this review is to compare conceptualizations of group cognition; that is to assess differences and similarities in how group cognition is conceptualized in the empirical literature in educational and psychological sciences. In doing so, this review wants to offer researchers a ground for conceptual clarity and to allow building forward on each others work. It has been unclear how the empirical studies relate to each other as they use many different concepts as well as different, but often implicit, understandings of group cognition. After having explicated and reviewed the different conceptualizations in three groups of studies, the following paragraphs discuss the differences, similarities and complementarities of the different perspectives as presented in the analysis. Founded on this comparison, it is questioned how future research can relate to these perspectives. This question will be explored on the one hand by considering tools to clarify their theoretical assumptions and on the other hand by exploring possibilities of cross-fertilization between the different perspectives can be fostered.

The various conceptualizations of group cognition were framed based on the socio-genetic views. It showed how respectively cognitive and socio-cultural perspectives on group cognition are discernable in both definitions and analyses in the studies (see Table 9). As described, the studies in the cognitive perspectives conceptualized and accordingly measured group cognition as a state of similarity or overlap between individual mental models. Thereby they localize cognition within the individual brain, and perceive it as a structure of elements (often in terms of knowledge). The focus of this perspective is on the state of (at least partly) unification of individuals' subjectivities. The studies in the socio-cultural perspective conceptualized and accordingly measured group cognition as

a process of coordination of actions, or as a dynamic unity of individual contributions in the joint activity (Matusov, 1996; Weick & Roberts, 1993). Cognition is then localized within the interrelated actions. It is also this activity which becomes the focus of the analysis. Considering these findings, it shows that these perspectives offer divergent conceptualizations of group cognition.

Along with these different conceptualizations, the studies connected to both perspectives use different key terms and even different discourses. The studies in the cognitive perspectives use academic terms such as information, knowledge, mental models, knowledge structures, building models, while the studies in the socio-cultural perspectives use academic terms such as participation, activity, interaction, processes and coordination. Furthermore, in the cognitive perspectives input-process-output models are used in studying processes, whereas in the studies with socio-cultural perspectives these models are not used. In these studies group cognition is considered to be a process-like and situated phenomenon, which continuously needs to be re-established.

Table 9

Cognitive versus socio-cultural perspectives on group cognition

Cognitive perspectives on group cognition	Socio-cultural perspectives on group cognition
Viewed as a state (having in common)	Viewed as a process (continuously negotiated)
Focus on individual subjectivities	Focus on joint activity
Focus on unification of participants' subjectivities	Focus on coordination of contributions
Focus on consensus	Focus on diversity and dynamic unity

If we want to be able to make use of and build on these various studies and their differences, it becomes interesting and relevant to wonder how they could contribute to co-create a useful and coherent theory on group cognition. To reflect on this, we need to pose the question to what extent and in what ways are the differences in the conceptualizations between the theoretical perspectives complementary? Moreover, we also need to question whether there are possibilities for synthesis between the perspectives. By conceptualizing group cognition as they do, what is it precisely that each of the perspectives leaves behind? As Greeno (1998) described, cognitive perspectives assume the decomposability of complex systems into a set of subsystems. Because of this assumption, the cognitive strategy is able to learn about the properties of each of these subsystems (an individuals' subjectivity) separately from the other subsystems, in order to build an understanding of the whole complex system (similarity between the individual's subjectivities). Socio-cultural perspectives assume systems of activity as "intact multiperson, human-technology systems" (Greeno, 1998). Hence, the socio-cultural tradition is able to learn about the intrinsic personality that complex systems (like groups or teams) endow, independent from those of its subsystems (individual members).

The drawback of each of these perspectives seems to be exactly what is essentially highlighted by the other perspectives. The cognitive tradition looses sight of the intrinsic nature of the complex system as a whole, and can only learn about it through the aggregation of the properties of subsystems. The shortcoming of this is that, in the end, groups are understood as some sort of sum of its members. In contrast, the socio-cultural tradition looses sight of the intrinsic nature of the subsystems, and learns about them only through the perspective of the system of which they are part. The drawback here is that subsystems (e.g., individuals, actions) are understood to be a function of their relations with other subsystems. Individuals are always participants of multiple social contexts. Anderson, Reder, and Simon (1997) noted that in such understandings, individuals tend to get 'absorbed' in the collectives of which they are part.

The above suggests the complementary makeup of both perspectives. In this review, we identified three studies that we perceived as boundary crossing. Let us return to these, and see what precisely these studies integrate and what we can learn from them regarding the complementary make-up of the perspectives. As we concluded, these three studies distinguish within their conceptualization of group cognition between a stable cognitive map or memory structure representing information and form, and dynamic, situated cognition representing coordination of information and actions. They focused on the interaction between these using the term distributed cognition in referring to this process of interaction. What they were able to do was to decompose subsystems within the whole complex system of a team and reveal their inherent properties, while simultaneously revealing the intrinsic nature of the complex system itself, separately from the subsystems. On the one hand, they identified individual subjectivities in terms of stable cognitive maps, and on the other hand they identified group processes in terms of the individual mental states situated in the interaction. So in a very precise and clear way they integrated in their focus the intrinsic nature of decomposable subsystems and the intrinsic nature of the whole system.

What follows is the question whether these studies, with integrating elements of both the cognitive and socio-cultural perspectives, pursued a fair account of each of these two perspectives. Looking at their integration from the perspective of the cognitive perspectives, one would say that they indeed managed to create a complete picture of cognition, extending individual cognition as structures within the individual mind to include situated processes in which cognition becomes mental states or the processing of information.

When looked at the practice of integration in these studies from the perspective of socio-cultural thinking, one doubts if it accounts for the socio-cultural tradition in the end. Of course, by focusing on distributed cognition, the studies considered not only the individual cognition but also the cognition that is situated in the activity processes. But, what is questionable in terms of socio-cultural thinking is treating cognition itself as decomposable. Distributed cognition is, at least in the three studies discussed here, treated as dividing up the cognitive processes taking place within the heads of individuals (individual cognition in terms of mental models, memory) and the processes taking place in the interaction (situated cognition). The situated cognition in fact only

refers to the information that is conversationally shared between these individuals. And with the term distributed cognition the studies signify that not all information relevant for a specific situation needs to be conversationally shared between all individuals, in order to build up the informational structure that is needed to coordinate the collaborative work well. Although choosing the term distributed cognition instead of situated cognition, the emphasis in these studies remains on exactly these informational structures, whereby information is divided amongst the individuals. To understand the collaboration processes it becomes most relevant to pinpoint the properties (e.g., contents of information) of the structures at specific times. Socio-cultural perspectives instead, perceive cognition (whether using the term situated or distributed) as the socially developed routine practices themselves, and rather focus on the dynamic transformation within these practices. Individual cognition is defined by its relations to social practices, as is illustrated by the following quote of Greeno:

> Regularities of an individual's activities, in a trajectory that spans participation at different times in a community and participation in different communities, are characterized as the individual's identity (Wenger, 1998), which is coconstituted by the individual's relation of those communities to the individual (Mead, 1934). (Greeno, 1998, p. 6)

In terms of socio-cultural perspectives, individual cognition is considered not as a property of structures (e.g., autonomous agents have knowledge), but rather as a continuous process of relation (e.g., participants knowing during practice). Despite the complementary nature of the two perspectives, it seems the boundary crossing literature about group cognition followed the cognitive perception of cognition and did not manage to fully account for the basic assumptions of socio-cultural perspectives.

Towards one theoretical perspective on group cognition?

What are the directions that future research can take? Is it advisable to strive for a coherent theory on group cognition, or is it better to have the two perspectives, as the differences are insurmountable? These matters raise the more fundamental question if it is at all possible for the two perspectives to reconcile or synthesize? Scrutinizing some of the most recent discussions and efforts of transcending the cognitive and socio-cultural perspectives (Anderson, Reder, & Simon, 1996, 1997; Billet, 1996; Cobb & Bowers, 1999; Gauvain, 2004; Glick, 2004; Greeno, 1997, 1998; Packer & Goicoechea, 2000; Saxe & Simonde, 2004), we conclude that there are three possible answers on this question.

First, one could say that it is not possible for the cognitive and the socio-cultural perspectives to be brought together, since both are different "theories", and theories are in essence incommensurable, because a theory has its own conceptual object and means of researching it (Glick, 2004), and its own questions and framing of assumptions (Greeno, 1997). Packer and Goicoechea (2000) even go so far as to state that the cognitive perspectives and socio-cultural perspectives not only differ in their epistemological assumptions (when is knowledge valid, what counts as truth), but also in their ontological assumptions (what is, what exists, and what it means for something to be). They stated that cognitive perspectives imply a dualist ontological approach, in which construction is viewed only as a cognitive activity in which subjectivity structures and

shapes data that comes from a distinct and separate objective world. As opposed to that, socio-cultural perspectives bring forward a non-dualistic ontological approach, in which subjectivities and the objects themselves are constructed and mutually define each other. We found substantial differences in conceptualizations between the studies within the cognitive perspectives and the studies within the socio-cultural perspectives. And indeed, reconsidering the socio-genetic framework in which the studies could be placed, the two perspectives reflect assumptions that seem ontologically different. Cognitive perspectives seem to assume that things (e.g., individuals or mental models) can exist independently, although it can change by its relations. Socio-cultural perspectives seem to assume an ontology in which things only exist in relation to other things (individuals are participants; minds are situated in social action). Because of these differences, Glick emphasizes that the only level at which a relationship between these perspectives can be sought is at the level of contributing to an arsenal of explanatory devices, perceiving theories and perspectives as tools.

A second answer is that it is possible for the two perspectives to start a true dialogical engagement. In fact, such a dialogical engagement was started between Anderson, Reder, and Simon (1996, 1997) representing the cognitive perspectives and Greeno (1997) representing the socio-cultural perspectives. After this exchange, which had more the undertone of a debate, these authors arrived at conclusion to their discussion (Anderson, Greeno, Reder, & Simon, 2000). Besides stating some very obvious educational matters on which the perspectives agreed, they noted that the different perspectives do propose alternative explanations for phenomena, but are each in an incomplete state, showing the need for further reconciliation. In reaction to this discussion, Cobb and Bowers (1999) wrote to be skeptic about the prospect of a dialogical engagement, saying: "In our view, a continuing intellectual exchange of the type envisioned by Greeno is virtually impossible unless proponents of each perspective come to understand the basic tenets of the other viewpoint" (p. 6). They emphasize that the discussion between Greeno (1998) and Anderson et al. (2000) proved that basic assumptions of the one perspective leads to misinterpreting the arguments of the other perspective. According to them, a dialogue can only be started through the development of a viable basis for communication. Alternative to an explicit scientific dialogue like the one between Greeno and Anderson et al. would be an attempt of each to resolve its own drawbacks by reckoning the highlights and explanations of the other perspective. This is also proposed by Greeno, who discusses two possible routes:

- To take the theory of individual cognition (here cognitive perspectives) as its basis and build toward a broader theory by incrementally developing analyses of additional components of situations that are considered as contexts for cognitive processes;
- To take the theory of social and ecological interactions (here socio-cultural perspectives) as its basis and build toward a more comprehensive theory by developing increasingly detailed analyses of structures of information that are produced by the interactions people have with each other and with the material and representational resources in their environments.

The analysis of the studies that we considered as boundary crossing literature showed that these studies are exactly a reflection of the first route, in which they depart from cognitive perspectives and attempt to extend it by including situated accounts of cognition. Before, we noted that Thompson (1998) described this route more generally in terms of a current movement of the cognitive perspectives. It seems that the socio-cultural tradition would construct the integration seen in the three boundary crossing studies in a different way. In our review, we have not found empirical studies reflecting the second route. Suggestions for the second route were made by Greeno (1998), Valsiner and Van de Veer (2000), and Packer and Goicoechea (2000). For the socio-cultural tradition, these suggestions imply defining individual cognition as structures of socio-cultural relations (which is a translation of the informational elements within the studies in the cognitive tradition). As Packer and Goicoechea illustrate, an integration of the second route, means that the ontological assumptions implied by the cognitive perspectives are included, but only secondary; the dualism of subject and object becomes a reality through the non-dualistic processes of their coming into being. Valsiner and Van der Veer and Hermans and Kempen (1993) implement this second route by considering the individual as a dialogical system by itself. Cognition is then defined as an individual property, but the individual itself is an inherently social entity, constituted through its social relations with others.

A third answer to the question about the reconciliation between the perspectives is that it would be possible to synthesize them into one coherent theory. Although the boundary crossing literature can be considered as attempts of synthesizing the perspectives, we also concluded that they did not succeed in a complete synthesis because of their neglect of some basic assumptions of the socio-cultural perspectives. We see a similar problem with theoretical attempts to transcend differences between the cognitive and the socio-cultural perspectives. For example, recently, Saxe and Simonde (2004) and Gauvain (2004) claimed to work towards an integrated view of human development. Central to their integration is the assumption that cognition should be understood in a framework embedding cognition in a social-historical context. The basic assumptions from which they depart indicate that, instead of a full synthesis, their integration reflects more the second route that Greeno (1998) described. They depart from a socio-cultural perspective and include precise accounts of individual cognition.

Reflecting on these three answers, it seems that a complete integration of the two perspectives is not possible; each perspective in its current status has in a sense its own object and a full integration at this point would mean loosing sight of some of the basic assumptions of one of the perspectives. Following Greeno's suggestion, we think that the most meaningful first step to bring together the values of both the cognitive perspectives and the socio-cultural perspectives is for each perspective to extend itself to include some of the explanations offered by the other perspective. This first step of cross-fertilization, however, requires researchers first to question carefully their basic assumptions (e.g., using Table 9) in conceptualizing group cognition, and relate themselves to more fundamental theoretical perspectives (e.g., using Table 1). Only then, is it possible to fully grasp the specific conceptualization of group cognition that is used and to build forward

on the findings of these studies. Besides, we suggest researchers choose terminology and methodologies accordingly (e.g., using analysis columns in Tables 2 to 8). For as each researcher clarifies their premises, future attempts for cross-fertilization are facilitated.
Concerning future research aiming at incorporating aspects of both perspectives on group cognition, the approach of the studies identified in this review as boundary crossing can be regarded as valuable and promising, since they try to include aspects from a different perspective on group cognition. We regard the two possible routes of integrations crucial for future studies to work towards more coherent theories of the concept of group cognition. By either extending cognitive conceptualizations of group cognition to include social accounts of cognition or by extending socio-cultural conceptualizations of group cognition to include more precise accounts of individual cognition, we believe the studies on group cognition would be more complete. They would both, in their own ways provide answer to the critical socio-genetic question posed by Valsiner and Van der Veer (2000): "How to construe persons as being social without abandoning their obvious personal autonomy, separateness from any social unit (group, crowd, community), while being members of such units?" (p. 6).

References

Studies indicated with * are included in the review.

Anderson, J. R., Greeno, J. G., Reder, L. M., & Simon, H. A. (2000). Perspectives on learning, thinking, and activity. *Educational Researcher, 29*, 11-13.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*, 5-11.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1997). Situative versus cognitive perspectives: Form versus substance. *Educational Researcher, 26*, 18-21.

Auer-Rizzi, W., & Berry, M. (2000). Business vs. cultural frames of reference in group decision making: Interactions among Austrian, Finnish, and Swedish business students. *The Journal of Business Communication, 37*, 264-292.*

Axelrod, R. (1976). *The structure of decision*. Princeton, NJ: Princeton University Press.

Banks, A. P., & Millward, L. J. (2000). Running shared mental models as a distributed cognitive process. *British Journal of Psychology, 91*, 513-531.*

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

Billet, S. (1996). Situated learning: Bridging sociocultural and cognitive theorising. *Learning and Instruction, 6*, 263-280.

Cannon-Bowers, J. A., & Salas, E. (2001a). Special issue preface. *Journal of Organizational Behavior, 22*, 87-88.

Cannon-Bowers, J. A., & Salas, E. (2001b). Reflections on shared cognition. *Journal of Organizational Behavior, 22*, 195-202.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. John Castellan Jr. (Ed.), *Individual and group decision making: Current issues* (pp. 221-246). Hillsdale, NJ: Lawrence Erlbaum.

Carley, K. M. (1997). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533-558.*

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

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational Researcher, 28*, 4-15.

Cooke N. J., Salas, E., Cannon-Bowers, J. A., & Stout, R. (2000). Measuring team knowledge. *Human Factors, 42*, 151-173.

Crook, C. (1998). Children as computer users: The case of collaborative learning. *Computers and Education, 30*, 237-247.

De Haan, M. (2001). Intersubjectivity in models of learning and teaching: Reflections from a study of teaching and learning in a Mexican Mazahua community. In S. Chaiklin (Ed.), *The theory and practice of cultural-historical psychology* (pp. 174-199). Aarhus, Denmark: Aarhus University Press.*

Derry, S. J., DuRussel, L. A., & O'Donnell, A. M. (1998). Individual and distributed cognitions in interdisciplinary teamwork: A developing case study and emerging theory. *Educational Psychology Review, 10*, 25-56.*

Dillenbourg, P., Traum, D., & Schneider, D. (1996). Grounding in multi-modal task-oriented collaboration. In W. Wahlster (Ed.). *Proceedings of the 12th European Conference on Artificial Intelligence*. Chichester, UK: John Wiley & Sons.

Druskat, V. U., & Pescosolido, A. T. (2002). The content of effective teamwork mental models in self-managing teams: Ownership, learning and heedful interrelating. *Human Relations, 55*, 283-314.*

Edelson, R. E. (2000). *The influence of supervisor-subordinate mental model congruence on group effectiveness and subordinates' satisfaction with their supervisor*. Unpublished doctoral dissertation, The Claremont Graduate University, Claremont.*

Engeström, Y., Engeström R., & Kärkkäinen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction, 5*, 319-336.

Ensley, M. D., & Pearce, C. L. (2001). Shared cognition in top management teams: Implications for new venture performance. *Journal of Organizational Behavior, 22*, 145-160.*

Fiol, C. M. (1994). Consensus, diversity, and learning organizations. *Organization Science, 5*, 403-420.*

Gauvain, M. (2004). *The contribution of contextual and sociocultural approaches to developmental theory*. Paper presented at the meeting of the American Educational Research Association, San Diego, CA.

Glick, J. (2004) *Coordinating cognitive and socio-cultural perspectives: How?* Paper presented at the meeting of the American Educational Research Association, San Diego, CA.

Granados, R. (2000). Constructing intersubjectivity in representational design activities. *Journal of Mathematical Behavior, 19*, 503-530.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher, 26*, 5-17.

Greeno, J. G. (1998). The situativity of knowing, learning and research. American *Psychologist, 53*, 5-26.

Hall, R., Stevens, R., & Torralba, T. (2002). Disrupting representational infrastructure in conversations across disciplines. *Mind, Culture and Activity, 9*, 179-210.*

Hare, L. R., & O'Neill, K. (2000). Effectiveness and efficiency in small academic peer groups. *Small Group Research, 31*, 24-53.

Hermans, H. J. M., & Kempen, H. J. G (1993). *The dialogical self: Meaning as movement*. San Diego, CA: Academic Press.

Homan, T. (2001). *Teamleren. Theorie en facilitatie*. [Teamlearning. Theory and facilitation]. Schoonhoven, the Netherlands: Academic Services.

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press.

Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference and consciousness*. Cambridge, MA: Harvard University Press.

Kaufer, D. S., & Carley, K. M. (1993). *Communication at a distance: The effect of print on socio-cultural organization and change*. Hilsdale, NJ: Lawrence Erlbaum.

Klimoski, R. & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management, 20*, 403-437.

Kraiger, K., Salas, E., & Cannon-Bowers, J. A. (1993). Measuring knowledge organization as a method for assessing learning during training. *Human Factors, 37*, 804-816.

Langan-Fox, J., Code, S., & Langfield-Smith, K. (2000). Team mental models: techniques, methods, and analytic approaches. *Human Factors, 42*, 242-271.

Langan-Fox, J., Wirth, A., Code, S., Langfield-Smith, K., & Wirth, A. (2001). Analyzing shared and team mental models. *International Journal of Industrial Ergonomics, 28*, 99-112.*

Levesque, L. L., Wilson, J. M., & Wholey, D. R. (2001). Cognitive divergence and shared mental models in software development teams. *Journal of Organizational Behavior, 22*, 135-144.*

Marks, M. A., Burke, C. S., Sabella, M. J., & Zaccaro, S. J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology, 87*, 3-13.*

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*, 273-283.*

Matusov, E. (1996). Intersubjectivity without agreement. *Mind, Culture and Activity, 3*, 25-45.

Mead, G. H. (1934). *Mind, self and society from the standpoint of a social behaviourist*. Chicago: University of Chicago Press.

Mohammed, S., & Dumville, A. B. C. (2001). Team mental models in a team knowledge framework: Expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*, 89-106.

Mohammed, S., Klimoski, R., & Rentsch, J. (2000) The measurement of team mental models. We have no shared schema. *Organizational Research Methods, 3*, 123-165.

Mohammed, S., & Ringseis, E. (2001). Cognitive diversity and consensus in group decision making: The role of inputs, processes and outcomes. *Organizational Behavior and Human Decision Processes, 85*, 310-335.*

Mulder, I., Swaak, J., & Kessels, J. (2002). Assessing group learning and shared understanding in technology-mediated interaction. *Educational Technology and Society, 5*, 35-47.*

O'Neill, E., Johnson, P., & Johnson, H. (1999). Representations in cooperative analysis and design for system development. *Human Computer Interaction, 14*, 43-91.*

Packer, M. J., & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychologist, 35*, 227-241.

Peterson, E., Mitchell, T., Thompson, L., & Burr, R. (2000). Collective efficacy and aspects of shared mental models as predictors of performance over time in work groups. *Group Processes & Intergroup Relations, 3*, 296-316.*

Rentsch, J. R., & Hall, R. J. (1994). Members of great teams think alike: A model of the effectiveness and schema similarity among team members. *Advances in Interdisciplinary Studies of Work Teams, 1*, 223-261.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*, 235-276.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological Bulletin, 100*, 349-363.

Rutkowski, A. F., & Smits, M. S. (2001). Constructionsist theory to explain effects of GDSS. *Group Decision and Negotiation, 10*, 67-82.*

Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education, 23*, 1-24.

Saxe, G. B., & Simonde, I. (2004). *Unintented consequences: The shifting structure of the Oksapmin's Indigenous Number System*. Paper presented at the meeting of the American Educational Research Association, San Diego, CA.

Schneider, S. C., & Angelmar, R. (1993). Cognition in organizational analysis: Who's minding the store? *Organization Studies, 14*, 347-374.

Sfard, A. (1998). On two metaphors for learning and the danger of choosing just one. *Educational Researcher, 27*, 4-13.

Stone, C. A. (1993). What is missing in the metaphor of scaffolding? In E. A. Forman, N. Minick, & C. A. Stone (Eds.), *Contexts for learning: Sociocultural dynamics in children's development* (pp. 169-183). Oxford, UK: Oxford University Press.

Stout, R. J., Cannon-Bowers, J. A., Salas, E., & Milanovich, D. M. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors, 41*, 61-71.*

Thompson, L. (1998). A new look at social cognition in groups. *Basic & Applied Social Psychology, 20*, 3-5.

Thompson, L., & Fine, G. A. (1999). Socially shared cognition, affect, and behavior: A review and integration. *Personality and Social Psychology Review, 3*, 278-302.

Valsiner, J., & Van der Veer, R. (2000). *The social mind. Construction of the idea*. Cambridge, UK: Cambridge University Press.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 841-873). New York, NY: MacMillan.

Wegner, D. M., Erber, R., & Raymond, P. (1991). Transactive memory in close relationships. *Journal of Personality and Social Psychology, 61*, 923-929.

Weick, K. E., & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly, 38*, 357-381.

Wenger, E. (1998). *Communities of practice, learning, meaning and identity*. Cambridge, UK: Cambridge University Press.

Yoo, Y., & Kanawattanachai, P. (2001). Developments of transactive memory systems and collective mind in virtual teams. *The International Journal of Organizational Analysis, 9*, 187-208.*

Appendix

Description of each study

Nr	Studies	Group cognition concepts used in article	Definition: Group cognition	Analysis of group cognition
1	Yoo, Y., & Knawattanachai, P. (2001). Developments of transactive memory systems and collective mind in virtual teams.	Socially shared distributed cognition, collective mind, transactive memory	Interrelation between: 1. collective mind = social cognitive system in which individuals heedfully interrelate their actions (Weick & Roberts, 1993) 2.transactive memory = shared system for encoding, storing, and retrieving information (Wegner et al. 1991)	1. Aggregation of intra group responses on four 5-point Likert scales questions about acting, understanding and interrelating in the team. 2. Aggregation of intra group responses on three 5-point Likert scales questions about who knows what
2	Derry, S. J., DuRussel, L. A., & O'Donnel, A M. (1998). Individual and distributed cognitions in interdisciplinary teamwork: a developing case study and emerging theory.	Distributed cognitions, compatible mental models, shared cognitions, common voice, shared perspectives, shared knowledge, collective intelligence	Compatible understandings of the task and team that become sufficiently aligned	The degree to which resulting ideas represent cognitions that have been more or less processed by group discussions
3	Mohammed, S. & Ringseis, E. (2001). Cognitive diversity and consensus in group decision making: The role of inputs, processes, and outcomes.	Cognitive consensus, shared assumptions, group representation, collective representation, shared cognition	Similarity among group members regarding how key matters are conceptualized	The degree of variation of group participants' responses on five-item 7-point Likert scale questions about how they interpreted the task (= negative measure)
4	Levesque, L. L., Wilson, J. M., & Wholey, D. R. (2001). Cognitive	Shared mental models, shared cognition, common	'Knowledge structures held by members of a team that enable them to form accurate	Overall intra-team similarity on team process items (22 items covering communication processes,

	divergence and shared mental models in software development project teams.	understanding, shared understanding, group mental models, shared view	explanations and expectations for the task, and in turn to coordinate their actions and adapt their behavior to demands of the task and other team members' (Cannon-Bowers et al., 1993)	climate, structure, progress) and team expertise ratings (ratings of each other's expertise).
5	Hall, R., Stevens, R., & Torralba, T. (2002)	representationa l infrastructure, shared understandings , distributed cognition	1. Sometimes explicit same understandings about proposed activity and its meaning 2. Across disciplines: infrastructures that enables coordinated action between communities with different interests, needs, and accountabilities	The degree to which coordinated action is reached, despite different ways in which people position themselves and others with respect to relevant events.
6	Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance.	Shared mental models, common mental models, shared vision, common vision	Convergence of individual mental models; mental model = 'mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states' (Rouse & Morris, 1986);	Correlation between matrices of individual ratings of the relations between critical (team and task based) attributes
7	Banks, A. P., & Millward, L. J. (2000). Running shared mental models as a distributed cognitive process.	Shared mental models	A distributed system which runs a model collectively trough the propagation of representational states across representational media ; mental model form = the homographic mapping consisting of elements and their relations	Comparison of the differences in the types of communications (model form interaction, model states interaction, and honing, widening or supporting states) between the distribution conditions (receiving either information completely, or on

			which represent the thing being modeled; the mental model state = the dynamic configuration of the aspects of the model that can be changed when running the mode	complete modules, or only part of the modules)
8	Peterson, E., Mitchell, T., Thompson, L., & Burr, R. (2000). Collective efficacy and aspects of shared mental models as predictors of performance over time in work groups	Shared mental models, shared cognition, transactive memory, group schemata, intersubjectivity, collective mind, group situation awareness, team schema similarity	Cognitive representations of task requirements, procedures and role responsibilities that members hold in common	Average of pair-wise comparisons between the amount of points attributed in the individual questionnaires; points attributed to: 1. the extent of contributions of the group members to the task (indicating 'disagreement of contributions') 2. the extent of contributions of oneself to the task (indicating egotism) 3. the importance of task components for producing good results
9	Ensley, M. D. & Pearce, C. L. (2001). Shared cognition in top management teams: Implications for new venture performance.	Shared cognition, shared strategic cognition	The extent to which the mental models about strategy are shared	Coefficient of variation of individual answers on 33 seven dimension scale items about business level strategy
10	Rutkowski, A. F., Smits, M. S. (2001). Constructionist theory to explain effects of GDSS.	Shared meaning; shared mental models, group vision	1. Constructionist conceptualize meaning as the expression of a specific pattern of coordinated interactions, internalized in concepts and reproducible quasi-individually each time an object is recognized	?

			and referred to the internalized process 2. Constructivist conceptualize meaning as brain-based (cognitive schemes) [no specific definition is given when something is shared]	
11	Fiol, C. M. (1994). Consensus, diversity, and learning in organizations.	Collective agreement, consensus, common understanding, common view, collective understanding, common mind	Convergence around (a specific dimension of) meaning	The extent of progressive convergence across subgroups in patterns of: 1. certainty of positions 2. perceived judgement of issues 3. perceived controllability of issues 4. scope of the arguments; as seen in the content and framing of expressions in the logged group entries
12	Hare, L.R., & O'Neill, K. (2000). Effectiveness and efficiency in small academic peer groups.	Shared vision, shared understanding	Sense of commonality which gives coherence to diverse activities	The result of a content analysis (affinity clustering technique) of the responses in individual interviews on 25 questions eliciting in-depth responses in a.o. the area of shared vision, mission and goals.
13	Langan-Fox, J., Wirth, A.., Code, S., Langfield-Smith, K., Wirth, A. (2001). Analyzing shared and team mental models.	Shared mental model / team mental models (as distinct concepts)	The extent to which a group (dyad) of individuals possesses a similar cognitive representation for some situation or phenomenon	The average (negatively calculated) of the dyadic differences between group participants' ratings of similarity between concepts
14	Carley, K. M. (1997). Extracting team mental models through textual analysis.	Team mental models	'Shared' or 'social' knowledge; (lossy) intersection of the individual mental maps	A team cognitive map, representing the (lossy) intersection of individual cognitive maps; an individual cognitive map consists of both concepts and the relationships between them, as extracted from

				individual answers on open-ended questions
15	Mulder, I., Swaak, J., & Kessels, J. (2002). Assessing group learning and shared understanding in technology-mediated interaction.	Shared understanding, common understanding	Mutual knowledge, mutual beliefs, and mutual assumptions (Clark & Brennan, 1991)	Means of the individual ratings on four 6 / 7 Likert scale items about the individual and group understanding of content, the procedure, the tools, and each other
16	Granados, R. (2000). Constructing intersubjectivity in representational design activities.	Intersubjectivity; common ground, mutual understanding, common understanding	Establishing and maintaining a common understanding in communication, through common ground (mutual knowledge, mutual beliefs and mutual assumptions) and grounding (a coordination of process)	Patterns of marking in communication by the participants to define, constrain, and maintain their understanding of the task at hand (e.g. including knowledge, setting goals, setting actions), as coded in the transcription of video segments
17	Auer-Rizzi, W., Berry, M. (2000). Business vs. Cultural frames of reference in group decision making: interactions among Austrian, Finnish and Swedish Business Students.	Frame of reference, shared assumptions; shared culture, common ground	Finding common ground for different business and cultural assumptions during decision making	Commonality of business and national assumptions about social relationships and preference for communication styles, as induced from argumentation during decision-making and in-depth interviews
18	O'Neill, E., Johnson, P., & Johnson, H. (1999). Representations in cooperative analysis and design for system development.	Common ground, shared knowledge, shared understandings, shared model, common understandings	Overlap between private models of group participants representing an understanding of the object of activity	Overlap between the internal private model representing the user's understanding of the object of the development activity and the internal private model representing the developer's understandings as inferred by the verbal and nonverbal communications which is presented through the

				interaction
19	Marks, M. A., Burke, C. S., Sabella, M. J., & Zaccaro, S. J. (2002). The impact of cross-training on team effectiveness.	Shared team-interaction mental models, shared mental models	Similarity among team members' team-interaction mental models; mental models is the content and organization of inter-role knowledge held by team members within a performance setting; team interaction models contains procedural knowledge about members' roles and task at particular times	1. (Experiment 1:) average similarity between team members' individual ratings of the relations among critical task concepts 2. (Experiment 2:) the percentage of concepts placed identically on the concept maps
20	Stout, R. J., Cannon-Bowers, J. A., Salas, E., & Milanovich, D. M. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established.	Shared mental model; shared expectations; shared understanding; common understanding	Common understanding of who is responsible for what task and what the information requirements are	Degree of similarity (index C using pathfinder) between team members' configural networks; one member's configural network is based on 190 judgments of the relatedness of concepts on 7 point Likert-scale
21	Edelson, R. E. (2000). The Influence of Supervisor-Subordinate Mental Model Congruence on Group Effectiveness and Subordinates' Satisfaction with Their Supervisor.	Shared mental models	Similarity between mental models of people; mental models = working models in the brains of people to understand the world and predict its happenings, by simplifying reality to permit adequate and rapid prediction of a system's behavior	(Calculated negatively:) 1. The mean difference of answers between the group members on 59 questions about the supervisor's interaction with the group 2. The mean difference of answers between the group members and between the supervisor on 36 5-point Likert scale questions about the supervisor's interaction with the group
22	De Haan, M. (2001). Intersubjectivity in Models of Learning and	Distributed cognition, intersubjectivity, joint meaning,	1. Context creation: the kind of efforts put into establishing intersubjectivity, 2. Identity of	Sequences of participation and control strategies showing: 1. if context creation was based either on assuming

Teaching: Reflections from a Study of Teaching and Learning in a Mexican Mazahua Community.	common understanding, mutual understanding, common perspective, communality, transference of perspectives, perspective building, coordination of actions	interlocutors: the kind of roles or identities that are assumed or created; 3. the kind of communicative structures and means created to organize common understanding	communality versus the need to overcome the differences between individual worlds through explicit communicative efforts, 2. identify of interlocutors with both having responsibility for establishing intersubjectivity, 3. communicative structures and means to organize common understanding either parallel or sequentially, and either continuously or through segmentation of the activity.

Chapter 3

Social and Cognitive Factors Driving Teamwork in Collaborative Learning Environments. Team Learning Beliefs & Behaviors*

A team is more than a group of people in the same space; physical or virtual. In recent years, increasing attention has been devoted to the social bases of cognition whereby research on information processing and its consequences for professional decision-making has taken into consideration how social processes in groups and teams affect performance.

This chapter investigates when and how teams in collaborative learning environments engage in building and maintaining mutually shared cognition, leading to increased perceived performance. In doing so, this research looks for discourse practices managing the co-construction of mutually shared cognition, and reveals conditions in the interpersonal context that contribute to engagement in these knowledge building practices.

A comprehensive theoretical framework was developed and tested. The constructs in the model were measured with the Team Learning Beliefs & Behaviors-questionnaire and analyzed using regression and path analysis methodology. Results showed that both interpersonal and soci-cognitive processes have to be taken into account to understand the formation of mutually shared cognition, resulting in higher perceived team performance.

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* Based on:

Van den Bossche, P., Gijselaers, W., Segers, M., & Kirschner, P. A. (2006). Social and cognitive factors driving teamwork in collaborative learning environments. Team learning beliefs & behaviors. *Small Group Research, 37*, 490-521.

Groups of people are increasingly acknowledged as the source of knowledge-construction. It is expected that teams, bringing together people with different experiences, values and knowledge, will be more effective in solving adequately the problems than individuals. However, In order to be able to adequately solve problems, they face the challenge of integrating these different perspectives and develop a shared understanding of the problem at hand. This can be established through rich interaction, interactive discussion, and negotiation (Daft & Weick, 1984; Roschelle, 1992). The continuing implementation of group-work at schools and of teamwork in organizations are instances of attempts to build on the potential of teamwork. However, research and practice shows that this potential effectiveness is not always reached (e.g., Barron, 2003). Research has revealed cases in which large variation in group-work interaction and performance is encountered between teams that seem not to differ in composition and assigned task (Barron, 2000). This research indicates that fruitful collaboration is not merely a case of putting people with relevant knowledge together. Understanding is required in the factors that make up successful collaboration.

This chapter leans on two primary perspectives on collaborative work and learning as identified by Olivera and Straus (2004), namely cognitive and social. The cognitive perspective stresses the influence of group work on cognitive processes and is dominant in research in educational sciences querying processes affecting cognitive outcomes in collaboration (e.g., Webb & Palincsar, 1996). The social perspective examines the social factors constituting successful performance in group- and teamwork and is primarily used in social and organizational research (Cohen & Bailey, 1997). Although these two perspectives on collaboration are profoundly intertwined, most research focuses only on one of them (Kreijns, Kirschner, & Jochems, 2003). The current study makes a contribution to the literature by providing a theoretical framework for conceptualizing learning in collaboration that entails both an understanding of how socio-cognitive processes give rise to cognitive development and an understanding of the social, interpersonal dimension of teamwork. This is done by taking a group-level perspective on the interactions that give rise to mutually shared cognitions, and by integrating this with findings on the importance of interpersonal, social factors as described in social and organizational research. The following introduction sketches the backgrounds and strengths of both approaches and shows how these perspectives can be complementary in providing insight in successful collaboration. This will lead to the development of a team learning model that integrates insights of both perspectives.

Cognitive and social perspectives on group learning

Cognitive research to date has established that knowledge structures affect information processing in predictable ways. The importance of domain-specific knowledge has especially been identified as the prime determinant of excellent performance across many different expertise domains (Ericsson & Smith, 1991; Patel, Arocha, & Kaufman, 1999; Schmidt & Boshuizen, 1993; Sternberg, 1999). This area of research concentrates on how individuals process information, how they assess and interpret situations, and how they solve problems. With the increasing interest in teamwork, the question of how these

individual cognitions become integrated and coordinated at the inter-individual level becomes of central interest (Wong, 2003). In this perspective, the construction of mutually shared cognition (i.e., shared conception of the problem) lies at the heart of collaboration (Roschelle, 1992; Barron, 2003). This implies that studying group performance requires an analysis of the socio-cognitive processes within the group. As Langfield and Smith (1992) have argued, to understand how collective knowledge structures are formed, it is a basic requirement that one must understand the interaction between cognition and social processes.

In the past, research on collaborative learning has particularly focused on determining the structural conditions leading to better outcomes. Conditions hereby investigated are group composition, group size, nature of the tasks, etc. (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Webb & Palincsar, 1996). Although general effects of these structural factors are indeed established in research, it is acknowledged that it is difficult to determine the immediate impact of these structural conditions on the effect of group work (Dillenbourg et al., 1996; Webb & Palincsar, 1996). Therefore, increasing attention is now being paid to the intermediate processes that give rise to effective collaboration. Barron (2003) points out that this entails an articulation of how characteristics of the interaction (discourse practices) interact with knowledge building processes that lead to mutually shared cognition.

Exemplary for this strand of research looking for patterns of interaction is the work on help related behavior in cooperative groups (Webb, Ing, Kersting, & Nemer, 2004). In this research, interactions were described by assessing how elaborated the help is which was provided by group members (ranging from giving the answer to giving a detailed explanation). One of the findings was that the explainers' problem-solving performance benefits from giving elaborated explanation and not from giving non-elaborated help. This stream of work analyzes group work in terms of speech act catalogues and interprets these in terms of impact upon individual psychological functioning (Dillenbourg et al., 1996; Crook, 1998). The focus on individual performance is logical, since it is mostly the individual who is assessed (Barron, 2000). However, within the perspective that successful collaboration requires mutually shared cognition, this view is limited (Barron, 2000).

To understand differences in collaborative outcomes, beside measures of individual functioning, we also need to gain insight in the functioning of the group, more precisely how they manage to collaboratively construct mutually shared cognition, and how they work out problems together (Barron, 2000). Research on collaborative learning needs to focus onto the socio-cognitive processes through which a shared conception is built. Insight needs to be gained in the conversational patterns, at the group level, instantiating the socio-cognitive processes that contribute to the development of mutually shared cognition. However, only few studies of collaborative learning have examined how groups of people create/develop mutually shared cognition (Crook, 1998; Roschelle, 1992).

These socio-cognitive processes taking place through discursive practices do not occur in a vacuum, but are influenced by the social context in which they take place (Keyton,

2000). It is this social context that nourishes the willingness to engage in the (joint) effort to build and maintain mutually shared cognition (Barron, 2003; Crook, 1998). A case in point is the research from Barron who concluded from her multiple case-studies on sixth-grade triads that relational aspects of the interpersonal context need to be taken into account to understand what happens in learning groups. These groups have to deal with, what Barron calls, both a relational and a content space, which compete for limited attention. Her case-study on less-successful groups indicates that relational issues such as competitiveness and friendships can respectively hinder or stimulate the group in dealing with the insights that are constructed in the group.

How the social context influences socio-cognitive processes in collaborative groups remains largely uninvestigated in educational psychology. Webb and Palincsar (1996, p. 855) argue in their hallmark review that: "Although social and organizational psychology has documented a great number of debilitating processes that inhibit group functioning and performance in out-of school settings, only a few researchers have investigated debilitating processes in educational settings that may be detrimental for learning". Examples from research in organizational psychology demonstrating that interpersonal factors – next to structural factors - play a salient role at the professional workplace are the studies from Lingard, Reznick, Espin, Regehr, and DeVito. (2002) and Edmondson (1999). Edmondson showed, for example, that experiencing psychological safety in hospital teams shapes the individual and team learning behavior. However, research in these domains seldom analyzes the processes through which these factors influence performance.

This chapter examines a team learning model specifying when and how teams in collaborative learning environments engage in building and maintaining mutually shared cognition, leading to increased perceived performance. This model presents an integrative perspective, building on the strengths of different research strands. It includes both discourse practices that manage the co-construction of mutually shared cognition and conditions in the interpersonal context that contribute to engagement in these knowledge building practices.

First we elaborate on this team learning model. This will be followed by the presentation of the field study that has tested this model.

Building a Team Learning Model

The presented theoretical framework is shaped by two complementary perspectives. First, collaborative learning will be analyzed as a fundamentally social process of knowledge building. We will present our view on collaborative learning and the characteristics of the discourse in which collaborative knowledge building is taking place. This perspective will be complemented by a description of crucial aspects of the social environment in which this learning takes place and by which this learning discourse is potentially influenced.

Collaborative learning as promoting conceptual understanding through "mutually shared cognition" (Webb & Palincsar, 1996)

In a collaborative learning environment, participants are brought together to simultaneously work on a task, in order to learn from this task. This study focuses on groups for which this task performance is the primary objective and in which the learning is considered a product of this collaboration for task performance. In this way, learning through collaboration is primarily a group-level phenomenon (Dillenbourg et al., 1996). Collaboration is defined as the process of building and maintaining a shared conception of a problem or task, distributing responsibility across members of the group, sharing expertise and mutually constructing and negotiating cognition (Roschelle, 1992).

From this viewpoint, the interaction between members of the group and the characteristics of their discourse is considered the process through which mutual understanding and shared cognition is reached. This social process of building mutually shared cognition is called the learning behavior of the team. In this process, 'negotiation' is key to determining to determine which kind of interactions, which patterns in discourse, can be considered to be forms of team learning behavior leading to mutually shared cognition (e.g., Dillenbourg et al., 1996; Baker, 1995). Negotiation here is seen as the process of achieving agreement between agents (Galliers, 1989 in Baker, 1995). Baker (1995, 1999) points out that achieving 'real' agreement presupposes joint understanding whereby two aspects are highly relevant. First, inserting meaning into the problem faced and solving it requires co-construction; this cannot be done through simple accumulation of the contributions of individuals, because each contribution is presumed to 'build on' previous ones. Second, agreement needs to be established upon the proposed meanings and solutions (Baker, 1995, 1999).

These two team learning processes through which the group perspective is built are elaborated on below.

Construction and Co-construction of Meaning

The process of building a shared conception of a problem, as we defined collaboration to be, starts with the articulation of personal meaning that is taken up in the social setting (Stahl, 2000). This process starts when one of the team members inserts meaning by describing the problem situation and how to deal with it, hereby tuning in to the fellow team-members. These fellow team-members are actively listening and trying to grasp the given explanation by using this understanding to give meaning to the situation at hand (Webb & Palincsar, 1996). We refer to these processes as construction of meaning.

These processes of construction of meaning can evolve into collaborative construction (co-construction), a mutual process of building meaning, by refining, building on, or modifying the original offer in some way (Baker, 1994). The outcome of this process is that 'new' meanings in the collaborative work emerge that were not previously available to the group.

Towards agreement: Constructive conflict

Mutually shared cognition is developed when agreement is reached around the (co-) constructed understandings. It is not sufficient that the inserted meanings are clarified

and that there is mutual understanding, they must also be accepted before they form the base for action (Alpay, Giboin, & Dieng, 1998). If accepted, the offered meaning can become part of the common ground, the agreed-upon interpretation of the situation: in other words the mutually shared cognition. However, the team members may diverge in their interpretation and tackle the situation from another point of view or perspective (i.e., a cognitive conflict). This rejection of the built understanding can lead to a further elaboration through the negotiation of the different meanings. However, Hewson and Hewson (1984), and more recently De Dreu and Weingart (2003), argued that the emergence of differences in opinion does not guarantee conceptual advancement because it may be taken as a paradox, and resolved by ignoring one of the conflicting elements. Another argument is that it may not be seen as a difference in the interpretation of the problem, but as a personal, emotional rejection and as such can interfere with productive team behavior (De Dreu & Weingart, 2003). So, disagreement or divergence in itself seems to be less important than the fact that it generates communication between peer members (Dillenbourg et al., 1996). The team will only benefit if divergence in meaning leads to further negotiation. Through this negotiation by argument and clarification, which we refer to as constructive conflict, the team works towards a convergence of meaning and mutually shared cognitions are reached.

The following hypothesis (H1) may be formulated based on the arguments made above: *Increasing (co-)construction and constructive conflict in the interaction of the team will positively influence the development of mutually shared cognition.*

In organizational science literature there is a lot of interest in mutually shared cognition as a group-level cognitive construct (Akkerman, Van den Bossche et al., 2005). This interest is mainly driven by the idea that it plays an important role in explaining the effectiveness of teams (Klimoski & Mohammed, 1994). Mutually shared cognition creates a context for efficient group decision-making. First, group members engage in a context that offers possibilities to learn from others' preferences and viewpoints, by knowing that there are different viewpoints, by accepting the existence of alternative viewpoints as legitimate, and perhaps the consideration of them in their own viewpoints (Engeström, Engeström, & Kärkkäinen, 1995). Second, the development of shared cognition facilitates coordinated action because it assures that all participants are solving the same problem and helps exploiting the cognitive capabilities of the entire team (Orasanu, 1990 in Klimoski & Mohammed, 1994). Third, the active use of different views in working on and solving problems may entail a consideration of more alternatives, a richer argumentation, and thereby the nature of communication itself and problem solutions may become more creative.

A broad approach to effectiveness is taken to grasp these potential effects of developing mutually shared cognition on team effectiveness. Hackman (1989) conceptualized the multiplicity of outcomes that matter in organizational settings in three ways. Not only is the degree to which the team output meets the standard of quality (performance) of importance. Also the degree to which the process of carrying out the work enhances the capability of members to work together in the future (viability); and the degree to which the team work contributes to the professional growth of the team members (learning)

need be taken into consideration. Also from a professional educational perspective these three dimensions are of crucial importance: the individual growth is important, but also the performance and the team viability is of importance, because these show that students have also the competence to produce a good product and deal with the complex situation of team learning.
Based on these insights, the following hypothesis (H2) can be formulated: *More developed mutually shared cognition in a team will result in higher team effectiveness.*

Groups as social systems: beliefs about the interpersonal context.
It follows from our argumentation that it is important to determine under which conditions the described interactions occur. Roschelle and Teasley (1995) conclude that "collaboration does not just happen because individuals are co-present; individuals must make a conscious, continued effort to coordinate their language and activity with respect to shared knowledge" (p. 94).
The identification of the social conditions under which teams make this effort to reach shared knowledge is an essential prerequisite for developing enhanced understanding of successful collaboration. Viewing collaborative learning as reaching mutually shared cognition, and thus as fundamentally social, stresses the need to take into account the social context in which these processes take place.
Salomon and Globerson (1989) point to the fact that most social effects arise from the evolution of the group as a social system. Shared beliefs and shared perceptions of the team-characteristics emerge in groups from the interaction between the team members (Arrow, McGrath, & Berdahl, 2000). As such, those beliefs are group-level variables; characteristics of the team more than of the team members (Edmondson, 1999). This study focuses on emerging team-level beliefs about the relations between the team members; in other words beliefs about the interpersonal context. The main question to be dealt with is: How does this team perceive the interpersonal context formed by their team? Subsequently, these beliefs will influence the behavior of the team (Cohen & Bailey, 1997), and more specifically the learning behavior of the team. It is supposed that they form a context that stimulates or inhibits learning behavior. The question that now arises is how to identify beliefs about the interpersonal context that influence learning and cognitive development in teams (Webb & Palincsar, 1996).
As Webb and Palincsar (1996) noted, few researchers have investigated these kinds of factors in educational settings that influence group-learning. However, ample research in social and organizational psychology focuses on the role of beliefs about the interpersonal context in group functioning and performance in out-of-school settings (e.g., Cohen & Bailey, 1997). Powerful group-level beliefs identified in this research, which potentially affect the learning behavior in teams, are psychological safety, cohesion, potency and interdependence. These four will be elaborated on in the following paragraphs, showing their meaning and their hypothesized influence on team learning behavior and performance.

Psychological Safety

Learning in groups can be threatening and stressful (Homan, 2001): Team members do not know each other, power games are played, people are left out, people blame each other for making mistakes… . The paradox however is that learning is often facilitated by taking risks and thinking freely. The notion of psychological safety, as such, is not new. In early research on organizational change, Schein and Bennis (1965) recognized the need to create psychological safety for individuals if they are to feel secure and capable of changing.

However, in her work on organizational learning and teamwork, Edmondson (1996, 1999) is one of the few researchers directly analyzing the effect of beliefs about the interpersonal context on team learning behavior, pointed to the importance of team psychological safety as a facilitating interpersonal context for team learning behavior. Team psychological safety is defined as a shared belief that the team is safe for interpersonal risk-taking (Edmondson, 1999). "The term is meant to suggest neither a careless sense of permissiveness, nor an unrelentingly positive affect but rather a sense of confidence that the team will not embarrass, reject, or punish someone for speaking up. This confidence stems from mutual respect and trust among team members" (Edmondson, 1999, p. 354). She argues that team psychological safety is said to facilitate learning behavior in teams because it alleviates excessive concern about others' reactions to actions that have the potential for embarrassment or threat, which learning behaviors often have. Psychological safety does not play a direct role in the team's performance; it facilitates appropriate behavior leading to better performance (Edmondson, 1999).

Hypothesis 3: *Psychological safety is positively associated with team learning behavior*.

Cohesion

Cohesion has been widely studied as an important aspect of group functioning. Festinger (1950, p. 274), as one of the earliest researchers of this construct, defined cohesion as "the resultant of all the forces acting on all the members to remain in the group". Two meta-analytic studies have indeed revealed that a small but positive relationship exists between group cohesion and group performance (Evans & Dion, 1991; Mullen & Copper, 1994).

Cohesion is a multidimensional construct. As research proceeded, different types of cohesion were distinguished, the most important of which is the distinction between task cohesion and social cohesion. Mullen and Copper (1994) operationalize it as cohesion due to the commitment to the task, and cohesion due to the interpersonal attraction. Task cohesion refers to the shared commitment among members to achieve a goal that requires the collective efforts of the group. Social cohesion refers to the nature and quality of the emotional bonds of friendship such as liking, caring and closeness among group members. They pictured the mechanisms by which these types of cohesiveness might affect performances as follows. If the cohesiveness-performance effect is primarily due to interpersonal attraction, group members will exert efforts toward performance for the sake of their well-liked group members. If the effect is primarily due to commitment to the task, group members will exert efforts toward performance for the pleasure of completing that task.

Their meta-analytic study indicated that task cohesion appears to be the critical and primary component of cohesiveness in the cohesiveness-performance effect, suggesting that teams that perform well are committed to successful task performance and regulate their behavior toward that end. Some studies even state that social cohesion can be detrimental by invoking 'groupthink' (Janis, 1972), while task cohesion prevents groupthink from occurring. However, research following this study has showed that the relation is not always that consistent and has pointed out that social cohesion is potentially a predictor of team viability, another desirable outcome of teamwork (Chang & Bordia, 2001).

All this leads us to hypothesize that task cohesion will be positively associated with learning behavior, because high task motivation shows the existence of shared goals and the motivation to strive for it. It regulates the (learning) behavior that fosters the achievement of these goals. The relation of social cohesion with learning behavior seems more complex. On the one hand it promotes learning behavior because it increases the willingness to help each other, while on the other hand high social cohesion could lead to uncritical acceptance of solutions.

Hypothesis 4a: *Task cohesion is positively related to team learning behavior*.

Hypothesis 4b*: Social cohesion is not related to team learning behavior*.

Interdependence

Interdependence is one factor that is both heavily studied in educational (e.g., Johnson & Johnson, 1989; Mesch, Marvin, Johnson, & Johnson, 1988) and organizational (e.g., Wageman, 1995) sciences. A classic distinction made is one between task interdependence and outcome interdependence. Task interdependence (initiated and received) refers to the interconnections between tasks such that the performance of one definite piece of work depends on the completion of other definite pieces of work (van der Vegt, Emans, & van de Vliert, 1998). Studies have shown that task interdependence leads to more communication, helping, and information sharing than individualistic tasks (Crawford & Gordon, 1972; Johnson, 1973). Some findings suggest that this interdependence is related to experienced responsibility for the work of others (Kiggundu, 1983). This in turn leads to a shared responsibility on team-level.

Outcome interdependence is defined as the extent to which team members their personal benefits and costs depend on successful goal attainment by other team members (van der Vegt et al., 1998). Concerning this construct, findings indicate that teams working under circumstances of positive outcome interdependence are more open-minded regarding other's arguments and desires, more concerned about each other's outcomes, and more inclined to search for solutions and compromises (e.g., Deutsch, 1980; Johnson & Johnson, 1989). So both outcome interdependence and task interdependence seem to lead to a shared responsibility on team-level and influence the level of cooperative social interaction in teams (Wageman, 1995). Wageman concludes in her study that whenever collaborative behavior is important to excellent task performance, high task interdependence supported with reward interdependence is critical. Gully, Incalcaterra, Joshi, and Beaubien (2002) point out that empirical evidence supports the notion that task and outcome interdependence tap into a general interdependence factor conjointly

influencing the behavior of the team. Following Johnson and Johnson (1989), Wageman (1995) and van der Vegt et al. (1998) we focus on the effect of perceived task and outcome interdependence.
Hypothesis 5: *Task and outcome interdependence will be positively related with learning behavior*.

Group Potency
Based on the idea of the role of self-efficacy in individual performance (Bandura, 1982), researchers have conceptualized group potency as a key determinant of team performance outcomes (Shea & Guzzo, 1987a). Group potency has been defined as "the collective belief of group members that the group can be effective" (Shea & Guzzo, 1987b, p. 26). This means that it is a group-level phenomena and a general, overall belief about the ability to be effective (Hecht, Allen, Klammer, & Kelly, 2002; Gully et al., 2002). It is stated that positive evaluations of the team's potency are expected to have positive effects on collective motivation and performance (Cohen & Bailey, 1997; Sargent & Sue-Chan, 2001).
Recently, Gully et al. (2002) reviewed the body of research on the concept of group potency and affirmed the positive relationship between group potency and team performance. However, this research work has not specified the processes through which shared perceptions of potency lead to good performance (Edmondson, 1999). A possibility is that potency fosters a team's confidence (Edmondson, 1999; Gully et al., 2002) and so determines whether a situation is framed as a possible threat or as an opportunity. This will influence the ability of a team to effectively regulate team processes and share and process information (Gully et al., 2002). Edmondson's (1999) research itself can give us some indications about these mechanisms. She found that team efficacy (resembling group potency) is positively associated with team learning behavior.
Hypothesis 6: *Group potency is positively related to team learning behavior*.

Until now, most research studied the identified factors in isolation. So the question remains how these factors relate between themselves. We hypothesize that the identified shared beliefs are complementary. This means that each of the shared beliefs should supplement the other beliefs' positive effect on the occurrence on team learning behaviors. Team members will engage in learning behavior if, first, there is a shared commitment towards the task at hand (task cohesion), second if they believe they have to believe that they need each other for dealing with this task (interdependence), third, if they believe they will not be rejected for bringing in new meanings (team psychological safety), and, fourth if they believe that the team is capable of using this new information to generate useful results (team potency). This would mean that each of the identified beliefs has a singular effect on the learning behavior of the team.

Team Learning: A Model
The above presented constructs fit into a model of collaborative work in which beliefs about the interpersonal context shape the willingness to engage in learning behavior. Learning behavior is defined as processes of construction and co-construction of

meaning, with constructive conflict as a vehicle to enhance (co-)construction. This learning behavior gives rise to mutually shared cognition, leading to higher team effectiveness. The above stated hypotheses can be summarized in the model presented in figure 1.

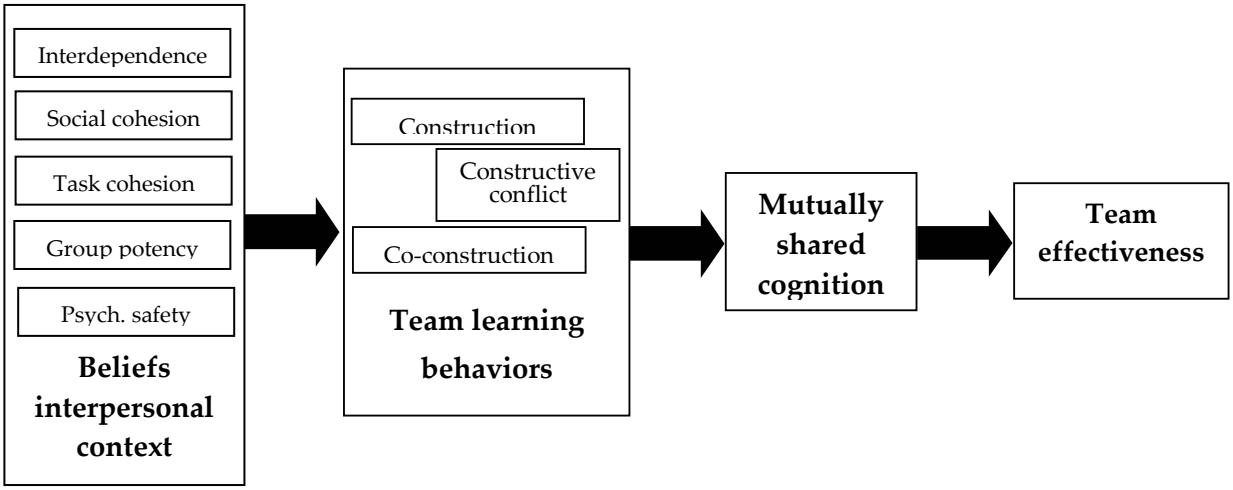

Figure 1: Team Learning Beliefs & Behaviors – model

Method

Setting & Procedure

The study took place in two first-year bachelor courses (Logistics and International Economics) of an International Business degree program. The students in these courses had two semesters of prior experience in working in groups. As a course requirement, students formed groups to work on an assignment during a 7-week period. This assignment consisted of advising a company or institution on its strategy, resulting in a paper and a presentation. This assignment was comparable over the two courses, only the context of the problems was specific for the two courses. The questionnaire was administered in the last week of the course.

Participants

Data were collected from 99 teams. Data were analyzed from only those teams which had a response of minimal two-thirds of the team-members (this was possible because group-level constructs were measured; the different individuals in the team can be seen as 'repeated measures'). Seventy five teams were selected for analysis. These teams had an average out of 3.45 members (SD = .68, range from 3 to 5) and on average 0.49 data of team members were missing (SD = 0.43).

Instrumentation

Constructs in the model were measured with a questionnaire ('Team Learning Beliefs & Behaviors-Questionnaire') composed of scales taken from validated questionnaires. The selection of instruments was guided by two criteria. First, the chosen instrument has to measure the same construct, that is, the construct that is originally measured has to be

conceptually identical to the way the construct is defined in the team learning model. Second, the psychometric qualities of the selected instrument must be high. The resulting questionnaire was thoroughly reviewed by experts and was cognitive pre-tested with a group of students to make sure the composed questionnaire was adapted to the situation (American Statistical Association, 1997).

Assessment of the psychometric properties was carried out through principal component analyses (varimax rotation with eigenvalues of 1.0 or above) of the scales connected to the same level of the model to confirm the uniqueness of the scales with respect to each other. This was supplemented by the computation of the internal consistency reliability of the scales (Cronbach's alpha). These analyses were executed using the individual participants' responses (Nunally & Bernstein, 1994).

In the next paragraphs, the different sections of the questionnaire are described pointing out the scales out of which they are composed. Also the results of the assessment of the psychometric properties are reported. This is followed by the presentation of the intercorrelations and internal consistency of the scales used in the main analysis.

Team Learning Behaviors

Our conception of collaborative learning leads to a focus on conversational actions enabling team members to become partners in the construction of shared knowledge (Roschelle, 1992). These conversational actions refer to the three aforementioned aspects of the learning behavior (construction, co-construction, and constructive conflict). These aspects were measured by means of 9 items from three questionnaires. Items were formulated based on the questionnaire of Visschers-Pleijers, Dolmans, and Wolfhagen (2003), measuring analogical learning processes (exploratory questions, cumulative reasoning and handling conflicts). This was completed with questions measuring perceptions of learning processes from the Edmondson questionnaire (1999) and the Van Offenbeek questionnaire (2001) to cover the full range of identified learning behaviors.

Examples of items operationalizing these learning behaviors were respectively 'Team members are listening carefully to each other' (construction), 'Information from team members is complemented with information from other team members' (co-construction) and 'This team tends to handle differences of opinions by addressing them directly'(constructive conflict).

The factor analysis revealed one factor on which all items loaded high (minimum: .66). Also the internal consistency was high, with an alpha of .88. This shows that these items tap into a general construct that can be defined as "team learning behavior".

Beliefs about the interpersonal context

Psychological safety

For measuring psychological safety, Edmondson's (1999) questionnaire was used. Sample items for psychological safety include 'No one in this team would deliberately act in a way that undermines my efforts' and 'It is safe to take a risk in this team'.

Interdependence

Questions measuring interdependence were based on the scales and items developed and used by van der Vegt et al. (1998), who used multiple items to picture the same

construct. Those items were selected that most strongly reflect the initial meaning of the construct in our setting. The degree of perceived task interdependence was measured using two items (e.g. 'I depend on my team members for information and advice'). The scale measuring outcome interdependence was also covered by two items (e.g. 'When my team members succeed in their jobs, it works out positively for me').

Cohesion

Social cohesion was measured using a scale developed by Sargent and Sue-Chan (2001), containing four items. Sample items include 'I like my team' and 'I feel a sense of belongingness to my team'. Task cohesion was operationalized using a scale from Carless and de Paola (2000). This scale consists of four items including for example 'This team is united in trying to reach its goals for performance' and 'The team members have conflicting aspirations for the team's performance' (reversely scored).

Group potency

Group potency was measured through a scale also used by Sargent and Sue-Chan (2001) and Gibson, Randel, and Earley (2000). This is an adapted version from a scale originally formulated by Guzzo, Yost, Campbell, and Shea (1993). Examples from the six items in this scale are 'This team has confidence in itself' and 'This team can get a lot done when it works hard'.

The factor analysis confirmed the scales as measured, except for one of the items of the task cohesion scale which also loaded highly onto two other factors, showing the lack of discriminative power. This item was therefore deleted in the further analysis. Three items of the psychological safety scale also loaded highly on other factors. Most likely this is a consequence of the broad operationalization of the concept by Edmondson (1999). Therefore these three items were also deleted. The four remaining items load onto two factors, both conceptually related to the essence of the construct as defined. The analyses of the internal consistency of the scales confirmed this picture. Cronbach's alpha of the scales social cohesion and group potency is .88 and .89 respectively. The interdependence scales internal consistency is smaller (alpha=.64. This is a consequence of the two slightly different constructs that are measured with this scale: task and outcome interdependence. The internal consistency of the task cohesion is hardly damaged by removing one of the items (alpha = .79). The internal consistency of the psychological safety scale is rather low (alpha = .50), this is also a consequence of the two aspects of the construct that are pictured in this scale.

Mutually Shared Cognition

Mulder (1999) developed and used in further research (Mulder, Swaak, & Kessels, 2002) a self-scoring instrument measuring 'shared understanding'. They defined and used shared understanding analogue to our construct of mutually shared cognition. They measured the perception of shared understanding both at a certain moment (product) and with respect to the development of shared understanding (process). We used only those items referring to the perceived shared understanding at a certain moment. To stress this, we added to the questions "at this moment". Mulder (1999) and Mulder et al. (2002) questioned the understanding of the task and the requirements of the task in one question. We split this up in two items. This resulted in a scale existing of the following

items: 'At this moment, this team has a common understanding of the task we have to handle' and 'At this moment, this team has a common understanding of how to deal with the task'.
Factor analysis reveals that both questions load very highly on one factor (minimum .938). Concomitant with this factor analysis is the high internal consistency of this scale (alpha = .86).

Team Effectiveness
This study examines the impact of team learning beliefs and behaviors on the three dimensions of team effectiveness as defined by Hackman (1989): performance, viability, and learning.. This was done through a self-reported subjective measure of group performance, a method commonly used in the study of work teams (Chang & Bordia, 2001; Cohen & Bailey, 1997). The above mentioned dimensions were measured using four items. Two items questioned the first dimension; team performance (e.g., 'I am satisfied with the performance of our team'). Two more items were used to get a grip on respectively the team viability ('I would want to work with this team in the future') and team learning ('As a team, we have learned a lot').
The internal consistency of these four items is high (alpha = .88), and also the factor analysis shows that these four items tap into a shared construct; all items have a high factor loading (minimum: .78).

Table 1
Chronbach's alpha and intercorrelations between team-level survey variables

	Variable	Mean	SD	1	2	3	4	5	6	7	8
1.	Interdependence	5.13	.51	**.62**							
2.	Social cohesion	5.31	.86	.35**	**.92**						
3.	Task cohesion	5.12	.76	.40**	.70**	**.81**					
4.	Psychological safety	4.98	.56	.53**	.50**	.50**	**.60**				
5.	Group potency	4.95	.73	.32**	.56**	.50**	.58**	**.92**			
6.	Team learning behaviour	5.34	.60	.60**	.61**	.60**	.73**	.63**	**.92**		
7.	Mutually shared cognition	5.53	.75	.47**	.59**	.59**	.57**	.40**	.67**	**.89**	
8.	Team effectiveness	5.20	.86	.25*	.78**	.70**	.49**	.66**	.67**	.66**	**.90**

Note:
**: Correlation is significant at the .01-level
*: correlation is significant at the .05-level

Aggregation on team level

The constructs measured in the survey are conceptually meaningful at the team-level. Therefore, the data gathered from individual team members to assess these team-level variables needed to be aggregated at that level. The within-group agreement was assessed using the multiple-item estimator rwg (James, Demaree, & Wolf, 1984). This analysis resulted in a mean value of .81 for interdependence, .89 for social cohesion, .76 for task cohesion, .81 for psychological safety, .85 for group potency, .88 for learning behavior, .83 for mutually shared cognition, and .78 for team effectiveness. These results justify the creation of a group-level data-set. Descriptive statistics (mean and standard deviation), intercorrelations, and the internal consistency of the scales at the team-level of analysis are presented in Table 1.

Methods of Analysis

The present study used (multiple) regression and path analysis to identify effects of potentially important theoretical relations. The analysis is presented in three parts. Analogue with the theoretical framework, it first tested whether the part of the model describing collaborative learning as 'building mutually shared cognition' holds. Next, it analyzed whether the identified beliefs about the interpersonal context influence team learning behavior. Finally, it analyzed whether the complete proposed model is acceptable. This is done in two steps: first the model describing the process leading towards mutually shared cognition is tested, and then the model -also including the variable team effectiveness- is analyzed.

The first two parts of the analysis were primarily based on (multiple) regression analyses. The last part of the analysis was informed through the path analyses. The adequacy of the models was assessed by LISREL version 8.52 (Jöreskog & Sörbom, 2002). Models were all tested with standardized coefficients obtained from the Maximum Likelihood method of Estimation (MLE). To ascertain the model fit, we emphasized the comparative fit index (CFI), the non-normed fit index (NNFI) and the standardized root mean square residual (SRMR) as well as the Chi-square test statistic. Values of the CFI and NNFI greater than respectively .90 and .95 are typically taken to reflect acceptable and excellent fits to the data (Schumacker & Lomax, 1996). The NNFI contains, contrary to the CFI, a penalty for a lack of parsimony of the model (Guay, Marsh, & Boivin, 2003). Hu and Bentler (1999) suggested the use of the SRMR in evaluating the model fit, with values less than .08 as an indication of a relatively good fit between the hypothesized model and the observed data. Only statistically significant paths are included in the presented diagrams

Results

Part 1: The Cognitive Side of Collaborative Learning

To test the hypothesis that team learning behaviors lead to mutually shared cognition and that this is subsequently related to higher team effectiveness, three regression analyses were performed. First, it was tested if team learning behavior significantly predicts the mutually shared cognition as reported by the team. Second, it was analyzed

if the reported mutually shared cognition predicts team effectiveness. Finally, it was analyzed if mutually shared cognition mediates the relation between team learning behavior and team effectiveness. For that, the contribution of team learning behavior should drop (for partial mediation) or become insignificant (for full mediation) when entered into the model together with variable mutually shared cognition (Baron & Kenny, 1986). The results of these computations are presented in table 2.

Table 2
Regression models of outcomes

	Mutually shared cognition			Team Effectiveness					
	Beta	t	p	Beta	t	p	Beta	t	p
Team Learning behavior	.67	7.644	.000				.41	3.799	.000
Mutually shared cognition				.66	7.514	.000	.39	3.560	.001
Adjusted R-Squared	.44			.43			.52		

Note: standardized Beta's are reported.

Table 2 shows that mutually shared cognition is significantly predicted by team learning behavior (Beta = .67, p = .000, adj. R-square = .44), providing support for H1. Mutually shared cognition significantly predicts team effectiveness (Beta = .66, p = .000, adj. R-square =.43), supporting H2. The third regression analysis shows that the relation between team learning behavior and team effectiveness is partially mediated by mutually shared cognition.
Figure 2 pictures the results if the latter analysis is presented as a path model. This is a fully defined and thus completely saturated model. The parameters are the standardized betas in the multiple regression analysis.

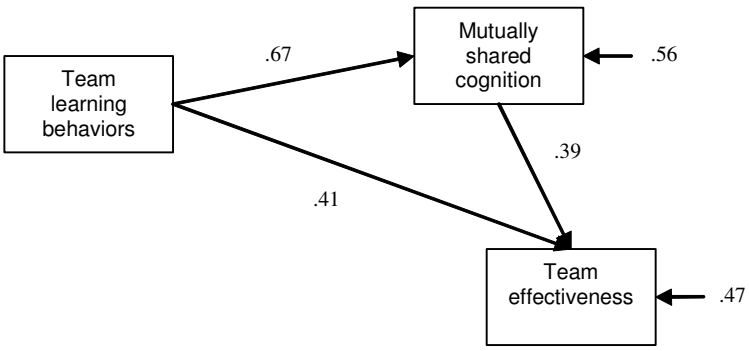

Figure 2: The Cognitive Side of Collaborative Learning

This analysis shows that the three team learning behaviors (i.e., construction, co-construction and constructive conflict) present themselves as knowledge building activities resulting in mutually shared cognition. The identified socio-cognitive processes give rise to a shared conception of the problem at hand. This mutually shared cognition can be seen as the primary and most profound learning outcome. In turn, this mutually shared cognition is identified as a part of the basis on which team effectiveness is built: it plays an important role in the total effectiveness of the team. The relation between the team learning behaviors and team effectiveness in the first analysis is only partially mediated by mutually shared cognition.

Part 2: The Social Side of Collaborative Learning

A multiple regression analysis was conducted to analyze if the identified team beliefs of the interpersonal context predict the occurrence of team learning behavior. The results are summarized in Table 3.

Table 3

Regression model of team learning behavior

	Beta	t	p	Adj. R-square
Interdependence	.254	3.317	.001	
Social cohesion	.083	0.866	.390	
Task cohesion	.247	2.550	.013	
Psychological safety	.299	3.243	.002	
Group potency	.202	2.376	.020	
				.70

Note: standardized Beta's are reported

Four of the five identified team beliefs significantly and substantially predict team learning behavior: Interdependence (Beta = .254; p = .001), task cohesion (Beta = .247; p = .013), psychological safety (Beta =.299; p =.002), and group potency (Beta =.202; p =.020). As expected, team learning behavior is not determined by social cohesion (Beta = .083; p =.390). Therefore this variable will be deleted in the further analyses. These results provide support for H3, H4a, H4b, H5, and H6, and also support the hypothesis that these beliefs are complementary.

This second part of the analysis focused on the relation between the beliefs about the interpersonal context and the team learning behavior. This analysis shows that teams engage in the described socio-cognitive processes of team learning behavior under certain conditions. All the identified beliefs about the interpersonal context set the stage for the occurrence of the team learning behavior. Interdependence, task cohesion, psychological safety and group potency form the context in which teams are motivated to display the crucial learning behavior. Social cohesion is the only measured belief that does not seem to play a role in this context. Based on the evidence displayed in the

literature this was to be expected: task cohesion is the more important aspect of cohesion in general in predicting productive team behavior.

Part 3: Testing the Model

The full team learning model is tested in two steps. A first model explains the development of mutually shared cognition and does not include team effectiveness. The second does include the variable team effectiveness.

Towards a model of mutually shared cognition

The originally hypothesized model is composed of paths leading from the four constructs measuring beliefs towards team learning behavior and a path from learning behavior towards mutually shared cognition. Though the fit of this model is acceptable for some of the indicators, this can be improved (Chi-square = 21.71, df = 4, $p < .05$; CFI = .94; NNFI = 0.76; SRMR = .065).

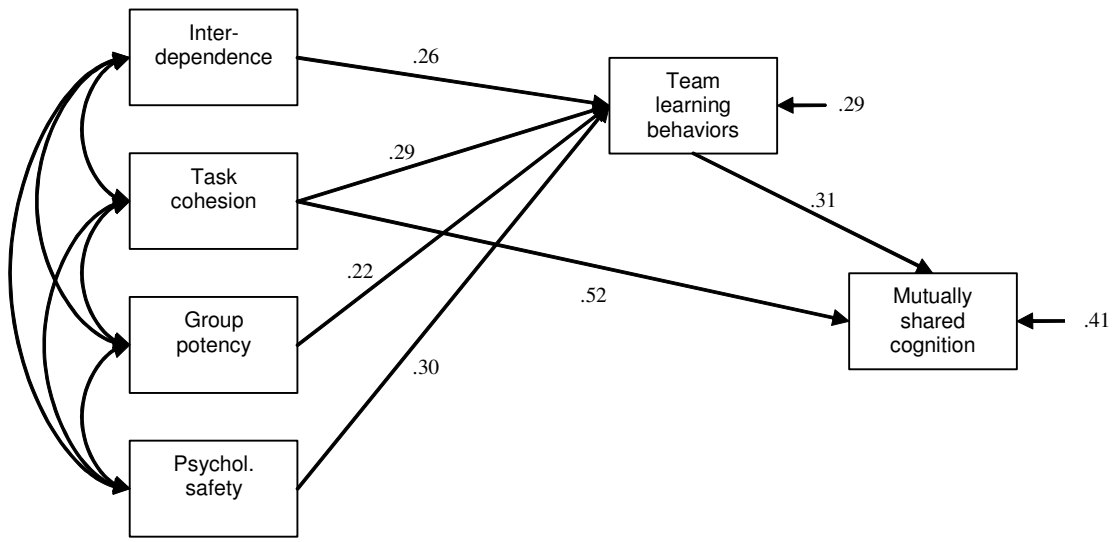

Figure 3: Model towards Mutually Shared Cognition

Inspection of the modification indices (Sörbom, 1989) suggests one additional path between task cohesion and mutually shared cognition. This model, pictured in figure 3, fits the data even better (Chi-square = 3.08, df = 3, p = .38, CFI = 1.00, NNFI = 1.00, SRMR = .022).

This model is most important and interesting if one looks from an educational point of view because in this model one can see the factors that are influencing the cognitive outcomes of team learning: the mutually shared cognition that is built through participating in the team learning activities. This is, in other words, the 'cognitive residue' or the 'conceptual development' resulting from team learning.

The model as confirmed by the data shows that the beliefs about the interpersonal context support the team learning behavior which in turn gives rise to mutually shared cognition. It is important to see that the influence of the beliefs on shared cognition is through the learning behaviors espoused by the team. The only exception is task cohesion, which has also, next to an indirect relation, a direct relation with the rise of

mutual shared cognition. The shared commitment towards the task seems to have effects on mutually shared cognition that are not grasped by the learning behaviors alone.

Towards a model of team effectiveness

First, the model presented in figure 3 was extended with the variable team effectiveness, including a path from mutually shared cognition to team effectiveness. However, the fit indices show that this model is not probable (Chi-square = 43.29, df = 8, p < .05; CFI = .91, NNFI = .77, SRMR = .096). Inspection of the modification indices (Sörbom, 1989) learned that two additional paths are necessary: one path from task cohesion towards team effectiveness and one path from group potency to team effectiveness.

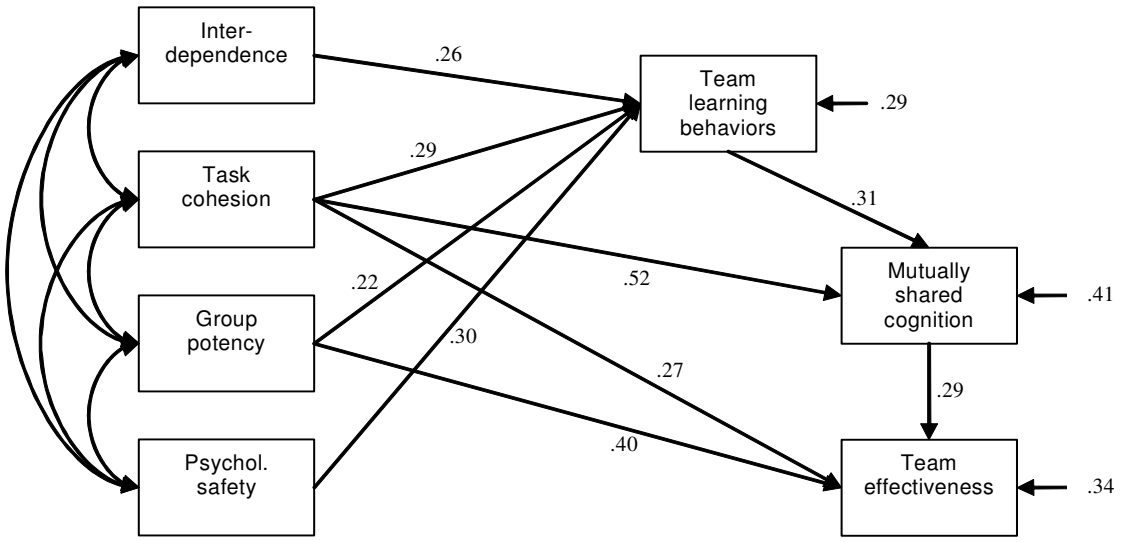

Figure 4: Model towards Team Effectiveness

Figure 4 contains this adapted model. The values of the fit indices indicate an acceptable fit of the path model applied to the data. The chi-square becomes significant (Chi-square= 13.18, df = 6, p = .04), but all the other fit measures show that this model is acceptable (CFI = .98; NNFI = .94, SRMR = .031). These finding argue for the appropriateness of the model structure as shown in figure 4.

The effectiveness of the team is influenced by the mutually shared cognition that is a result of the team learning behaviors of the team. This means that the data collected through the 'Team Learning Behavior and Beliefs'-questionnaire confirm the hypotheses underlying the team learning model as presented. The only modifications that needed to be made were: 1) an extra path from task cohesion to team effectiveness; and 2) an extra path from group potency to team effectiveness. Both adjustments seem theoretically acceptable. This is probably because a high shared commitment to the task and a high group potency of the team will probably show itself also in other team behavior leading to effectiveness that is not fully grasped by the identified team learning behaviors.

It can be pointed out that these analyses show that the relation between team learning behaviors and team effectiveness is fully mediated by mutually shared cognition (see

figure 4). In the previous analysis presented in part 1 of the results, this relation was only partially mediated by mutually shared cognition. This seems evident in the light of the fact that a part of the relation between team learning behavior and team effectiveness can be classified as spurious as a consequence of the relation of task cohesion and group potency with both team learning behavior and team effectiveness. Therefore, this spurious relation is elapsed in this last analysis in which the complete model is tested.

Conclusion and Discussion

These results have a number of theoretical and practical implications. The team learning model as presented and tested in this chapter is constituted by integrating ideas from different research strands. Conclusions and implications can be drawn for each of them.

Collaborative learning was conceptualized as the creation of mutually shared cognition. Discourse patterns were considered socio-cognitive processes through which mutually shared cognition is constructed. We identified these processes as team learning behaviors and framed them as construction, co-construction and constructive conflict. The results of this study show that this approach makes it possible to grasp team learning processes towards mutually shared cognition.

This chapter argued together with Roschelle and Teasley (1995) that these team learning behaviors do not take place just by putting people together. Interpersonal context needs to be taken into account to understand the engagement of team members to coordinate their understanding. To identify some crucial aspects of the interpersonal context we have made use of research in organizational and social psychology. The identified aspects such as interdependence, task cohesion, psychological safety and group potency turned out to be crucial for the engagement in team learning behavior in teams, which in turn give rise to mutually shared cognition, in turn leading to higher perceived team effectiveness. The results of this research show that constructs and insights from organizational science concerning interpersonal beliefs in teams are transferable to collaborative learning in educational settings. More specifically, the results suggest the importance of a team-belief such as psychological safety for learning: it seems to open the possibility to engage in learning behavior that asks team-members to "build" on and to "disagree" with each other (Edmondson, 1999). Wegerif (1998) noted that "forming a sense of community, where people feel they will be treated sympathetically by their fellows, seems to be a necessary first step for collaborative learning. Without a feeling of community people are on their own, likely to be anxious, defensive and unwilling to take the risks involved in learning" (p. 48). Also beliefs as task cohesion and interdependence seem to promote learning processes; the task commitment supplemented with a shared responsibility drive people to collective learning processes. Furthermore a high group potency belief strengthens the idea that investment will pay off and so encourages processes of learning. Conversely, our results underline the potential of a group learning perspective in understanding the processes that mediate the effect of these interpersonal factors on performance. It underpins the results of Edmondson (1999), showing the richness of a team learning approach, and extends it by incorporating different beliefs about the interpersonal context and by conceptualizing the team learning behavior from the perspective of building mutually shared cognition.

All this means that linkages between educational and organizational science have the potential of yielding additional insights in the development of shared cognition and performance in teams.

Moreover, the results of the present research suggest practical consequences for both education and professionals in teams. Since collaborative learning formats are frequently used in education for the professions and teamwork is omnipresent in those professions, teachers and managers need to pay explicit attention to the basic requirements for fostering interpersonal processes and beliefs that promote learning (e.g., Smith, 1996). This entails that students and professionals need (to learn how) to cope with these interpersonal beliefs and processes. This research suggests different pathways in the interpersonal context where attention can or needs to be focused on if knowledge building is aimed for. Possible handles can be sought in task design and/or assignment, leadership, and allocating time for group development.

Also, this research sheds light on the cognitive demands of teams in dealing with the framing of the task or problem at hand; both understanding and agreement need to be dealt with. This means that room for construction, co-construction and constructive conflict needs to be made in the process of reaching mutual shared cognition. This can involve slowing down the interaction in order to inquire about meanings and test understandings (Argyris & Schön, 1996; Marsick, Watkins, & Wilson, 2002). Also, conflicts need to be seen as windows of opportunity instead of threats to progress. By taking them as conflicts around the interpretation of a problem, they can be the motor of further communication (Dillenbourg et al., 1996). Through this negotiation mutually shared cognitions are constructed.

Limitations and issues for future research

The present study is founded on perceptions of the team-members. Future research should try to establish how perceptions of mutually shared cognition relate to measurements more informed by cognitive sciences. Hereby the challenge will be to directly measure the mutually shared cognition of a team (for a review, see e.g. Akkerman, Van den Bossche et al., 2005). Also, one can question how perceptions of the team learning behaviors are related to the concrete behaviors of team members. In order to deal with this concern, we used multiple observers, i.e. the different team members. Furthermore, one can question who the best observer of this team learning behavior is; the team members or an external observer? Hereby keeping in mind that this external observer adds nothing more than an extra perception of the situation (and who is best capable of evaluating if, for example, a 'critical question' is posed?). Moreover, consistency is found between the self-reported learning behaviors and the learning behaviors as reported by an external observer (Edmondson, 1999). Also the research design can be expanded with more objective measures of team effectiveness. For example, the team performance can be assessed by experts. The performance on transfer tasks (new assignment and/or members in a new team) can give further insight in the professional development of the team. And indications of system viability maybe can be found in behavioral measures as absenteeism and drop-out (Cohen & Bailey, 1997).

Further research also needs to be directed at the extra paths that are included in the team learning behavior model. Paths were added from task cohesion and group potency towards team effectiveness. These paths suggest processes leading towards team effectiveness that are not included in the team learning behaviors. Research should shed light on the processes underlying these paths in the model as we know it.

Future research will also need to take a methodological approach that makes it possible to get a better grip on the time and developmental aspects of beliefs about the interpersonal context. The quantitative methodologies used in the present research indicate the existence of the considered constructs. A selection of qualitative approaches will be more capable to deliver insight into how and why relationships develop in team contexts (Keyton, 2000).

Finally, this study focused only on groups of students in one educational context. It is conceivable that the tested relationships differ for different populations. The studied teams worked in a specific educational institution and the conclusions are therefore not immediate transferable to complete different educational institutions. And although the task tackled by these teams is comparable to the task of some professional teams, this sample of students in an educational context may not be fully representative for professional work teams. Future studies in different contexts could strengthen the validity of the findings.

References

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., & Simons, R.-J. (2005). *Shared mind in groups: Cognitive and socio-cultural perspectives*. Paper presented at the biennial conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Alpay, L., Giboin, A., & Dieng, R. (1998). Accidentology: An example of problem solving by multiple agents with multiple representations. In M. W. van Someren & P. Reimann & H. P. A. Boshuizen & T. de Jong (Eds.), *Learning with multiple representations* (pp. 152-174). Amsterdam: Pergamon.

American Statistical Association (1997). *What is a survey? How to conduct pretesting*. Alexandria, USA.

Argyris, C., & Schön, D. (1996). *Organizational learning II: A theory of action perspective*. Reading, MA: Addison Wesley.

Arrow, H., McGrath, J. E., & Berdahl, J. L. (2000). *Small Groups as complex systems. Formation, coordination, development and adaptation*. Thousand Oaks, CA: Sage Publications, Inc.

Baker, M. (1994). A model for negotiation in teaching-learning dialogues. *Journal of Artificial Intelligence in Education, 5*(2), 199-254.

Baker, M. J. (1995). Negotiation in collaborative problem-solving dialogues. In R.-J. Beun, M. Baker & M. Reiner (Eds.), *Dialogue and instruction. Modeling interaction in intelligent tutoring systems* (pp. 39-55). Berlin: Springer-Verlag.

Baker, M. J. (1999). Argumentation and constructive interaction. In P. Coirier & J. Andriessen (Eds.), *Foundations of argumentative text* (pp. 179-202). Amsterdam: University of Amsterdam Press.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*, 122-147.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediatior variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173-1183.

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

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

Carless, S. A., & de Paola, C. (2000). The measurement of cohesion in work teams. *Small Group Research, 31*, 71-88.

Chang, A., & Bordia, P. (2001). A multidimensional approach to the group cohesion-group performance relationship. *Small Group Research, 32*, 379-405.

Cohen, S. G., & Bailey, D. E. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management, 23*, 239-290.

Crawford, J. L., & Gordon, A. H. (1972). Predicisional information-seeking and subsequent conformity in the social influence process. *Journal of Personality and Social Psychology, 23*, 112-119.

Crook, C. (1998). Children as computer users: The case of collaborative learning. *Computers and Education, 30*, 237-247.

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review, 9*(2), 284-295.

De Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A Meta-analysis. *Journal of Applied Psychology, 88*, 741-749.

Deutsch, M. (1980). Fifty years of conflict. In L. Festinger (Ed.), *Retrospections on social psychology* (pp. 46-77). New York: Oxford University Press.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier.

Edmondson, A. C. (1996). Learning from mistakes is easier said than done: Group and organizational influences on the detection and correction of human error. *Journal of Applied Behavioral Science, 32*(1), 5-28.

Edmondson, A. C. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350-383.

Engeström, Y., Engeström R., and Kärkkäinen, M. (1995). Polycontextuality and Boundary Crossing in Expert Cognition: Learning and problem solving in complex work activities. *Learning and Instruction, 5*, 319-336.

Ericsson, K. A., & Smith., J. (1991). Prospects and limits of the empirical study of expertise: an introduction. In K. A. Ericsson & J. Smith, (Eds.), *Toward a General Theory of Expertise; Prospects and Limits* (pp. 1-38). Cambridge, MA: Cambridge University Press.

Evans, C. R., & Dion, K. L. (1991). Group cohesion and performance: A meta-analysis. *Small Group Research, 22*, 175-186.

Festinger, L. (1950). Informal social communication. *Psychological review, 57*, 271-282.

Gibson, C. B., Randel, A. E., & Earley, P. C. (2000). Understanding group efficacy. An empirical test of multiple assessment methods. *Group & Organization Management, 25*(1), 67-97.

Guay, F., Marsh, H. W., & Boivin, M. (2003). Academic Self-concept and Academic Achievement: Developmental Perspectives on their Causal Ordering. *Journal of Educational Psychology, 95*(1), 124-136.

Gully, S. M., Incalcaterra, K. A., Johi, A., & Beaubien, J. M. (2002). A meta-analysis of team-efficacy, potency and performance: Interdependence and level of analysis as moderators of observed relationships. *Journal of Applied Psychology, 87*(5), 819-832.

Guzzo, R.A., Yost, P.R., Campbell, J.R., & Shea, G.P. (1993). Potency in teams: Articulating a construct. *British Journal of Social Psychology, 32*, 87-106.

Hackman, J. R. (Ed.). (1989). *Groups that work (and those that don't). Creating conditions for effective teamwork*. San Francisco, CA: Jossey-Bass.

Hecht, T. D., Allen, N. J., Klammer, J. D., & Kelly, E. C. (2002). Group beliefs, ability, and performance: The potency of group potency. *Group Dynamics: Theory, Research, and Practice, 6*(2), 143-152.

Hewson, P.W. & Hewson, M.A. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science, 13* (1), 1-13.

Homan, T. (2001). *Teamleren. Theorie en facilitatie* [Teamlearning. Theory and Facilitation]. Schoonhoven, The Netherlands: Academic Publisher.

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternations. *Structural Equation Modelling, 6*, 1-55.

James, L. R., Demaree, R. G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology, 69*(1), 85-98.

Janis, I. L. (1972). *Victims of groupthink*. Boston: Houghten Mifflin.

Johnson, D. W. (1973). Communication in conflict situations: A critical review of the research. *International Journal of Group Tensions, 3*, 46-67.

Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Edina, MN: Interaction Book Co.

Jöreskog, K., & Sörbom, D. (2002). *Lisrel 8.52*. Scientific Software International, Inc.

Keyton, J. (2000). The relational side of groups [Introduction to a special issue]. *Small Group Research, 31*, 387-396.

Kiggundu, M. N. (1981). Task interdepence and the theory of job design. *Academy of Management Review, 6*, 499-508.

Klimoski, R., & Mohammed, S. (1994). Team Mental Model: Construct or metaphor? *Journal of Management, 20*, 403-437.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior, 19*, 335–353.

Langfield-Smith, K. (1992). Exploring the need for a shared cognitive map. *Journal of Management Studies, 29*, 349-368.

Lingard, L., Reznick, R., Espin, S., Regehr, G., & DeVito, I. (2002). Team communications in the operating room: Talk patterns, sites of tension, implications for novices. *Academic Medicine, 77*, 232- 237.

Marsick, V. J., Watkins, K. E., & Wilson, J. A. (2002). Informal and incidental learning in the new millennium: The challenge of being rapid and/or being accurate! In M. Pearn (Ed.), *Individual differences and development in organisations*. Chichester, England: John Wiley & Sons.

Mesch, D., Marvin, L., Johnson, D. W., & Johnson, R. T. (1988). Impact of positive interdependence and academic group contingencies on achievement. *Journal of Social Psychology, 128*, 345-352.

Mulder, I. (1999). *Understanding Technology Mediated Interaction Processes. A theoretical context*. Telematica Instituut.

Mulder, I., Swaak, J., & Kessels, J. (2002). Assessing group learning and shared understanding in technology-mediated interaction. *Educational Technology & Society, 5*(1), 35-47.

Mullen, B., & Copper, C. (1994). The relation between group cohesiveness and performance: An integration. *Psychological Bulletin, 115*, 210-227.

Nunally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.

Olivera, F., & Straus, S. G. (2004). Group-to-individual transfer of learning. Cognitive and social factors. *Small Group Research, 35*, 440-465.

Patel, V. L., Arocha, J. F., & Kaufman, D. R.. (1999). Expertise and Tacit Knowledge in Medicine. In R. Sternberg & J. Horvath (eds.), *Tacit Knowledge in Professional Practice. Researcher and Practioner Perspectives* (pp. 75-99). Mahwah, NJ: LEA.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*(3), 235-276.

Roschelle, J., & Teasley, S. D. (1995). Construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning*. New York: Springer-Verlag.

Salomon, G. & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research, 13*, 89-99.

Sargent, L. D., & Sue-Chan, C. (2001). Does diversity affect group efficacy? The intervening role of cohesion and task interdependence. *Small Group Research, 32*, 426-450.

Schein, E. H., & Bennis, W. G. (1965). *Personal and Organizational Change through Group Methods. The Laboratory Approach*. New York: John Wiley & Sons, Inc.

Schmidt, H. G. & Boshuizen, H. P. A. (1993). On the origin of intermediate effects in clinical case recall. *Memory and Cognition, 21*, 338-351.

Schumacker, R. E., & Lomax, R. G. (1996). *A beginner's guide to structural equation modeling*. Mahwah, NJ: Erlbaum.

Shea, G. P., & Guzzo, R. A. (1987a). Groups as human resources. In K. M. Rowland & G. R. Ferris (Eds.), *Research in personnel and human resources management* (Vol. 5, pp. 323-356). Greenwich, CT: JAI Press.

Shea, G. P., & Guzzo, R. A., (1987b). Group effectiveness: What really matters? *Sloan Management Review, 28*, 25-31.

Smith, K. A. (1996). Cooperative Learning: Making 'Group work' Work. In T.E. Sutherland, & C.C. Bonwell (Eds.), *Using active learning in college classes: A range of options for faculty*, New Directions for Teaching and Learning No. 67.

Sörbom, D. (1989). Model modification. *Psychometrika*, 54, 371-384.

Stahl, G. A. (2000). *A model of collaborative knowledge building*. Paper presented at the 4th International Conference of the Learning Sciences.

Sternberg, R. J. (Eds.). 1999. *The Nature of Cognition*. Cambridge, MA: MIT Press.

Van der Vegt, G., Emans, B., & van de Vliert, E. (1998). Motivating effects of task and outcome interdependence in work teams. *Group & Organization Management, 23*, 124-143.

Van Offenbeek, M. (2001). Processes and outcomes of team learning. *European Journal of Work and Organizational Psychology, 10*, 303-317.

Visschers-Pleijers, A. J. S. F., Dolmans, D. H. J. M., Wolfhagen,. I. H. A. P., & Van der Vleuten, C. P. M. (2003). *Development and validation of a questionnaire to identify interactions that promote deep learning in PBL*. Paper presented at the 10th European conference of research on learning and instruction, Padova, Italy.

Wageman, R. (1995). Interdependence and group effectiveness. *Administrative Science Quarterly, 40*, 145-180.

Webb, N. M., Ing, M., Kersting, N., & Nemer, K. M. (2004, april). *Impediments to productive help seeking and help giving in cooperative learning groups.* Paper presented at the American Educational Research Association, San Diego.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D.C. Berliner & R.C. Calfee (Eds.) *Handbook of Educational Psychology* (pp. 841-873). New York: MacMillan.

Wegerif, R. (1998). The social dimension of asynchronous learning networks. *Journal of Asynchronous Learning Networks, 2*(1), 34–49.

Wong, S.-S. (2003). *Collective cognition in team: The role of interactive learning and effects on team performance.* Paper presented at the Academy of Management, Seattle.

Chapter 4

Sharing Expertise in Management:
A Study on Team Learning and its Effect on Shared Mental Models*

To gain insight in the social processes that lead to shared mental models, this chapter questions which team learning behaviors lead to the construction of a shared mental model. Additionally, it explores how the development of shared mental models mediates the relation between team learning behaviors and team effectiveness. Analyses were performed on 27 teams engaged in a business simulation game. The measurement of shared mental models was based on cognitive mapping techniques.
The results indicate that a team learning perspective provides insight in how people share knowledge. Particularly the team learning behaviors identified as co-construction and constructive conflict are related to the development of shared mental models. In addition, a shared mental model of the task environment in a team appears to lead to in improved business performance. This stresses the importance of the group sense-making. Moreover, the development of shared mental model fully mediates the relation between team learning behavior and business performance. This was not the case for the performance of the team as perceived by the team members; a direct relation with team learning behavior is established, but this relation is not mediated by the level of shared mental model.

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* Based on:

Van den Bossche, P., Gijselaers, W., Segers, M., Woltjer, G., & Kirschner, P. A. (under revision). Sharing Expertise in Management: A Study of Team Learning and its Effect on Shared Mental Models.

The most fundamental challenge managers face today is that their decision environment is extremely complex, uncertain, and even equivocal and ambiguous (Zack, 2001). The data they have to handle are unclear and suggest multiple interpretations about the environment (Daft & Weick, 1984). Therefore, it is argued that within today's organizations, problems cannot longer be addressed by high-expert individuals, but by teams of people with different perspectives (Weick, 1969). It is generally assumed that a rich interaction, interactive discussion and negotiation between these people will lead to the development of a shared understanding and conceptual scheme through which events can be interpreted (Daft & Weick, 1984; Zack, 2001). The resulting shared understanding will be richer than each of the individual knowledge frameworks, since it incorporates different perspectives, and will allow for rich problem analysis and solutions (Beers, Boshuizen, Kirschner, & Gijselaers, 2005).
Yet, experiences in organizations show that the sharing of expertise remains a challenge for managers (Hinds & Pfeffer, 2003). A recent meta-analysis (Webber & Donahue, 2001) concluded that there was no relationship between diversity in skills, experiences or perspectives and performance. The authors suggested that bringing together people with different perspectives does not automatically lead to more effective teamwork. The crucial question that emerges is: Why is it the case that though highly expert people are brought together, they do not always seem capable of group sense-making (i.e., the elicitation and creation of group knowledge relevant to an emerging situation; Nosek & McNeese, 1997)? The present dissertation is based on the notion of shared mental model to grasp sense-making at group-level.

This chapter will focus on two questions. First, it questions the kind of team learning behaviors leading to the construction of a shared mental model. This research question will be based on an elaborated conceptual framework as a guide for defining relevant team learning behavior leading to the development of shared mental models. And second, it questions the relation between the sharedness of mental models in a team and team performance. By doing so, it shows the importance of the development of shared mental models and underlines the role of team learnng behaviors. It will start from a specific definition of shared mental models that guides the measurement issue. The central methodology for assessing the shared mental model of the teams will be based on cognitive mapping techniques as explored by Carley (1997). By this, we take a different approach on the measurement issues than most current research so as to capture the idiosyncratic content of the knowledge structures.

Team Learning Behaviors and Shared Mental Models

Shared mental models and team effectiveness

Shared mental models refer to the overlapping mental representation of knowledge by members of a team. Cognitive psychology has focused on the way individuals make sense of their environment through 'knowledge structures', conceptualized by Johnson-Laird (1983) as mental models, perceived of as internal representations of (aspects of) the

environment that provide a conceptual framework for describing, explaining and predicting future system states (Rouse & Morris, 1986). Klimoski and Mohammed (1994) used this understanding of individual sense-making to conceptualize cognition as a group-level phenomenon.

The interest in the construct of shared mental model is mainly driven by the idea that it is useful in explaining the functioning of teams and plays an important role in the effectiveness of those teams (Klimoski & Mohammed, 1994; Cannon-Bowers & Salas, 2001). It is stated that the aggregation of individuals' knowledge structures creates a context for efficient group decision-making (Klimoski & Mohammed; Cannon-Bowers et al.). Shared mental models assure that all team members are solving the same problem and help exploit the cognitive capabilities of the entire team (Orasanu, 1990 in Klimoski & Mohammed). The shared mental model integrates and coordinates the perspectives of the team members. This enables the team to have a complex and rich understanding of the task environment (Nosek & McNeese, 1997).

Shared mental models can refer to shared representations of tasks, equipment, working relationships and situations (Mohammed & Dumville, 2001). It is stated that probably all of these types of knowledge need to be shared in effective teams. Although different researchers have different interpretations (and operationalizations) of shared mental models (e.g., Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Ensley & Pearce, 2001; Stout, Canon-Bowers, Salas, & Milanovich, 1999; Smith-Jentsch, Mathieu, & Kraiger, 2005), their research has yielded some insights in shared mental models and their influence on performance. For example, Mathieu et al. made a distinction between team-work (i.e., on team-related aspects of the situation) and task-work (i.e., on task-related features of the situation) shared mental models. They tested the impact of teammates' mental model sharedness on performance, using undergraduate teams completing a series of missions on a PC-based flight simulator. The results indicated that sharedness of both team-work and task-work mental models related positively to subsequent team processes and performance. These kinds of results have supported the theoretical proposition that relates effective team performance with the existence of shared mental models.

The present dissertation will only focus on the task-aspect since it is interested in how teams come to a shared interpretation of their task environment for decision-making. Shared mental model is defined, based on the definition given by Klimoski and Mohammed (1994), as team members' overlapping mental representation of key elements of the team's task environment.

The development of shared mental models

The growing acknowledgement of and insight in the relation between shared mental models and performance, raises the question on how group cognitions develop. In order for teams to achieve a shared mental representation of the key elements of the task environment, changes in the knowledge of team members occur (Mohammed & Dumville, 2001). Mohammed and Dumville stress the significant role of group learning, defined as the development, modification and reinforcement of mental models through processes of group interaction.

This is concurrent with past theorizing of organizational and team researchers, stating that interacting individuals develop similar understandings and interpretations of events (e.g., Rentsch, 1990; Walsh et al., 1988). Walsh and colleagues indicated that indirect evidence within team research showed that interaction between team members is a primary cause of mental model agreement. A case in point is the research of Rentsch and Klimoski (2001) who questioned the relation between team size and shared mental models. Team size was taken as a rough estimate of team member interaction opportunity. Their results showed that team size was negatively related to the sharedness of the mental models: larger teams faced a lower likelihood of sharing mental models. This seems to suggest that shared mental models are indeed cognitive residues from an interactive learning process (Wong, 2003). It remains unclear which processes specifically play an important role in this interaction and make the team learning happen.

Although there is a great deal of research on team learning, there are very few examples of empirical research specifically investigating group processes, unravelling the interactions taking place, and their (direct) effects on group learning in teams (Mohammed & Dumville, 2001; Rentsch & Klimoski, 2001; Argote et al., 1999). As one of a few, Edmondson (1999) provides a research example studying the influence of team learning behavior on team effectiveness. She analyzed 51 work teams in a manufacturing company focusing on how team learning is shaped by behaviors such as seeking feedback, sharing information, experimenting, asking for help, and talking about errors. These behaviors showed to lead to more effective performance of the investigated teams. More recently, Wong (2003) investigated the influence of interactive learning behaviors on collective cognition in teams. The data suggested no relation between the learning of the teams and the cognitive overlap (i.e., a shared mental model) in task knowledge. Wong indicated that the method used may not capture detailed task knowledge that is specific to any one in the team. This suggests that further research on this issue has to be conscientious with the problematic issue of measurement of this group-level construct (Mohammed et al., 2000; Cannon-Bowers & Salas, 2001).

Unraveling team learning behaviors

To determine the interactions, that is the patterns in discourse, that can be considered as team learning behavior, we make use of the concepts of construction, co-construction and constructive conflict, building on research in the learning sciences (e.g., Dillenbourg et al., 1996; Alpay, Giboin, & Dieng, 1998) and branches of linguistic research on models of conversation, discourse or dialogue (Baker, 1995, 1999; Edmondson, 1981; Roulet, 1992). These two disciplines provide a framework on interactions constituting team learning (Dillenbourg et al.) and note that achieving a shared mental model presupposes joint understanding (Baker, 1995). It is, however, not only a matter of understanding each other's representation (mutual understanding), but also of accepting and incorporating each other's ways of seeing (mutual agreement) (Alpay et al., 1998). In reaching mutual understanding and agreement, the following processes are crucial. First, meaning or understanding needs to be (co-)constructed. This is not done through simple accumulation of the contributions of individuals, because these contributions 'build on'

previous ones. Second, agreement needs to be established about the proposed solution (Baker, 1995). The role of conflict, as the process resulting from differences in point of view, is highly relevant here (De Dreu & Weingart, 2003). These two team learning processes, through which the shared mental model is built, are elaborated on below.

Towards mutual understanding: Construction and Co-construction of meaning

The process of building a shared conception of a problem or situation starts with the articulation of personal meaning in the social setting (Stahl, 2000). This process starts when one of the team members inserts meaning by describing the problem situation and how to deal with it, hereby tuning in to fellow team-members. These fellow team-members are actively listening and trying to grasp the given explanation by using this understanding to give meaning to the situation at hand (Webb & Palincsar, 1996). We refer to these processes as construction of meaning.

Processes of construction of meaning can evolve into collaborative construction (i.e., co-construction), which is a mutual process of building meaning by refining, building on, or modifying the original offer in some way (Baker, 1994). The outcome of this process is that 'new' meanings emerge in the collaborative work that were not previously available to the group.

Towards mutual agreement: Constructive conflict

Shared mental models are developed when agreement is reached around the (co-) constructed understandings. It is not sufficient that the inserted meanings are clarified and that there is mutual understanding. They must also be accepted before they form the basis for action (Alpay et al., 1998). If accepted, the offered meaning can become part of the common ground which is the agreed-upon interpretation of the situation. However, the team members may diverge in their interpretation and tackle the situation from another point of view or perspective. This rejection of the built understanding can lead to a further elaboration through the negotiation of the different meanings. However, Hewson and Hewson (1984) and more recently De Dreu and Weingart (2003), argued that the emergence of differences of opinion does not guarantee conceptual advancement because it may be taken as a paradox, and resolved by ignoring one of the conflicting elements. Another argument is it may not be seen as a difference in the interpretation of the problem, but as a personal, emotional rejection and can as such interfere with productive team behavior (De Dreu & Weingart, 2003). So, disagreement in itself seems to be less important than the fact that it generates communication between peer members (Dillenbourg et al., 1996). The team will only benefit if divergence in meaning leads to deep-level processing of the diverse information and viewpoints in the team (van Knippenberg et al., 2004). Through this negotiation by argument and clarification, the team works towards a convergence of meaning in order to reach shared mental models. Therefore, we define constructive conflict as negotiation of differences in interpretation between team members by arguments and clarifications.

This framework leads to the following hypotheses. First, it is hypothesized that a *higher frequency of processes as (co-) construction and constructive conflict in the interaction of the team will positively influence the level of shared task mental models (H1)*. Second, it is hypothesized

that teams with greater levels of shared task mental models will be more effective than teams with lower levels of shared task mental models. And thus *the team learning behaviors (co-)construction and constructive conflict will influence team effectiveness through the development of shared mental models* (i.e., a mediator) *(H2)*.

Measurement of Shared Mental Models

Many authors have pointed to the problematic issue of the measurement of shared mental models (e.g., Kraiger & Wenzel, 1997; Cannon-Bowers & Salas, 2001; Mohammed & Dumville; 2001). Researchers used many methods, each of them having strengths and weaknesses. This paragraph elaborates on the considerations for dealing with this measurement issue. Mohammed et al. (2000) proposed relevant guidelines for choosing a methodology for measuring group-level cognitions. We follow these in our choice of methodology.

Selecting a group-level cognitive structure measurement technique must begin with a clear specification of the phenomenon to be tested and modeled (Mohammed et al., 2000). We have conceptualized shared mental models as team members' overlapping mental representation of key elements of the team's task environment. They also stress that a mental model can be seen as a knowledge structure, indicating that it contains both concepts and relations between those elements. This means that our measurement technique must deal with both, what Mohammed et al. call elicitation and representation to uncover the convergence of the team members' mental models. *Elicitation* refers to the technique used to determine the components or content of a mental model. *Representation* refers to the technique used to reveal the structure, the relationships between elements in the mental model. This is crucial, because meaning is affected by the use of concepts in their context.

This conceptualization makes the most common method of dealing with team mental models which uses Likert-scale questionnaires dealing with task or team functioning elements, and computes sharedness between team-members on these items to picture the team mental model (e.g., Peterson et al., 2000; Ensley & Pearce, 2001) no longer an option. These methods do not provide the necessary insight in the structure-aspect of a shared mental model. Mohammed et al. (2000) reviewed a range of promising methods for shared mental model research dealing with both content and structure, such as pathfinder, multi-dimensional scaling, card sorting, and cognitive mapping. In making a deliberate choice, it is important to consider how one wants to deal with the measurement issues elicitation and representation, taking into account the situation and the constructs one wants to draw conclusions about.

Regarding elicitation, measurement methods vary with regard to whether the cognitive content information is supplied by the researcher or is directly requested from the participants. In the former, the comparison of the individual's mental model is facilitated. In contrast, in the latter where the content is requested from the participants better captures the idiosyncratic content of the knowledge structure of an individual. Richer data are generated through the second kind of elicitation (Cooke, 1994). For this reason, we chose to rely on a methodology that depends on an open exploration of the participants' mental model of the participants, namely cognitive mapping

methodologies. These methodologies deliver representations of both the content and structure of individuals' idiosyncratic belief systems in a particular domain (Mohammed et al., 2000). Cognitive mapping is used extensively by researchers of organizational behavior, strategic management, and political science (e.g., Axelrod, 1976; Eden, 1988; Fiol & Huff, 1992; Swan, 1995). Cognitive mapping as methodology includes a diversity of elicitation techniques (interactively requesting the data from participants through interviews or through post hoc analysis of data like texts). We considered techniques that elicit as much information as possible, with a non-intrusive, extensive data-collection method. This led us to the cognitive mapping based on texts. Such text-based cognitive mapping is based on non-invasive and non-reactive data collection, avoiding recall biases of interviews (Axelrod, 1976). Texts contain a portion of the author's mental model at the time the text was created (Kaufer & Carley, 1993). Therefore, textual analysis techniques are used to extract and analyze these samples of the content and structure of the author's mental model.

Carley's (1997) research delivered the methodology of text-based cognitive mapping for assessing shared mental models. She collected evidence on the reliability and validity of the method, which showed to be satisfactory. Our present research builds on her measurement results on shared mental models and teams. We will first briefly describe the approach as operationalized by her.

Method of Carley[2]

Carley (1997) presented and explored an automated approach for extracting a map representing individual's mental model from a text, analyzing it, and combining the individual's mental models to a representation of the team mental model. In this approach, texts are first coded as networks of concepts representing individual mental models. To this end, the concepts (i.e., a single ideational category) that appear in the text are identified. This is achieved through a process of filtering in which is decided how concepts of the texts are to be coded. The researcher determines whether all words in the text are used or whether some will be deleted. Further, she or he also decides whether to use the exact words in the text, or whether certain words will be generalized using a thesaurus. Deletion and generalization can facilitate the comparison of texts. Its drawback is that it stands further from the original individual and idiosyncratic input. Next, relationships between concepts are identified. Different authors have made different conceptualizations of these relationships (e.g., Axelrod, 1976; Danowski, 1988). Carley (1997) however argues that in all these conceptualizations the pattern of relations is of importance, and that only those concepts can be related that are physically proximal. This means that the researcher has to decide how proximally distant concepts can be from each other and still have a relationship (windowing). The identified concepts and relations between them give rise to statements. The combinations of these statements form the mental model.

2 For a more thorough description of this method and literature on the methodological and theoretical underpinnings, we refer to Carley (1997).

Carley (1997) automated this approach in the program Automap®, combining her semi-automated approach to coding texts (Carley, 1986, 1988) with Danowski's (1982, 1988) completely automated approach for proximity analyses. The former uses a delete-list to identify the words that need to be overlooked and a thesaurus to identify the concepts that need to be generalized; the latter places a link between each pair of words within a window (i.e., within a certain number of words of each other).
After coding the individual mental models, the shared mental model of the team is derived. This entails that the representation of individual mental models are combined to form a representation of the team mental model. The intersection of the different maps of the team members is also a map and can be seen as a representation of the shared mental model. Automap also supports this procedure (Carley, 1997).

Method

Participants
The subjects were 81 first-year bachelor students in an International Business Economics degree program, following a skills training for two weeks at the end of the first year. They were divided into 27 teams of three voluntary students.

Task
Teams were confronted with the business simulation game "Steer the Economy", developed by Woltjer (1995, 2005), which simulates a business-economic system. Teams of players represent the management of different companies and make their company's decisions. All companies playing the game are interlinked through a computer network. The cumulative efforts of each team represent the general economy's movements. The macro-economy consists of four markets: a market for consumption goods, a labor market, a market for investment goods and a credit market. There are five main types of actors: companies, consumers, employees, banks and governments. The computer model simulates the decisions of the consumers, employees, banks and governments. The mission of the companies is to maximize the value of their companies by the end of the game. This value consists of equity, which is the sum of equity at the start of the game plus all retained profits during the game, and 'goodwill', which is an estimate of the net present value of future profits (Woltjer, 1995, 2005).
This task was chosen because of its authenticity: management teams, confronted with a fast changing and complex environment, are required to make management decisions. An overwhelming amount of authentic data on the economy and the company itself is available. Teams have to decide on the information relevant for their decisions.

Procedure
The business simulation game "Steer the Economy" is part of the skills-training program within the first year of an International Business Economics degree program. The course is composed out of two cycles. In the first cycle the teams have the opportunity to get acquainted with the technology and can explore the game. In the second cycle, the teams play the game with the goal of maximizing the value of their company.

Data on the mental models and the performance were collected in week two at the end of the first two hours of the second cycle. In these two hours the students had managed their company for a simulated period of circa eight years. Data on team learning behaviors were collected with regard to both cycle 1 and cycle 2.

Measures

Team learning behaviors

The three aforementioned aspects of the team learning behavior (construction, co-construction, and constructive conflict) were questioned by 9 items (Van den Bossche et al., 2006). Examples of items operationalizing these learning behaviors were respectively 'Team members are listening carefully to each other', 'Information from team members is complemented with information from other team members' and 'This team tends to handle differences of opinions by addressing them directly'.

A confirmatory factor analysis showed that the three aspects of team learning behavior were discernable in the questionnaire. One item ('In this team, I share all relevant information and ideas I have') was changed from the first dimension to the constructive conflict-dimension based on this analysis (χ^2 = 21,08; df= 24; p = 0,63; RMSEA= .00; NNFI = .99; CFI = 1.0).

Shared mental model of the team

Data on team members' mental model was collected through two open-ended questions. These questions asked for both declarative and procedural knowledge on the management of the company in the economy game ("Which variables in the game do you think are important to consider playing this economy game? and In which way do you think these variables influence the success or failure of your company?"). The answers delivered by the participants were coded using the program AutoMap® 1.2 (Diesner & Carley, 2004). The procedure described earlier was used to extract the map representing the individual mental model (Carley, 1997). During coding, two important steps are taken: filtering and windowing. When the texts are filtered, words are deleted and generalized. This was based on a delete list and a thesaurus. The delete list contained all words not contributing to the question (articles, conjunctions, et cetera) and words that indicated the relation between concepts (leading to, causing, et cetera). The thesaurus contained two types of generalization: concepts which in this context had similar meaning were taken as the same concept and concepts with the same base but different endings were recoded as the same concept (e.g., market and markets both became market). Both lists were made by an individual experienced with the game and were based on all the texts of the participants. The window size was put at eight (Carley, 1997), which means that relations were identified in a range of eight concepts, without taking into consideration the deleted items. Shared mental models (team maps) were identified as containing those statements that were identical in at least two out of three individual's cognitive maps.

Two measures were computed in order to get a quantitative measure for the sharedness of the mental model: The number of concepts that were identical in at least two out of three individual's cognitive maps and the number of statements (two concepts and their

relation) that were identical in at least two out of three individual's cognitive maps. This latter measure also grasps the structure of the mental model.

Team Effectiveness

Perceived Team Effectiveness:

A broad approach to effectiveness was taken to include the multiplicity of outcomes that matter in organizational settings (Hackman, 1989). Not only is the degree to which the team output meets the standard of quality (team performance) of importance, but also the degree to which the process of carrying out the work enhances the capability of members to work together in the future (team viability), and the degree to which the team work contributes to the professional growth of the team members (team learning). These dimensions were questioned using four items. Two items questioned the first dimension; team performance (e.g., 'I am satisfied with the performance of our team'). Two more items were used to get a grip on respectively the team viability ('I would want to work with this team in the future') and team learning ('As a team, we have learned a lot'). A confirmatory factor analyses showed that these items belonged to one factor, independent from the three factors constituting team learning behavior (χ^2= 45.20; df = 48; p = 0.59; RMSEA = .00; NNFI= .97; CFI = .98).

Actual Team Performance

In addition to assessing the perception of the team effectiveness by the team members, we also collected data on the actual performance of the company they were managing in the game. Mean equity and goodwill in the last year (of the eight years the game lasted) were taken as measures of actual team performance.

Aggregation on team level

The constructs measured in the survey (team learning behaviors and perceived team performance) are conceptually meaningful at the team-level. Therefore, the data gathered from individual team members to assess these team-level variables were aggregated at the team level. The within-group agreement was assessed using the multiple-item estimator rwg (James, Demaree, & Wolf, 1984). This analysis resulted in a mean value of .89 for construction, .90 for co-construction .91 for constructive conflict, and .93 for team effectiveness. These results justify the creation of a group-level data-set. Descriptive statistics (mean and standard deviation), the intercorrelations and the internal consistency of the scales at the team-level of analysis are presented in Table 1.

Results

The results will be presented in the two following sections. The first section deals with the hypothesized influence of team learning behaviors on the development of a shared mental model. The second section presents analyses testing the hypothesized relation between shared mental models in teams and team performance. This is followed by an examination of shared mental models as mediator of the relationship between team learning behaviors and team effectiveness.

Table 1
Means, Standard deviations and Intercorrelations (alpha-coefficients for the questionnaire are given on the diagonal).

Variable	1	2	3	4	5	6	7	8
1. construction	**.84**							
2. co-construction	.77**	**.84**						
3. constr. conflict	.60**	.69**	**.83**					
4. SMM-conc	.16	-.06	.31	---				
5. SMM-stat	.11	-.15	.21	.91**	---			
6. perceived team performance	.42*	.46*	.75**	.28	.16	**.83**		
7. actual team performance: equity	.21	.20	.28	.51**	.43*	.32	---	
8. actual team performance: goodwill	-.21	-.27	.07	.50**	.50**	.20	.41*	---
Mean	6.00	5.73	5.72	6.00	10.18	5.99	10128539.6	9477871.8
S.d.	.61	.59	.53	2.41	10.51	.64	20343459.6	6965830.3

Sign 2-tailed: *: significant at the .05 level /**: significant at the .01 level
SMM-conc: number of concepts shared by 2 or 3 members of the team
SMM-stat: number of statements shared by 2 or 3 members of the team

Team learning behaviors and shared mental models

It was hypothesized that team learning behaviors would influence the development of shared mental models. Two multiple regression analyses were conducted to test this hypothesis. In these analyses, the three identified team learning behaviors (construction, co-construction and constructive conflict) were regressed onto the two indicators of shared mental model (shared concepts and shared statements).

The results presented in Table 2 show that the identified learning behaviors significantly influence the development of a shared mental model of the task in a team. The results for both indicators of shared mental models, shared concepts and shared statements, are very similar. The team learning behaviors co-construction and constructive conflict contribute to the development of a shared mental model in the team. However, these results show that, contrary to the expectations, the co-construction behavior of the team does not contribute to the development of shared mental models. In fact, the unique effect of co-construction is negatively connected to the sharedness of mental models. The intercorrelation of the variables co-construction and shared mental model (indicated by sharing of concepts and statements) as presented in Table 1 is close to zero. The regression learns that if we also take into consideration the construction and constructive conflict behavior, the singular effect of co-construction behaviors becomes negative.

Table 2
Regression analysis team learning behaviors predicting shared mental model

	SMM-conc	SMM-stat
construction	.39	.45
Co-construction	-.78*	-.86**
Constructive conflict	.62*	.53*
R2	.30	.29
Adjusted R2	.21	.20
F	3.283	3.146
sign	.039	.045

Standardized beta coefficients are reported
*: significant at the .05 level / **: significant at the .01 level

Shared mental models and team effectiveness

To test the relation between shared mental models in teams and team effectiveness regression analysis of the two indicators of shared mental models onto the different criteria of team performance are conducted. Results of these analyses are presented in Table 3.

Table 3
Regression analysis shared mental models predicting team performance

	Perceived team performance			Actual team performance equity			Actual team performance goodwill		
	Beta	Adj R^2	F (sign)	Beta	Adj R^2	F (sign)	Beta	Adj R^2	F (sign)
SMM-conc	.28	.08	2.08 (.16)	.51**	.23	8.62 (.007)	.50**	.22	8.48 (.007)
SMM-stat	.16	.00	.67 (.42)	.43*	.15	5.59 (.026)	.50**	.22	8.45 (.008)

Standardized beta coefficients are reported
*: significant at the .05 level / **: significant at the .01 level

The results indicate a significant and important relation between the two indicators of shared mental models and the results of the company managed by the team in the economy game. Sharing concepts in the team is linked with both the equity results (Beta = .51, p = .007) and the goodwill (Beta = .50, p = .007), as well as the number of shared statements is positively linked with both equity (Beta = .43, p = .026) and goodwill (Beta = .50, p = .008) of the company. No significant link is observable between the developed shared mental model and the team performance as perceived by the team itself; both for

the indicator shared concepts (Beta = .28; n.s.) and for the indicator shared statements (Beta = .16; n.s.).

Mediation

Additional analyses were conducted to examine whether shared mental model fully mediate the influence of team learning behavior on team effectiveness. These analyses were informed by a procedure suggested by Barron and Kenny (1986). The analyses already described have established that team learning behaviors account for significant variance in shared mental model (i.e., the mediator). Also it is shown that the level of shared mental model is significantly related to actual team performance. However no relation is found between the developed shared mental model and the perceived team performance.

To test for mediation, two more regression equations should be estimated (Barron & Kenny, 1986). The first tests whether team learning behavior accounts for significant variance in team effectiveness (perceived and actual). Results from stepwise multiple regression analyses indicate that team learning behaviors account for variability in actual team performance indicator goodwill (R^2 = .20, F(2,24) = 3.002, p = .069; $\beta_{\text{co-construction}}$ = -61, p = .02; $\beta_{\text{constructive conflict}}$ = .48, p= .06) and perceived team performance (R^2 = .56, F(3,23) = 9.734, p = .00; $\beta_{\text{construction}}$ = .03, ns; $\beta_{\text{co-construction}}$ = -12, ns; $\beta_{\text{constructive conflict}}$ = .81, p= .00). But it does not for the actual team performance indicator equity (R^2 = .08, F(1,25) = 2,074, p = .16). Finally, the team learning behaviors were entered in the regression equation after controlling for the level of shared mental model. On the condition that relations are established in the previous regression analyses, if team learning behaviors fail to account for significant incremental variance, the evidence is consistent with full mediation of shared mental model. Adding the team learning behaviors to the equation in which equity was regressed on the level of shared mental model failed to account for significant additional variance for both indices of shared mental models (shared concepts, ΔR^2 = 0.063, p = .57; shared statements, ΔR^2 = 0.075, p = .54). Similar results were obtained when team learning behaviors were added to the equation in which goodwill was the dependent variable, also for both indices of shared mental models (shared concepts, ΔR^2 = 0.063, p = .57; shared statements, ΔR^2 = 0.075, p = .54). The preconditions for shared mental model mediating the effect of team learning behaviors on perceived team effectiveness are not met. Due to this no further test of mediation is meaningful.

To summarize, these analyses give substantial support for the idea that the effect of team learning behaviors on the actual team performance is mediated by the development of a shared mental model. For goodwill as a dependent variable, all conditions were met. In the case of equity as a dependent variable all conditions were not met. Whereas team learning behaviors do not show any significant relationship with equity, they did have a positive influence on the level of shared mental model, which in turn are significantly related to performance. These results are strongly indicative of an indirect effect (Mathieu et al., 2000). Contrary to these findings, the results of these analyses suggest

that the effect of team learning behaviors on perceived team effectiveness are not mediated by the development of a shared mental model.

Conclusions and Discussion

This study sought to determine those team learning behaviors which lead to the construction of a shared mental model, leading to increased team performance.

Team learning behaviors and shared mental model

The findings of this study support the premise that team learning behaviors are related to the development of a shared mental model. However, the relation appears to be more complex than initially hypothesized. Constructive conflict was found to be a significant behavior in the process of building shared mental model. On the other hand, the team behaviors conceptualized as co-construction do not in themselves contribute to the development of shared mental models. The findings actually show that they even hinder this development. Although this is not in line with our hypothesis, it strengthens the theoretical assertion that for the development of shared mental models both mutual understanding and mutual agreement are necessary (Baker, 1995, 1999). These results suggest that mere co-construction behavior (complementing each other information and ideas) is not enough. The role of constructive conflict is critical. Only if there is a critical stance regarding each others contributions, if there is thorough consideration of each other ideas and comments, and if team members address differences in opinion and can speak freely, will there be really construction of a shared mental model. If this behavior is lacking, team learning is not taking place (Van Knippenberg et al., 2004). Showing constructive conflict behavior reflects a true engagement in reaching a shared view on the topic.

These findings are particularly important because they provide evidence that a group learning perspective contributes to understanding the development of shared mental models. The results confirm the theoretical idea stressing the role of group learning in developing group cognitions (Mohammed & Dumville, 2001). They add to the indirect evidence within team research that interaction between team members affects mental model agreement (Walsh et al., 1998; Rentsch & Klimoski, 2001). This research goes beyond previous findings by identifying the kind of interactions that can be considered as team learning behavior leading to the development of shared mental models. The concepts of co-construction and constructive conflict proved to be valuable in conceptualizing team learning behaviors. Furthermore, this research extends previous team learning research by establishing a relation between team learning behavior and the level of shared mental model (Edmondson, 1999; Wong, 2003). This also shows the added-value of the possibility of measuring the idiosyncratic shared mental model of the team with the methodology of cognitive mapping as operationalized by Carley (1997). A more fine-grained measurement of this group cognition adds to the validity of the shared mental model measurement.

Shared mental model and team effectiveness

With regard to the second goal, this study shows that the development of a shared mental model in a team through team learning behaviors results in better team performance. The results of a company, as shown by their equity and goodwill, improved if the management team has developed a higher level of shared mental model of their environment. This evidence supports Nosek and McNeese's (1997) assertion of the importance of group sense-making: those that do a better job will have increased competitive advantage. These results add to similar findings that indicate that shared mental models are related to important team outcomes (e.g., Mathieu et al., 2000; Stout et al., 1999). These previous results are mainly established in so-called 'action teams' (e.g., teams performing missions in a flight simulator). This study suggests that there is also a relation between shared mental models and performance for strategic decision-making teams. Moreover, the analyses presented in this chapter suggest that shared mental models fully mediate the relation between team learning behaviors and actual team performance. As such it provides evidence for Ensley and Pearce's view (2001) of a direct relation between –what they called- shared strategic cognition in top management teams and organizational performance.

The results showed that team effectiveness, as perceived by the team members, is related differently to the level of shared mental model of the team than is the actual performance. A tendency towards a positive link between the shared mental model of the team and the perceived team performance by the team itself was discernable. However, this relation did not reach significance. On the other hand, constructive conflict was significantly related to the perceived effectiveness. This relation was thus not mediated by the level of shared mental model of the team. In evaluating this result, we must take into account that the team performance as studied in the survey is broadly conceptualized (Hackman, 1989). It not only contains team performance, but also considers effects on the development of the team and the team viability. Nevertheless, the results show that a shared mental model of the task is not significantly related to this broad conceptualization of team effectiveness. Other mental models should probably be considered (e.g., mental model of the team or the team interaction) to get a better understanding of the relation between shared mental models and these different aspects of team effectiveness.

It is remarkable that no substantial differences were found between the analyses based on either the numbers of concepts shared or the number of statements shared as indicator of the shared mental model of the team. It was expected that the statements would better reflect the shared mental model, since this measurement grasps the structure of the knowledge and thus reflects more the meaning of the knowledge elements (Mohammed et al., 2000; Carley, 1997). However, no substantial differences were found. This is also reflected in the high correlation between the number of statements and the number of concepts shared. This suggests that if concepts were shared, they mostly had the same meaning and thus were part of the same knowledge structure (i.e., statements).

Generalizability

This research was conducted with first-year business students performing a complex business simulation. Generalizability to real-life settings is often questioned in these laboratory-like studies. Mathieu (2000, p. 280) argues that "(…) questions of generalizability, or external validity, hinge on making inferences about the applicability of the results of a given study to some other target population and setting. Important considerations in this regard include questions about the comparability of the tasks or situational demands, the sample populations and time-related factors". As described in the method section, the business simulation game that was used in this research offered a challenging environment that shares some basic characteristics with the situations management teams are confronted with. It can be argued that, although this simulation limits a complete correspondence with 'real-life' settings, it does provide a controlled examination of some critical factors influencing team learning and effectiveness (Mathieu et al., 2000; Mathieu et al., 2005). This is not to say that the findings would directly generalize to management teams, but it should give us insight in how team learning, shared mental models and performance relate (Mathieu et al., 2000; Marks et al., 2000).

The fact that we used students that only had to work together for 2 weeks makes it questionable if these results can be reliably generalized to teams consisting of more skillful members with a longer history. Future research should point out what is the influence of these different populations and of the time factor.

Future research & practical implications

In this research we focused on mental models about the task environment. Other types of shared mental models (e.g., of the team) should be considered in order to get a more complete understanding of the knowledge that needs to be shared for effective teamwork and team performance (Mathieu et al., 2000). Mathieu et al. (2005) go even one step further by also examining the quality of the mental models shared by the team members. It can be questioned if this approach is valuable for the kind of situations that are considered in this research. The strategic decision-making teams are confronted with an environment that is complex and ambiguous and thus by definition no single 'answer' can provide 'the' solution. Therefore, prudence is called for if such an analysis is aimed for. Certainly an approach, such as implemented by Mathieu et al. (2005) in which different expert models are taken into consideration to examine the quality of the mental models, is asked for.

Furthermore, as organizations bring together people with different information, knowledge, values or background in teams, assuming that it will stimulate knowledge building practices (Jehn & Bezrukova, 2004), it becomes interesting to see in what way these individual factors and differences between individual influence productive team learning behaviors as identified in this research. The results of this research suggest that these team learning behaviors can give insight in the intervening processes that relate team diversity with team performance. Future research can elaborate this by considering team diversity as an input variable.

The results of the present research suggest consequences for the use of teams to assess complex situations and formulate acceptable actions. This research suggests that sharing

knowledge is indeed crucial for increasing the effectiveness of those teams. To achieve this, these teams will have to pay explicit attention to their socio-cognitive processes in order to promote team learning as an avenue to develop shared mental models. The results underline the power of disagreement or conflict (Jehn, 1994), but even more they stress the potential and need of dealing constructively with different opinions that may arise in a team. Previous research has shown that an interpersonal context characterised by, for example, psychological safety (Edmondson, 1999; Van den Bossche et al., 2006) can foster these learning behaviors. This stresses the need for the management of both social and cognitive processes in teams.

References

Alpay, L., Giboin, A., & Dieng, R. (1998). Accidentology: An example of problem solving by multiple agents with multiple representations. In M. W. van Someren, P. Reimann, H. P. A. Boshuizen & T. de Jong (Eds.), *Learning with multiple representations* (pp. 152-174). Amsterdam: Pergamon.

Argote, L., Gruenfeld, D., & Naquin, L. (1999). Group learning in organizations. In M. E. Turner (Ed.), *Groups at work: Advances in theory and research*. New York: Erlbaum.

Axelrod, R. (1976). *The structure of decision*. Princeton, NJ: Princeton University Press.

Baker, M. (1994). A model for negotiation in teaching-learning dialogues. *Journal of Artificial Intelligence in Education, 5*, 199-254.

Baker, M. (1995). Negotiation in collaborative problem-solving dialogues. In R.-J. Beun, M. Baker & M. Reiner (Eds.), *Dialogue and instruction. Modeling interaction in intelligent tutoring systems* (pp. 39-55). Berlin: Springer-Verlag.

Baker, M. J. (1999). Argumentation and constructive interaction. In P. Coirier & J. Andriessen (Eds.), *Foundations of argumentative text processing* (pp. 179-202). Amsterdam: University of Amsterdam Press.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediatior variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173-1183.

Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Gijselaers, W. H. (2005). Computer support for knowledge construction in collaborative learning environments. *Computers in Human Behavior, 21*, 623-643.

Cannon-Bowers, J. A., & Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behavior, 22*, 195-202.

Carley, K. M. (1986). An approach for relating social structure to cognitive structure. *Journal of Mathematical Sociology, 12*, 137-189.

Carley, K. M. (1988). Formalizing the social expert's knowledge. *Sociological Methods and Research, 17*, 165-232.

Carley, K. M. (1997). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533-558.

Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. *Int. J. Human-Computer Studies, 41*, 801-849.

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review, 9*, 284-295.

Danowski, J. A. (1982). A network-based content analysis methodology for computer-mediated communication: An illustration with a computer bulletin board. In *Communication yearbook* (pp. 904-925). New York: Sage.

Danowski, J. A. (1988). Organizational infographics and automated auditing: Using Computers to unobtrusively gather and analyze communication. In G. Goldhaber & G. Barnett (Eds.), *Handbook of organizational communication*. Norwood, N J: Ablex.

De Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A Meta-analysis. *Journal of Applied Psychology, 88*(4), 741-749.

Diesner, J., & Carley, K. M. (2004). *Automap 1.2-Extract, analyze, represent, and compare mental models from texts.* (Technical report CMU-ISRI-04-100): Carnegie Mellon University, School co Computer Science, Institute for Software Research International.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier.

Eden, C. (1988). Cognitive mapping. *European Journal of Operational Research, 36*, 1-13.

Edmondson, W. (1981). *Spoken discourse: A model for analysis*. London: Langman.

Edmondson, A. C. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350-383.

Ensley, M. D., & Pearce, C. L. (2001). Shared cognition in top management teams: Implications for new venture performance. *Journal of Organizational Behavior, 22*, 145-160.

Fiol, C. M., & Huff, A. S. (1992). Maps for managers: Where are we? Where do we go from here? *Journal of Management Studies, 29*(3), 267-285.

Hackman, J. R. (Ed.). (1989). *Groups that work (and those that don't). Creating conditions for effective teamwork.* San Francisco: Jossey-Bass.

Hewson, P. W., & Hewson, M. A. (1984). The role of conceptual conflict in conceptual change and the desing of science instruction. *Instructional Science, 13*(1), 1-13.

Hinds, P. J., & Pfeffer, J. (2003). Why organizations don't "know what they know": Cognitive and Motivational Factors affecting the transfer of expertise. In M. Ackerman, V. Pipek & V. Wulf (Eds.), *Sharing expertise. Beyond Knowledge Management*. Cambridge, Massachusetts: MIT Press.

James, L. R., Demaree, R. G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology, 69*(1), 85-98.

Jehn, K. A., (1994). Enhancing effectiveness: An investigation of advantages and disadvantages of value-based intragroup conflict. *International Journal of Conflict Management, 5*, 223-238.

Jehn, K. A., & Bezrukova, K. (2004). A field study of group diversity, workgroup context, and performance. *Journal of Organizational Behavior, 25*, 703-729.

Johnson-Laird, P. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kaufer, D. S., & Carley, K. M. (1993). *Communication at a distance: The effect of print on socio-cultural organization and change*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Klimoski, R., & Mohammed, S. (1994). Team Mental Model: Construct or metaphor? *Journal of Management, 20*(2), 403-437.

Kraiger, K., & Wenzel, L. H. (1997). Conceptual development and empirical evaluation of measures of shared mental models as indicators of team effectiveness. In T. M. Brannick & E. Salas (Eds.), *Team performance and assessment measurement: Theory, methods, and applications* (pp. 63-84). Mahwah, NJ: Lawrence Erlbaum Associates.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*(2), 273-283.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Cannon-Bowers, J. & Salas, E. (2005). Scaling the Quality of Teammates' Mental Models: Equifinality and Normative Comparisons. *Journal of Organizational Behavior, 26*, 37-56

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*, 89-106.

Mohammed, S., Klimoski, R., & Rentsch, J. R. (2000). The measurement of team mental models: We have no shared schema. *Organizational Research Methods, 3*(2), 123-165.

Nosek, J. T., & McNeese, M. D. (1997, March 24-26). *Issues for knowledge management from experiences in supporting group knowledge elicitation & creation in ill-defined, emerging*

situations. Paper presented at the AAAI Spring Symposium Artificial intelligence in knowledge Management, Stanford University.

Peterson, E., Mitchell, T., Thompson, L., & Burr, R. (2000). Collective efficacy and aspects of shared mental models as predictors of performance over time in work groups. *Group Processes & intergroup Relations, 3*(3), 296-316.

Rentsch, J. R. (1990). Climate and culture: Interaction and qualitative differences in organizational meanings. *Journal of Applied Psychology, 75*(6), 668-681.

Rentsch, J. R., & Klimoski, R. J. (2001). Why do 'great minds' think alike?: Antecedents of team member schema agreement. *Journal of Organizational Behavior, 22*, 107-120.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*(3), 235-276.

Roulet, E. (1992). On the structure of conversation as negotiation. In H. Parret & J. Verschueren (Eds.), *(On) Searle on Conversation*. Amsterdam: John Benjamins.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological Bulletin, 100*, 359-363.

Smith-Jentsch, K. A., Mathieu, J. E., & Kraiger, K. (2005). Investigating Linear and interactive effects of shared mental models on safety and efficency in a field setting. *Journal of Applied Psychology, 90*, 523-535.

Stahl, G. A. (2000). *A model of collaborative knowledge building.* Paper presented at the 4th International Conference of the Learning Sciences.

Stout, R. J., Cannon-Bowers, J. A., Salas, E., & Milanovich, D. M. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors, 41*, 61-71.

Swan, J. A. (1995). Exploring knowledge and cognitions in decisions about technological innovation: Mapping managerial cognitions. *Human Relations, 48*(11), 1241-1270.

Van den Bossche, P., Gijselaers, W., Segers, M., & Kirschner, P. A. (2006). Social and cognitive factors driving teamwork in collaborative learning environments. Team learning beliefs & behaviors. *Small Group Research, 37*, 490-521.

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*(6), 1008-1022.

Walsh, J. P., Henderson, C. M., & Deighton, J. (1988). Negotiated belief structures and decision performance: An empirical investigation. *Organizational Behavior and Human Decision processes, 42*, 194-216.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), Handbook of educational psychology. New York: Simon & Schuster Macmillan.

Webber, S. S., & Donahue, L. M. (2001). Impact of highly and less job-related diversity on work group cohesion and performance: A meta-analysis. *Journal of Management, 27*, 141-162

Weick, K. E. (1969). *The social psychology of organizing*. Reading, MA: Addison-Wesley.

Woltjer, G. (1995). *Coordination in a Macroeconomic Game. Its design and its role in education and experiments*. Maastricht: Universitaire Pers Maastricht.

Woltjer, G. (2005). Decisions and Macro-economics: Development and Implementation of a simulation game. *Journal of Economic Education, 36*(2).

Wong, S.-S. (2003). *Collective cognition in team: The role of interactive learning and effects on team performance.* Paper presented at the Academy of Management.

Zack, M. H. (2001). If managing knowledge is the solution, then what's the problem? In Y. Malhotra (Ed.), *Knowledge management and business model innovation*: Idea Group Publishing.

Chapter 5

Harvesting Diversity.
Unravelling mechanisms in diverse teams to yield high team performance*

Two studies explore the mechanisms by which working in diverse teams leads to team performance. Both task conflict and constructive conflict are considered as processes involved. It is evaluated how they contribute to the development of a shared mental model, since this is argued to be a crucial factor to bring to bear the potential of the diversity of knowledge available in the team. Furthermore, they examine how the structural composition of the team (informational and social category diversity) and the interpersonal context (psychological safety) sets the stage for these processes.
Both studies indicate the crucial role of constructive conflicts for high performance and show the positive impact of psychological safety. Mixed results are found for the influence of informational and social category diversity in the teams and for the mediating role of shared mental models. Discussion centers on measurement issues surrounding shared mental models and implications for the management of teams in professional learning and working contexts.

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Van den Bossche, P., Van Gennip, N., Gijselaers, W., Segers, M., & Kirschner, P. A. (submitted). *Harvesting diversity. Unravelling mechanisms in diverse teams to yield high team performance.*

Implementation of work groups, special task forces, or multi-professional teams in professional organizations gains ground as an answer to an environment that is extremely complex, uncertain, and even equivocal and ambiguous (Zack, 2001). The potential of these teams is that they can bring a diversity of knowledge bases, professional orientations and/or disciplinary backgrounds to bear on a problem (Beers, Boshuizen, Kirschner, & Gijselaers, 2005). It is expected that they are therefore capable of managing problem complexity more efficiently and to produce more viable ideas (Dierkes, Berthoin Antal, Child, & Nonaka, 2002). However, this requires the integration of the different perspectives in a shared interpretation of the team's task environment, defined as a shared mental model (Mohammed & Ringseis, 2001; Ensley & Pearce, 2001). If an integration of perspectives is pursued, the shared mental model can be richer than each of the individual knowledge frameworks, and therefore will allow for rich problem analysis and solutions (Beers et al., 2005).

Despite the potential of multi-professional teams, due to divergent perspectives, team conflicts can arise (Jehn, 1995). Conflict, as one of the most researched intermediate processes between diversity attributes of teams and the performance of the teams, signifies the experience of disagreements between team members (Williams & O'Reilly, 1998; Pelled et al., 1999). This may hinder the development of a shared mental model, which can be described as a team members' overlapping mental representation of key elements of the team's task environment (Klimoski & Mohammed, 1984). But if teams are are capable of constructively dealing with different points of view, they may have a greater wealth of knowledge to draw upon (West et al., 2004). We refer to constructive conflicts as the learning behaviors of teams that enable them to integrate the available perspectives (Van den Bossche et al., 2005) and foster a shared mental model relevant to the task at hand. It is important to consider that processes as constructive conflict do not occur in a vacuum, but are influenced by the social context in which they take place (Keyton, 2000). In this light, researchers have pointed to the importance of a climate of trust in teams (De Dreu & Weingart, 2003). Alike, Edmondson's (1999) research has established a relation between psychological safety in the team and productive team processes.

As becomes clear, the present dissertation takes an integrative perspective on the mechanisms through which working in diverse teams leads to team performance by relying on different strands of research. A first strand of research is the traditional research in work-group diversity and performance, with a focus on dimensions of diversity in team composition and related aspects of group processes. The information/decision-making perspective in this line of research focuses on disagreements on task-issues in teams, so-called task conflicts, as a key process linking team composition with performance (van Knippenberg, De Dreu, & Homan, 2004). It is supplemented with insights from organizational and, more specifically, team learning. This second strand of research has emphasized the importance of learning behaviors as constructive conflict, stressing the need for constructively integrating differences of opinion (e.g., Van den Bossche et al., 2005; West et al., 2004). It also points to the role of interpersonal factors to explain effectiveness (e.g., Edmondson, 1999). These two strands

of research are complemented with ideas from research on shared mental models, stressing the significance of having a shared interpretation of the team's task environment (Akkerman et al., 2005).

Two studies will be presented here. The first focuses on student teams and identifies the processes that promote team performances. In this respect, both task conflict and constructive conflict are considered to be the most probable processes involved. To get a better grip on these processes, it is also evaluated how they contribute to the development of a shared mental model, since this is stated to be a crucial factor to bring to bear the potential of the diversity of knowledge available in the team. Furthermore it examines how the structural composition of the team (informational and social category diversity) and the interpersonal context (psychological safety) sets the stage for these processes. A second study is conducted with professional work teams in an insurance company and searches to validate the findings of the first study in an organizational context. In the next section, we will elaborate on the key variables of both studies: diversity, task conflict, constructive conflict, and interpersonal beliefs.

Diversity

Diversity in teams refers to real or perceived differences on attributes between team members (e.g., Williams & O'Reilly, 1998). A great deal of research differentiates between a social category dimension of diversity, referring to attributes such as sex, age, and ethnicity, and an informational dimension of diversity, referring to less readily visible, but more job-related, attributes as functional and educational background (van Knippenberg et al., 2004; Jehn et al., 1999). Overall, it is expected that social category diversity will result in lower team performance and that informational diversity will have positive effects on team performance (van Knippenberg et al., 2004). However, recent reviews concluded that there is insufficient empirical support for the proposition that the effects of diversity are contingent on diversity type (van Knippenberg et al., 2004; Webber & Donahue, 2001) and that it is difficult to determine the immediate impact of types of diversity on the performance of groups. More recently, increasing attention has been paid to the intermediate processes that give rise to effective teamwork.

As a result, the present research does not put forward any hypotheses on the effects of types of diversity on intermediate processes and performance. It aims to explore the relations between diversity types and crucial aspects of the intermediate processes.

Identifying key processes

Task Conflict

Conflict is seen to play a central role in the way diverse professional teams operate (e.g., Williams & O'Reilly, 1998; Pelled et al., 1999). Conflict is the process that results from the tension between team members because of real and perceived differences (De Dreu & Weingart, 2003). Recently, more attention has been given to the possible positive consequences of conflict. Conflict around task issues is considered to be beneficial for task performance because it encourages team members to scrutinize task issues and to engage in deep and deliberate processing of task-relevant knowledge. This learning

behavior can foster greater cognitive understanding of the considered issues and even the development of new insights. As a result, teams should become more effective and innovative (Jehn, 1994, 1995, 1997; Simons & Peterson, 2000; De Dreu & Weingart, 2003). However, Hewson and Hewson (1984) and more recently De Dreu and Weingart (2003), argued that the emergence of a cognitive conflict does not guarantee conceptual advancement because it may be taken as a paradox, and resolved by ignoring one of the conflicting elements. Another argument is it may not be seen as a conflict on the interpretation of the problem, but as a personal, emotional rejection and can as such interfere with productive team behavior (De Dreu & Weingart, 2003).

Recent reviews on the evidence of the relation between task conflict and team performance show that the link is not straightforward (De Dreu & Weingart, 2003; Simons & Peterson, 2000). Some studies have reported strong positive correlations between the occurrence of task conflicts and team performance (e.g., Jehn, 1994), but others have found no (e.g., Pelled et al., 1999), or even negative (e.g., Jehn, Northcraft & Neale, 1999) relations. Not surprisingly, De Dreu and Weingart (2003) conclude in their meta-analysis that the overall evidence points to a negative relation between task conflict and team performance. These results reveal that conflicts around task issues is not the key or at best a proxy of or a precursor to the processes that can lead to successful team performance (van Knippenberg et al., 2004).

Constructive conflict

If conflict itself does not show to be the process that seizes the potential of teamwork, what processes can then be indicated? The performance of a team will not benefit from task conflicts in itself, but from deep-level processing of the diverse information and viewpoints in the team (van Knippenberg et al., 2004). Diversity will only lead to better results if learning takes place as a result of the meaningful confrontation of different ideas. A recent study of Van der Vegt and Bunderson (2005) underlined this idea by showing that the potential benefits of diversity were realized through the cross-fertilization of ideas that occurs through intra-team learning efforts.

These findings underpin the assertion that a rich interaction, interactive discussion and negotiation between team members will lead to the development of a shared understanding and conceptual scheme, integrating the knowledge available in the team, through which events can be interpreted (Daft & Weick, 1984; Zack, 2001). These team behaviors can be labeled as 'constructive conflict', pointing to the efforts of the team members to deal constructively with their experienced differences in viewpoints (Van den Bossche et al, 2005). Constructive conflict is characterized by critical exploration of different opinions and attempts to integrate point of views.

It is assumed that the resulting shared mental model of the situation will be richer than each of the individual knowledge frameworks, since it incorporates the different perspectives, and is therefore more capable of dealing with the complex issues that one is confronted with. This assertion is based on the idea that the aggregation of individuals' knowledge structures creates a context for efficient group decision-making making (Klimoski & Mohammed, 1994; Cannon-Bowers et al., 1993).

On the basis of the above, it is expected in the present research that conflicts on task issues will have no association with the performance of the team. On the contrary, it is hypothesized that constructive conflicts will have a positive association with the performance of a team. Moreover, it is hypothesized that constructive conflicts will have a positive association with shared mental models and that these shared mental models are positively associated with team performance.

Role of interpersonal belief

What makes teams more inclined to manage their diversity in such a way that differences are dealt with in a constructive way instead of taking it as paradox (and getting stuck) or as a personal, relationship conflict? Simons and Peterson (2000) suggest the importance of the construct of group-level trust. Their study showed that within-team trust prevents conflicts around task issues to be interpreted as relationship conflicts. These kinds of studies indicate that teams can benefit from different ideas when they cultivate an environment that is open and tolerant of diverse viewpoints (Amason, 1996; De Dreu & Weingart, 2003). This atmosphere would allow teams to deal constructively with their diverse ideas.

A similar idea was proposed by Edmondson (1999) who re-introduced the construct of psychological safety to grasp a team climate characterized by interpersonal trust and mutual respect. She defines this construct as a shared belief held by members of a team that the team is safe for interpersonal risk-taking (Edmondson). It is stated that team psychological safety should facilitate learning behavior (e.g., elaboration of different point of views) because it alleviates excessive concern about others' reaction to actions that have the potential for embarrassment or threat, which these learning behaviors often have. It prevents teams from perceiving differences in viewpoints as 'disagreements', but creates a context in which these differences can be seen as opportunities to frame a problem in all its complexity, engaging them in constructive conflict.

Thus, it is hypothesized that psychological safety will be positively associated with constructive conflicts and will be negatively associated with task conflicts.

Study 1

Method

Participants

The study took place in a mandatory graduate course of an Educational Sciences degree program. The students in this course had ample (at least 3 years) experience with working in small task-oriented groups. Also, these students were highly acquainted with each other, since they were part of a small cohort of students. The student group in this program was highly diverse regarding sex, age, educational level (some had already followed higher education) and work experience.

Setting & Procedure

During the course, students had to work every week in groups on an assignment resulting in a presentation at a meeting at the end of the week. Every week, the 11

students were randomly assigned to different teams. This resulted in five different teams for each assignment. Data collection took place at three moments in time (3 assignments random chosen from the 5 assignments). This resulted in a sample of fifteen teams. Owing to illness, one team could not participate. This resulted in a final sample of fourteen teams.

The assignments consisted out of a short case description, followed by a general problem statement (see appendix for an example of an assignment). The students were provided with a long list of potentially relevant literature. This task environment was developed by the instructors to be complex and sometimes ambiguous for the students. Data on diversity, psychological safety, mental models, and the occurrence of task conflict and constructive conflict were collected in the final meetings. Individual questionnaires were administered from the students before they had to give their presentation.

Instrumentation

Diversity Measures

Informational diversity measures assessed heterogeneity of educational level before starting the current program. Also it was determined if the student had a job besides the study and if so, the functional position in this job (e.g., operational, managing). Social category diversity measures assessed heterogeneity of sex, age, marital status and being parent or not. These lead to an identification of the informational and social category diversity of the groups. As in past research (Schippers et al., 2003; Jehn et al., 1999), the Teachman's index (Teachman, 1980) was used to form an aggregate measure of the informational and social category diversity within the teams:

$$\text{Diversity} = \Sigma (- (P (\ln P))$$

Where P represents the proportion of team members that has each of the diversity characteristics. If a characteristic is not represented in the team, the value is zero. The higher this index is, the greater is the distribution of characteristics within the group.

Psychological safety

The psychological safety construct was measured using the scale from Edmondson (1999). The items were measured using seven 5-point Likert items, and anchored by "1 = Totally True" and "5 = Totally Untrue". Sample items for psychological safety include 'No one in this team would deliberately act in a way that undermines my efforts' and 'It is safe to take a risk in this team'. The Cronbach alpha of this scale was .86.

Conflict

An adapted version of the intragroup conflict scale as developed by Jehn (1995) was used to measure the amount of task conflict in the teams. Item selection was based on the validation study of Pearson, Ensley, and Amason (2002), which refined the intragroup scale by selecting the most important items. The current research was based on a Dutch translation of these items. As they were originally negatively formulated with respect to the occurrence of conflict (e.g., how much disagreement was there among the members of your group over there opinions), they were reformulated in a more neutral way. Three items measured task conflict (e.g., 'Do people in the team disagree about opinions?'), having a Cronbach alpha of .84. Constructive conflict was measured through a scale developed by Van den Bossche, Gijselaers, and Segers (2004). An example of an item is

'Does this team handle differences of opinions by addressing them directly?'. This scale has an alpha of .88. A factor analysis (principal component analysis, direct oblimin rotation) confirmed the scales as measured.

Shared mental models (SMM)

A mental model can be seen as a knowledge structure, indicating that it contains both concepts and the relations between those concepts. This means that the measurement technique must deal with both elicitation and representation to uncover the convergence of the team members' mental models (Mohammed et al., 2000). Elicitation refers to the determination of the components or content of a mental model. Representation refers to the technique used to reveal the structure, the relationships between elements in the mental model.

Concept mapping is a measurement technique that can capture the mental models of the team members and the overlap therein (Marks, Burke, Sabella, & Zaccaro, 2002). Cooke (1994) reviews a range of conceptual techniques that produces elicitation of domain concepts and their structure (i.e., representation). Two of them are concept listing, in which the participant is asked to list the critical domain aspects (elicitation), and construction of a representation by engaging in a graph construction task (representation, e.g. Thorsden, 1991 in Cooke, 1994). Both are encompassed in the concept-mapping technique. The present research elicited the mental model of the team members by using a pre-structured concept map. Participants were asked to fill in concepts that they thought to be of crucial importance for the completed assignment. They also had to indicate which concepts were related by drawing lines between them. This resulted in a concept map containing both content and structure, and representing the individual mental model of each team member. After coding the individual mental models, the shared mental model of the team is derived. This entails combining the representation of individual mental models to form a representation of the team mental model. The intersection of the different maps of the team members is also a map and can be seen as a representation of the shared mental model. A shared mental model measure was computed by dividing the absolute number of shared concepts and relations by the total number of unique mentioned concepts and relations in the individual concept maps.

Performance

Performance of the teams was assessed based on the presentations by those teams at the end of the week. The presentations were independently graded on quality of content, structure and argumentation by two university lecturers. Since the inter-rater agreement was acceptable (Pearson correlation = .72), the grades given by the two lecturers were aggregated.

Method of Analysis

The constructs measured in the survey (task conflict, constructive conflict and psychological safety) are conceptually meaningful at the team-level. Therefore, the data gathered from individual team members to assess these team-level variables were aggregated at the team level. The within-group agreement was assessed using the multiple-item estimator rwg (James, Demaree, & Wolf, 1984). This analysis resulted in a

mean value of .70 for task conflict, .80 for constructive conflict, and .74 for psychological safety. These results justify the creation of a group-level data-set.
A first exploration of the data and the hypothesized relations was done through the product-moment correlation between the defined variables. This was complemented by path analysis, used to test the fit of the covariance/correlation matrix against a causal model. The adequacy of the models was assessed by EQS version 6.1 (Bentler, 1985). All Models were tested with standardized coefficients obtained from the Maximum Likelihood method of estimation. A model development approach was taken. The starting model was the one indicated by the hypotheses, completed with the relations for which no hypothesis was formulated. The proposed model is tested and trimmed based on changes suggested by the modification indices (Wald and Lagrange Multiplier tests). To ascertain the model fit, the comparative fit index (CFI), the non-normed fit index (NNFI) and the root mean square error of approximation (RMSEA) as well as the Chi-square test statistic were emphasized. Values of the CFI and NNFI greater than .90 and .95 respectively are typically taken to reflect acceptable and excellent fits to the data (Schumacker & Lomax, 1996). The NNFI contains, contrary to the CFI, a penalty for a lack of parsimony of the model (Guay, Marsh, & Boivin, 2003). Values smaller than .08 for the RMSEA index are regarded as suggesting acceptable model fit (Browne & Cudeck, 1993; Guay, Marsh, & Boivin, 2003).

Results

Table 1 presents means, standard deviations and Pearson correlations among study variables. The results of this univariate analysis show a negative relation between the occurrence of task conflict and constructive conflict, suggesting that these two processes are partially mutually exclusive.

Table 1
Descriptives and intercorrelations between team-level variables (N=14)

	Mean	Sd	1	2	3	4	5	6	7
1. Social category	.35	.22							
2. Informational diversity	.44	.22	-.29						
3. Psychological safety	3.99	.56	.09	.17					
4. Task conflict	2.62	.63	-.25	.54*	-.69**				
5. Constructive conflict	4.13	.73	.41	-.25	.74**	-.54*			
6. Shared mental models	16.67	8.17	.01	.17	.42	-.06	.50†		
7. Performance	5.72	2.58	.30	.10	.22	.01	.56*	.48†	

Note: † p<.10; * p<.05; ** p<.01

Figure 1 presents the model that resulted from the path analysis. In comparison to the proposed model based on the hypotheses, modifications were implemented in two areas

as suggested by Wald tests. Two relations between the diversity measures and the process variables were excluded (the relation between informational diversity and constructive conflict and the relation between social category diversity and task conflict). Also shared mental models showed not to be a mediator between the process measures and performance, but was only an outcome of constructive conflict. The indices show that the resulting model fits the data very well ($\chi 2$= 6.322; df = 14; p = .96; NNFI= 1.450; CFI = 1.00; RMSEA= .000).

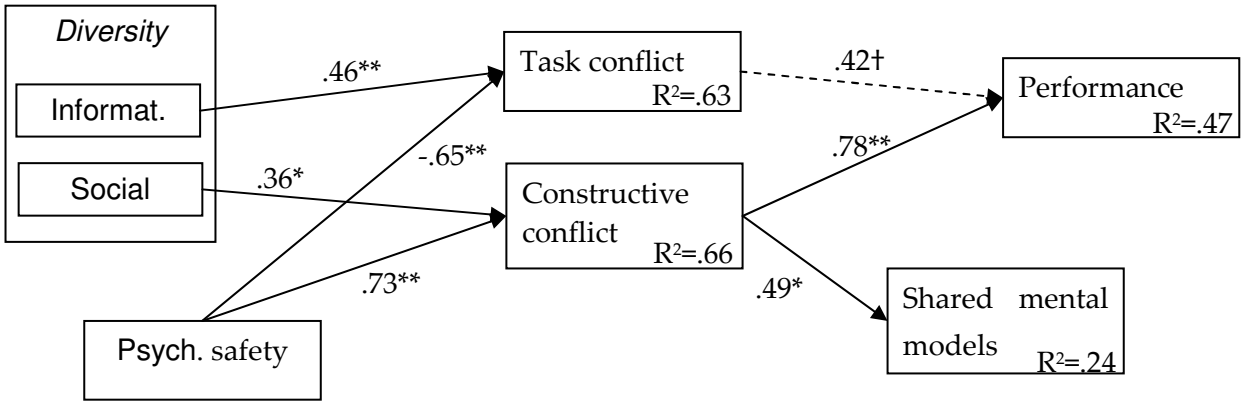


Figure 1: Path model I
Note: Standardized Beta's are reported; † p<.10; * p<.05; ** p<.01

No hypotheses were formulated regarding the relation between informational and social category diversity on the one hand and the team processes task conflict and constructive conflict on the other. Exploration of these relations show that informational diversity leads to an increase in task conflict (path coefficient = .46; critical ratio = 2.69) and social category diversity is related with more constructive conflict (p.c. = .36; c.r. = 2.21). Psychological safety has a strong positive association with constructive conflict (p.c. = .73; c.r. = 4.51) and a strong negative relation with task conflict (p.c. = -.65; c.r. = -3.84). This confirms the hypotheses.

Regarding the team processes that nurture team performance, it was hypothesized that it is not the occurrence of task conflicts that benefits team performance, but the efforts of integrating differences in viewpoint through constructive conflict that will lead to higher team performance. The results of the present analysis support this. There is a tendency towards a positive relation between task conflict and team performance, but the relation is only marginally significant (p.c. = .42; c.r. = 1.82). In contrast, constructive conflicts have a strong positive association with the performance of the team (p.c. = .78; c.r. = 3.39).

It was argued that the effect of constructive conflict on team performance would be a consequence of the resulting shared mental model. Teams that engage in constructive conflict would develop a shared mental model, integrating their knowledge, and as a consequence increase their performance. Therefore, it was hypothesized that constructive conflicts will be positively associated with the degree of achieving a shared mental model and that shared mental models will be positively associated with team performance. The results only partially confirm this. The results of the analysis show that constructive

conflicts are related to shared mental models (p.c. = .49; c.r. = 2.02). However, the analyses suggest no relation between shared mental models and team performance. This means that the results do not indicate that the positive relation between constructive conflict and performance of the team is mediated by shared mental models. The process towards shared mental models seems to be more important regarding performance then the shared mental models in itself.

Study 2

Method

Participants

The sample consisted of 144 employees (divided over a total of 23 work-teams) in one of the leading insurance companies (around 5000 employees) in Europe. The sample was taken from the headquarters of this firm which houses all major functional areas in business (Marketing, Strategy, Finance, etc.). The company is divided in seven sub-divisions, one of which is "People and Work Insurance". The division offers solutions for employers for the absenteeism risk in their company. Employees participating in the study were part of this sub-division and operated in designated work units (teams). Task demands between those teams were substantially different. Demands ranged from teams working with standardized tools and procedures to teams that had to create new products and services. The goal of the management in implementing teams was not only confined to the overall effectiveness, but were also directed to the satisfaction and professional growth of the employees.

Procedure

Survey data were collected in team meetings of the individual teams. While filling out the survey, team-members were asked to keep a particular project selected by the team in mind. Participants were informed that anonymity was ensured. In addition to filling out the survey, the team leader also had to fill in a short second questionnaire about team performance.

Measures

Diversity

Informational diversity was measured by heterogeneity of education level before entering the company, and functional position of that job (e.g., operational, managing). Social category diversity measured the heterogeneity of sex, age, marital status and whether they had children or not. As in study 1, the Teachman's index (Teachman, 1980) was used to form an aggregate measure of the informational and social category diversity within the teams.

Conflict

As in study 1, task conflict and constructive conflict were measured, using the same scales. The coefficient alphas for task and constructive conflict were both .64. A factor analysis (with direct oblimin rotation) established that task conflict and constructive conflict load separately. This confirms the discriminant validity of the conflict variables.

Psychological safety
As in study 1, psychological safety was measured with a scale developed by Edmondson (1999). The Cronbach alpha of these items was .74.
Shared mental models
The measurement technique used for capturing the shared mental models was similar to the first study.
Performance measure
A broad approach to effectiveness was taken to include the multiplicity of outcomes that matter in organizational settings (Hackman, 1989; Cohen & Bailey, 1997; Chang & Bordia, 2001). Not only is the degree to which the team output meets the standard of quality (team performance) of importance. Also the degree to which the process of carrying out the work enhances the capability of members to work together in the future (team viability), and the degree to which the team work contributes to the professional growth of the team members (team learning) need be considered. The above mentioned dimensions were questioned using four items. Two items questioned the first dimension; team performance ('This team is efficient' and 'This team is innovative'). Two more items were used to get a grip on the team viability ('I would want to work with this team in the future') and team learning ('I have learned a lot in this team'). The items were measured using 5-point Likert scales, and anchored by "1 = Totally True" and "5 = Totally Untrue". The Cronbach alpha of these items was .73.
Additional information about performance was collected from the team leaders. Six items questioned efficiency (e.g., 'How well did the team stick to the budget?') and effectiveness (e.g., 'How innovative was the team'). The coefficient alpha of these items was .59 (data were collected from 22 team-leaders, 1 team-leader did not contribute). The information provided by the team leaders is used to further validate the performance measurement as provided by the team members.

Method of analysis
Data were aggregated to the team level since the measured constructs are meaningful at the team-level. The within-group agreement was assessed using the multiple-item estimator rwg (James, Demaree, & Wolf, 1984). This analysis resulted in a mean value of .85 for task conflict, .83 for constructive conflict, .91 for psychological safety and .89 for team performance as assessed by the team members. These results justify the creation of a group-level data-set.
An analysis was conducted analogue to the one used in study 1.

Results
Descriptive statistics and intercorrelations are reported in Table 2. Several checks were performed on the correlational properties of the data before testing the hypotheses. The results of this analysis show a high intercorrelation between informational diversity and social category diversity. Factor analysis reveals that these two types of diversity load strongly on the same factor, suggesting that these two types of diversity coincide strongly in the selected teams. It was chosen to include only social category diversity in the further analysis since informational diversity does not explain anything over and

beyond social category diversity. Furthermore, the significant correlation between performance as perceived by the team and as perceived by the team leader provides evidence concerning the validity of the former.
Moreover, the bivariate analysis, presented in table 2, indicates that neither relation is established between shared mental models and task conflict or constructive conflict, nor between shared mental models and the performance of the team.

Table 2
Descriptives and intercorrelations between team-level variables (N=23)

	Mean	Sd	1	2	3	4	5	6	7
1. Informational diversity	.45	.17							
2. Social category diversity	.57	.15	.68**						
3. Psychological safety	4.08	.37	-.36†	-.27					
4. Task conflict	2.73	.46	.31	.50*	-.72**				
5. Constructive conflict	3.76	.38	-.27	-.36†	.52*	-.43*			
6. SMM	19.53	14.11	-.25	-.15	.18	-.22	-.09		
7. Performance	3.77	.40	-.03	-.23	.53**	-.45*	.51*	.18	
8. Performance by team leader	3.47	.46	.05	.04	.20	-.13	.08	-.07	.57**

Note: † p<.10; * p<.05; ** p<.01

Figure 2 displays the model that resulted from the analysis based on the path analysis. During the trimming process, two paths are deleted based on the Wald test; the path between social category diversity and constructive conflict and the path from task conflict to team performance. The variable shared mental models was dropped from the model since no relation was established between this variable and the other variables in the model.The resulting model shows to have excellent fit with the data ($\chi 2$=6.600; df = 6; p = .359; NNFI= .968; CFI =.981; RMSEA= .067).

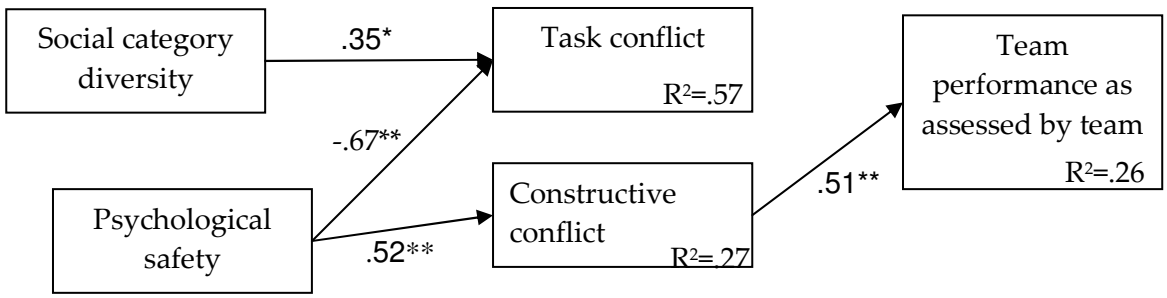


Figure 2: Path model II
Note: Standardized Beta's are reported; * p<.05; ** p<.01

Social category diversity appears to be positively related with task conflict (p.c. = .35; c.r. = 2.49). No relation with constructive conflict is discernable.
The results indicate that, as hypothesized, a team with high levels of psychological safety leads to the occurrence of more constructive conflict (p.c. = .52; c.r.= 2.85). At the same time does the results show that a high level of psychological safety leads to a decrease in task conflict (p.c. = -.67; c.r. = -4.75).
Furthermore, the results confirm the hypothesis that there is no relation between the amount of task conflicts and team performance as assessed by the team members; the model trimming process indicated that model fit would increase if the path between task conflict and team performance as assessed by the team members is deleted. Also confirmed is the positive association between constructive conflicts and the performance of the team (p.c. = .51; c.r. = 2.76).

Conclusions & Discussion

The two studies presented in this chapter questioned the mechanisms by which working in diverse teams leads to team performance. Discerned mechanisms were: task conflict, constructive conflict, psychological safety and the development of shared mental models. The subsequent conclusions bring together the results of the two studies.

Key processes

The outcomes suggest, as hypothesized, that there is only a marginal or even no relation between task conflict and team performance. The first study showed a marginal positive relation between task conflict and team performance. The second study found no relation between task conflict and the performance as assessed by the team members. The bivariate analysis showed even a negative correlation in both studies. We are not the first to find that task conflict is not significantly or even negatively related to performance. Thatcher et al. (2003) and Jehn et al. (1999) found that higher levels of task conflict lead to lower levels of performance. By this, our results are in line with the conclusion of the meta-analyis of De Dreu and Weingart (2003), indicating a negative relation between task conflict and team performance.
Contrary to task conflict, and as hypothesized, constructive conflict proved to be positively related to performance: Higher levels of constructive conflict lead to higher levels of performance. This effect was substantiated in both studies. These results confirm the idea of De Dreu and Weingart (2003) and van Knippenberg et al. (2004), that it is not conflict as such that is important, but the way a team deals with their differences in perspective. Moreover, the bivariate analyses in both studies show that there is a negative correlation between task conflict and constructive conflict. This suggests that task conflict is not even a precursor or proxy of the processes that lead to successful team performance (van Knippenberg et al., 2004); it is more fruitful to conceptualize the key-process as constructive conflict. These results add to the evidence that the potential benefits of diversity are realized through the cross-fertilization of ideas that occurs through intra-team learning efforts and fail to support a role for intra-team conflict in mediating the relationship between diversity and team performance. (Van der Vegt & Bunderson, 2005). Moreover, the present research identifies one crucial aspect of the team

behavior being of crucial importance in harvesting the benefits of diverse teams, namely constructive conflict (Van den Bossche et al., 2005).

Psychological safety

Psychological safety appeared to have great impact on the identified processes in the team. The results indicate that psychological safety is negatively related to task conflict. This implies that a high degree of psychological safety lowers the likelihood that such conflicts emerge, while at the same allows for constructively dealing with differences in opinion. This outcome confirms earlier findings from Edmondson (1999) and Van den Bossche et al. (2004). It shows that constructive conflict – as part of the group process leading to learning – requires a high degree of psychological safety within groups. More specifically, the results of this study suggest the importance of a team belief as psychological safety for learning: it seems to open the possibility to engage in learning behavior that asks team-members to "build" on each other (Edmondson, 1999).

Shared mental models

It was stated that constructive conflicts were of crucial importance since these bring to bear the potential of the diversity of knowledge available in the team by leading to the integration of the different perspectives in a shared mental model (Mohammed & Ringseis, 2001; Ensley & Pearce, 2001). It was hypothesized therefore that shared mental models would mediate the effect of constructive conflicts on team performance. This was tested in the two studies presented. The results of the first study suggest that constructive conflicts give rise to shared mental models. However, the results also show that, contrary to expectations, the development of shared mental models do not mediate the effect of constructive conflicts on performance. It can be concluded that the processes towards shared mental models seem to be more important regarding performance than the shared mental models themselves.

This result is in line with the (also unexpected) findings of Ensley and Pearce (2001). They tried to frame these results in the shared cognition literature by referring to the seminal work of Klimoski and Mohammed (1994). Ensley and Pearce argue that although it is stated that group processes and shared cognition would be interrelated, no direct relation is proposed between shared cognition and group performance. Rather it is suggested that the performance effects of shared cognition would be felt through the processes that lead to the creation of shared cognition. However, together with Ensley and Pearce (2001), we would reason here that future research should probe into this matter. In light of previous research that has shown that shared mental models mediate the effect of team processes as constructive conflict on team performance (Van den Bossche et al., 2005), future research designs could shed light on this matter. It might be the case that more fine-grained measures of shared mental models are necessary to grasp the true effects on performance (see e.g., Van den Bossche et al., 2005).

A similar plea for future research with more sensitive measures of shared mental models is warranted regarding the results of the second study reported. The second study revealed neither relations between the identified processes and shared mental models, nor a relation between shared mental models and the performance of the team. This

seems to indicate that the development of shared mental models is in no way related in bringing to bear the potential of teamwork. However, we would like to argue that the reason for not finding any relations between the variables identified and the shared mental models is severely connected to methodological choices in operationalizing the construct of shared mental model in this study.

The method used for knowledge elicitation in the studies presented can be classified as a conceptual technique (Cooke, 1994; Cooke, Salas, Kiekel, & Bell, 2004). As explained, these techniques produce representations of concepts and their structure or interrelations. On the one hand, the advantage of these techniques is that they tend to be less obtrusive than interview and verbal report techniques. They can also handle better aggregation of representations knowledge structures over a number of people, which is required to grasp shared mental models (Cooke, 1994). On the other hand, it is argued that such techniques tend to be restricted in their coverage of the full range of knowledge and are largely suited for eliciting knowledge about concepts and their relations (Geiwitz et al, 1990 in Cooke, 1994). Because of this limitation, some have argued that conceptual techniques are best used in combination with other techniques eliciting different knowledge types (Cooke, 1994; Cooke et al., 2004).

The teams that were part of the sample differed substantially in task demands. Demands ranged from teams working with standardized tools and procedures to teams that had to create new products and services. This probably gives rise to different importance of different knowledge types in the teams that were investigated. While the instrument that was used focused on a particular type of knowledge. This 'mismatch' became apparent through some teams that had great difficulty in completing the instrument. Therefore, we would argue that the measurement technique used for shared mental models was not capable of capturing the essential knowledge of some of the teams in the second study. Future research should employ a more sensitive measure of shared mental models. The selection of the most appropriate knowledge elicitation techniques should be guided by the tasks the teams is confronted with (Cooke, 1994). This will remain a challenge as no orderly relation exists between knowledge elicitation technique and the type of knowledge that results.

Types of diversity

The findings of both path analyses show relations between the different types of diversity and task conflict and constructive conflict. However the results look inconsistent across the two studies. In the first study, informational diversity seems to give rise to task conflicts and social category diversity is related to the occurrence of constructive conflicts. Different results in the second study showed social category diversity to be related to task conflicts. However, it has to be noted that in this study informational diversity and social category diversity appear to overlap in the examined teams. So partly, these results replicate the findings of, for example, Jehn et al. (1999) who found informational diversity to be related to task conflict, suggesting that a higher diversity of perspectives in a team increases the occurrence of disagreement around task issues. Furthermore, a relation of social category diversity with constructive conflict was established in the first study. No trace of that, however, was found in the second study;

the discerned types of diversity are not related with the constructive dealing of the conflict. The reason for finding this relation in the first study can be related to the particularity of the sample. The differences in social category can have given rise to the existence of a sort of master-pupil relation between people since all participants have a strong educational background and it concerned a study of educational sciences. This could have fostered constructive conflict in situations in which there were, for example, large age differences.

Nevertheless, these results only partially elucidate the relation between the diversity types, processes, and performance. Probably more complex measures of diversity are necessary to reveal the influences of diversity on process and outcome. A perspective that could be more powerful is to focus on the issue of alignment as put forth in the group faultline theory introduced by Lau and Murnighan (1998), which depends on the compositional dynamics of multiple attributes. Furthermore, one should also try to get a grip on the salience of diversity attributes in groups (Van Knippenberg et al., 2004), as not all diversity attributes influence the behavior of team members at all times. Diversity only becomes 'active' through the perception of the team-members, which implies that research attempts should try to examine how (and when) these perceptions are established and influence performance. Possibly even more important, these results suggest that a more fruitful approach to get a grip on how diversity influences performance is to focus on the processes through which diversity influences performance (van Knippenberg et al., 2004).

Limitations

Despite the potential of this research, some limitations need to be mentioned. The relevant samples for the analyses in both studies were respectively 14 and 23 teams, suggesting that statistical power was relatively weak. However, the fact that we were able to find statistically significant effects even with small samples indicates that the relationships we were studying had considerable strength (Mohammed & Ringseis, 2001). Moreover, the replication of the main findings in both samples adds substantially to the validity of the established relations and conclusions. Nevertheless, the results should be replicated with a larger sample.

Future samples should also consider different organizations and professions to allow generalizations to more organizational settings. The second study was conducted in an insurance company; it can be wondered if the results of the research at hand can be generalized to other professional organizations without any discussion. Each profession is confronted with specific types of problems and, as a consequence, develops their own types of teams with specific role divisions and learning processes (Edmondson, 2002). Furthermore, the teams that were included in this research ranged from middle management, over sales-teams to internal services. Future research should include these aspects such as task demands and role division as moderating variables (Bowers, 2000).

Practical implications

Since this research is based on samples of both student and professional work teams, it is interesting to reflect on the practical implications for both a learning and a performance

context. All the more since the results show that performance benefits from a learning attitude.

Organizations increasingly embrace more decentralized organizational forms, in which work teams are composed that bring together the knowledge of workers (Webber & Donahue, 2001). Professional education has frequently been prompted by professional practice to deliver graduates who possess – next to sufficient academic knowledge – the personal competencies to deal with (cultural) diversity in organizations (Johnson & King, 2002), or team building (Hansen, 2002). Also, collaborative learning formats are embraced by educational institutions. This reflects the importance of this study, in that it tried to get a handle on the impact of diversity on team processes and team performance. The results of the present research suggest consequences for both professional education and professionals in teams. Teachers and managers need to pay explicit attention to the basic requirements fostering beliefs and processes that promote learning.

Nurturing a team climate typified by psychological safety seems a facilitating condition to realize the potential of teams. This seems even more important in diverse teams since the team climate, as indicated by psychological safety, is under pressure in those teams. This stresses the need for allocating time for group development. Furthermore, managing the cognitive processes in a team means to harvest the potential of diverse points of views. This can happen through a critical stance regarding each others contributions, addressing differences in opinion, combined with a thorough consideration of each other ideas. These team behaviors constitute a constructive stance towards team diversity and form the basis for improving team performance driven by diversity.

This research also identifies suggestions for the design of professional learning environments. Educational environments need to be designed in such a way that students are confronted with diverse points of views and learn how to constructively deal with them. Both the task and social dimension of the learning environment need to be considered (Arts, Gijselaers, & Segers, in press). Tasks used in professional learning curricula are too often 'constructed for education' and do not require the cognitive activities that the workplace requires (Arts et al., in press). Realistic problem descriptions with a 'rich set of data' ('authentic learning environments') offer better opportunities for generating diverging ideas, perspectives and problem explanations. At the social dimension, teams of students need to be formed which provide optimal opportunity to be faced with multiple perspectives and thereby learn how to deal with this diversity and at the same time more deeply process the knowledge at hand. This entails that small groups of students are better learning units to tackle learning tasks. Larger groups impose more difficulties concerning coordination and creation of cohesion and feelings of trust (c.q., psychological safety) (Birmingham & McCord, 2002), which prevents multiple point of views to surface and to constructively deal with them. Related research (Arts et al., in press) has shown that redesigning a learning environment according these principles resulted in increased problem-solving performance of the students.

In conclusion, understanding the mechanisms by which diversity in teams affects team performance is important since organizations rely on their potential to manage problem complexity more effectively. The present research identifies the central role of

constructively dealing with different points of view. These team learning behaviors, and not the existence of mere conflict, harness the knowledge of the team. Moreover, psychological safety in the team creates a beneficial context for engagement in these behaviors.

References

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., & Simons, R.-J. (2005). *Shared mind in groups: Cognitive and socio-cultural perspectives.* Paper presented at the biennial conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Amason, A. C. (1996). Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management groups. *Academy of Management Journal, 39*, 123-148.

Amason, A. C., & Schweiger, D. M. (1997). The effect of conflict on strategic decision making effectiveness and organizational performance. In C. de Dreu & E. Van de Vliert (Eds.), *Using conflict in organizations* (pp. 101-115). London: Sage.

Arts, J. A. R., Gijselaers, W. H., & Segers, M. S. R. (in press). Enhancing problem-solving expertise by means of an authentic, collaborative, computer supported and problem-based course. An effect outcome comparison of a traditional and a refined PBL course. *European Journal of Psychology of Education*.

Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Gijselaers, W. H. (2005). Computer support for knowledge construction collaborative learning environments. *Computers in Human Behavior, 21*, 623-643.

Bentler, P. M. (1985). *EQS 6.1*: Multivariate Software, Inc.

Birmingham, C., & McCord, M. (2002). Group process research: Implications for using learning groups. In L. K. Michaelsen, A. B. Knight & L. D. Fink (Eds.), *Teambased learning: A transformative use of small groups in college teaching* (pp. 73-94). Sterling: Stylus.

Bowers, C. A. (2000). When member homogeneity is needed in work teams. *Small Group Research, 31*, 305-328.

Browne, M.W. & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. Bollen and R. Stine, eds., Testing Structural Equation Models, pp. 136–162, Newbury Park, CA: Sage.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed.), *Individual and group decision making: Current issues*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Chang, A., & Bordia, P. (2001). A multidimensional approach to the group cohesion-group performance relationship. *Small Group Research, 32*, 379-405.

Cohen, S. G., & Bailey, D. E. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management, 23*(3), 239-290.

Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. *International Journal of Human-Computer Studies, 41*, 801-849.

Cooke, N. J., Salas, E., Kiekel, P. A., & Bell, B. (2004). Advances in measuring team cognition. In E. Salas & S. M. Fiore (Eds.), *Team Cognition. Understanding the Factors that Drive Process and Performance* (pp. 83-106). Washington: American Psychological Association.

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review, 9*, 284-295.

De Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*, 741-749.

Dierkes, M., Bertoin Antal, A., Child, J., & Nonaka, I. (Eds.) (2001). *Handbook of Organizational Learning and Knowledge*. Oxford: Oxford University Press.

Douglas Johnson, C., & King, J. (2002). Are we Properly Training Future HR/IR Practitioners? A Review of the Curricula. *Human Resource Management Review*, *12*, 539-554.

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350-383.

Ensley, M. D., & Pearce, C. L. (2001). Shared cognition in top management teams: Implications for new venture performance. *Journal of Organizational Behavior, 22*, 145-160.

Guay, F., Marsh, H.W. & Boivin, M. (2003). Academic self-concept and academic achievement: Developmental perspectives on their causal ordering. *Journal of Educational Psychology 95*(1): 124–136.

Hackman, J. R. (Ed.). (1989). *Groups that work (and those that don't). Creating conditions for effective teamwork.* San Francisco: Jossey-Bass.

Hansen, W.L. (2002). Developing new proficiencies for human resource and industrial relations professionals. *Human Resource Management Review*, *12*, 513-538.

Hewson, P. W., & Hewson, M. A. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science, 13*(1), 1-13.

James, L. R., Demaree, R. G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology, 69*(1), 85-98.

Jehn, K. A. (1994). Enhancing effectiveness: An investigation of advantages and disadvantages of value-based intragroup conflict. *International Journal of Conflict Management, 5*, 223-238.

Jehn, K. A. (1995). A multimethod examination of the benefits and detriments of intragroup conflict. *Administrative Science Quarterly, 40*, 256-282.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference: A field study of diversity, conflict, and performance in workgroups. *Administrative Science Quarterly, 44*, 741-763.

Jehn, K.A. (1997). A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative Science Quarterly, 42*, 530-557.

Keyton, J. (2000). The relational side of groups [Introduction to a special issue]. *Small Group Research, 31*, 387-396.

Klimoski, R., & Mohammed, S. (1994). Team Mental Model: Construct or metaphor? *Journal of Management, 20*, 403-437.

Lau, D. C., & Murnighan, J. K. (1998). Demographic diversity and faultlines: The compositional dynamics of organizational groups. *Academy of Management Review, 23*, 325-340.

Marks, M. A., Burke, C. S., Sabella, M. J., and Zaccaro, S. J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology,* 87, 3-13.

Mohammed, S., & Ringseis, E. (2001). Cognitive diversity and consensus in group decision making: The role of inputs, processes, and outcomes. *Organizational Behavior and Human Decision Processes, 85*, 310-335.

Mohammed, S., Klimoski, R., & Rentsch, J. R. (2000). The measurement of team mental models: We have no shared schema. *Organizational Research Methods, 3*, 123-165.

Pearson, Ensley & Amason (2002). An assessment and refinement of Jehn's intragroup conflict scale. *The International Journal of Conflict Management. 13* (2), 110-126.

Pelled, L. H., Eisenhardt, K. M., & Xin, K. R. (1999). Exploring the black box: An analysis of work group diversity, conflict, and performance. *Administrative Science Quarterly, 44*, 1-28.

Schippers, M. C., Den Hartog, D. N., Koopman, P. L., & Wienk, J. A. (2003). Divrsity and team outcomes: The moderating effects of outcome interdependence and group longevity and the mediating effect of reflexivity. *Journal of Organizational Behavior, 24*, 779-802.

Schumacker, R. E., & Lomax, R. G. (1996). *A beginner's guide to structural equation modeling*. Mahwah, NJ: Erlbaum.

Simons, T. L., & Peterson, R. S. (2000). Task conflict and relationship conflict in top management teams: The pivotal role of intragroup trust. *Journal of Applied Psychology, 85*, 102-111.

Teachman, J. D. (1980). Analysis of population diversity. *Sociological Methods and Research, 8*, 341-362.

Thatcher, S. M. B., Jehn, K. A., & Zanutto, E. (2003). Cracks in diversity research: The effects of diversity faultlines on conflict and performance. *Group Decision and Negotiation, 12*, 217-241.

Van den Bossche, P., Gijselaers, W. H., & Segers, M. S. R. (2004). *Effects of social factors on shared cognition and teamwork in collaborative learning environments.* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego.

Van den Bossche, P., Gijselaers, W., Segers, M., & Woltjer, G. (2005). *Sharing expertise in management: An experimental study on team learning and its effect on shared mental models.* Paper presented at the Academy of Management, Hawaii.

van der Vegt, G., & Bunderson, J. S. (2005). Learning and performance in multidisciplinary teams: the importance of collective team identification. *Academy of Management Journal, 48*(3), 532-547.

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*(6), 1008-1022.

Webber, S. S., & Donahue, L. M. (2001). Impact of highly and less job-related diversity on work group cohesion and performance: A meta-analysis. *Journal of Management, 27*, 141-162.

West, M. A., Hirst, G., Richter, A., & Shipton, H. (2004). Twelve steps to heaven: Succesfully managing change through developing innovative teams. *European Journal of Work and Organizational Psychology, 13*(2), 269-299.

Williams, K. Y., & O'Reilly, C. A. (1998). Demography and diversity in organizations: A review of 40 years of research. *Research in Organizational Behavior, 20*, 77-140.

Zack, M. H. (2001). If managing knowledge is the solution, then what's the problem? In Y. Malhotra (Ed.), *Knowledge management and business model innovation*: Idea Group Publishing.

Appendix: example of an assignment (study 1)

NEEDED: A New Way to Train Doctors

"Since World War II, the pace of medical discovery has quickened, spurred by billions of dollars in federal aid each year to finance research. The knowledge of physicians has grown enormously; the methods for diagnosing and treating illness have multiplied. With government support, medical schools faculties grew fivefold from 1960 to 1980, teaching hospitals transformed themselves into vast temples of research, and laboratories blossomed with equipment of immense sophistication.
With such extraordinary advances in scientific knowledge, not to mention the metamorphosis of the health care system and its attendant policy problems, one would have expected comparable changes in the shape and substance of medical education."

(Derek Bok (1984). Needed: A new way to train doctors. Harvard Magazine, 32-43)

1. Which developments in the external environment are of importance for the functioning of doctors in their profession?
2. What can education do to solve these problems?
3. Which obstacles do you expect when implementing changes?

Chapter 6

SUMMARY and GENERAL CONCLUSIONS & DISCUSSION

Teams are increasingly being employed to discuss and manage complex problems. Organizations rely on these teams to deal with a fast-changing and highly competitive environment. Teams are ascribed high potential since they can bring together people with different experience and expertise. It is generally assumed that making decisions in such teams enhances the likelihood that the decisions will not only incorporate multiple perspectives but that new levels of understandings will develop (Kline, 2005).
Also educational environments see benefits in the implementation of learning environments that have a crucial team-learning component. It is assumed that teamwork will lead to deeper elaboration of the subject matter and will facilitate a sense of agency through the tangible accomplishments that can result from collaborative work on interesting and complex problems (Barron, 2000).
However, research and practice shows that this potential effectiveness is not always reached. Research has revealed cases in which large variation in group-work interaction and performance is encountered between teams that seem not to differ in composition and assigned task (Barron, 2000). This research indicates that fruitful collaboration is not merely a case of putting people with relevant knowledge together. The present dissertation addressed this issue and aims to understand the social and cognitive factors that support team's quest to reach high standards of performance. The main challenge in this endeavor is grasping when and how teams develop a joint understanding.

The conceptual model of this dissertation

The foundational conceptual framework of the present dissertation is shaped by an input-mediator-process-output framework (Marks, Mathieu, & Zaccaro, 2001). This framework was presented in chapter 1 and is depicted in figure 1. It proposes that crucial mediators for effective teamwork can be found in the development of shared mental models, achievement of a beneficial interpersonal context, and engagement in learning behavior. The latter, learning behavior, grasps essential socio-cognitive processes, the former two, shared mental models and interpersonal context are emergent states, respectively cognitive and social by nature. Concerning the input variables, we focused on diversity in composition of the team. For measuring the team output, we took a broad approach regarding team effectiveness including performance, viability and learning.

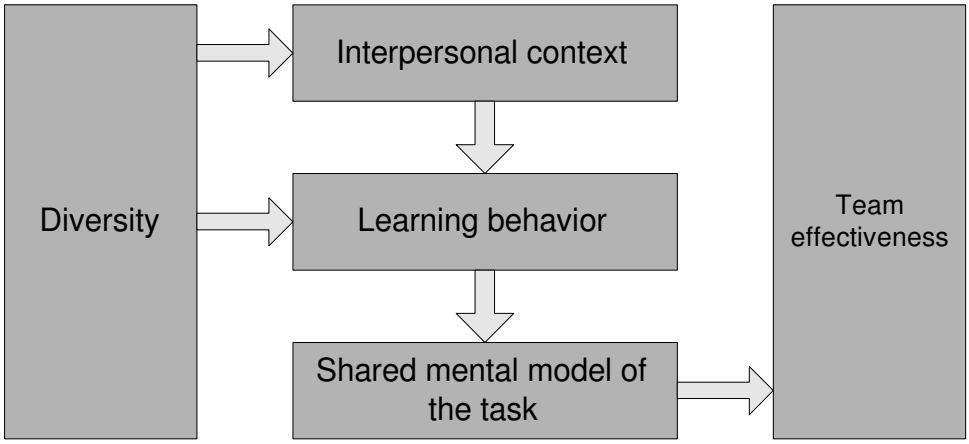


Figure 1: Team effectiveness framework

Several researchers describe team behavior and explain team performance from the cognitive standpoint of *shared mental models* (e.g., Cannon-Bowers & Salas, 2001) (see figure 1). It has been argued that the shared mental model of the task integrates and coordinates the perspectives available in the team and enables the team to have a complex and rich understanding of the task environment (Nosek & McNeese, 1997), resulting in better problem-solving performance.

The present dissertation emphasizes that the development of shared mental models is more than a cognitive process of integrating and coordinating perspectives. We stress the relevance of socio-cognitive processes that serve as mediators promoting the development of shared mental models. We define these socio-cognitive processes as '*learning behaviors*' (see figure 1), stressing how characteristics of the behaviors interact with knowledge building processes that lead to shared mental models (Barron, 2003). An elaborated conceptual framework is developed as a guide for defining relevant team learning behavior. To determine the team interactions that can be considered as team learning behavior we refer to the processes of construction, co-construction and constructive conflict to reach the necessary mutual understanding and agreement. First, meaning or understanding needs to be (co-)constructed. This is not done through simple accumulation of the contributions of individuals, because these contributions 'build on' previous ones. Second, agreement needs to be established about the proposed solution (Baker, 1995, 1999). The role of conflict, as the process resulting from differences in point of view, is highly relevant here (De Dreu & Weingart, 2003). The team will only benefit if divergence in meaning leads to deep-level processing of the diverse information and viewpoints in the team (van Knippenberg, De Dreu, & Homan, 2004). Through this negotiation by argument and clarification, the team works towards a convergence of meaning in order to reach shared mental models.
Moreover, this dissertation aims to identify social conditions under which teams make the effort to reach shared mental models. Viewing teamwork as reaching shared mental models, and thus as social, stresses the need to take into account the social context in which these processes take place. Therefore, the studies focus on emerging team-level beliefs about the relations between the team members; in other words beliefs about the

interpersonal context (see figure 1). It is supposed that these interpersonal beliefs form a context that influences team learning behaviors. This research identifies a number of powerful group-level beliefs which potentially affect the learning behavior in teams: psychological safety, cohesion, potency and interdependence. It was hypothesized that teams will engage in learning behavior when specific social conditions are realized; first, there has to be a shared commitment towards the task at hand (task commitment), further they have to believe that they need each other for dealing with this task (interdependence), third, they believe they will not be rejected for proposing ideas (team psychological safety), and they believe that the team is capable of using this new information to generate useful results (team potency).

One of the starting points of this dissertation is the idea that the potential of teams is for a large part due to teams bringing together people who have a variety of backgrounds, points of view, education, and/or expertise. These resources make it possible that teams can bring multiple perspectives to bear on a problem, which can allow a rich problem conceptualization required to solve complex problems (Lomi et al., 1997; Vennix, 1996; Beers, 2005). For that reason, this dissertation considers the ways in which *diversity* (see figure 1) influences the mediators. This dissertation deals explicitly with the issue of a diverse composition of the team by depicting the informational and social category diversity of the teams.

As mentioned, this dissertation takes a broad approach to *team effectiveness* (see figure 1). Team performance, team viability and team learning are taken as important dimensions of team effectiveness. With regard to team performance both actual and perceptual data are collected. Team viability and team learning are evaluated solely based on perceptions of the team members.

By exploring the research questions and developing the conceptual model, it became clear that different disciplines had their own perspective on these issues. The conceptual model that resulted is an integration of different approaches that are discernable in those strands of research. However, concerning the central concept of shared mental models, there remained, or it became clear that there was, a confusion of tongues. That is why we first wanted to review more thoroughly the different kind of conceptualizations of cognition at group-level that can be found in the literature. Only when the assumptions with regard to group cognition can be made explicit, the path will be smooth for empirical verification of the hypotheses that can be deduced from the conceptual model.

Outcomes Dissertation Research

This dissertation presents four studies that question parts of the team effectiveness framework: one conceptual review on the concept of group cognition and three empirical studies. Figure 2 show how these studies shed light on the different parts of the proposed framework.

A review on the literature addressing group cognition

This dissertation argues that one of the main challenges of teamwork is to come to a shared conception of the problem at hand. The idea of shared mental models is proposed as a central issue in understanding (effective) group work (Cannon-Bowers & Salas, 2001; Klimoski & Mohammed, 1994). It states that the aggregation of individuals' knowledge structures creates a context for efficient group decision-making (Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed).

Teams have been the subject of research for a long time and within various disciplines. Because of the various perspectives taken, many related concepts have been developed in order to describe the collective meaning emerging in teams and the coordinating activities of a team: common ground, team mental models, shared understanding, distributed cognition and collective mind. Additionally, various studies have used a multitude of conceptualizations and research methodologies. This rich landscape of studies indicates the complexity of the subject studied. However, the lack of conceptual clarity jeopardizes cross-fertilization and makes it difficult to build on previous research in order to push further our understanding of the phenomenon of group cognition. The purpose of this review is to contribute to the development of a conceptual framework by comparing conceptualizations of group cognition; that is, to assess differences and similarities in how 'group cognition' is conceptualized in the empirical literature. For that reason, we rely on a framework that highlights the important dimensions on which these conceptualizations differ. The framework draws on two socio-genetic views, representing two different ideas about the social nature of cognition. A cognitive and a socio-cultural perspective are identified.

The analysis shows that three approaches could be discerned. Some studies conceptualize group cognition as a state of similarity or overlap between individual mental models representing a cognitive perspective, other studies conceive group cognition as a process of coordination of actions or as a dynamic unity of individual contributions in the joint activity, hereby taking a socio-cultural perspective. Finally, some studies use conceptualisations of group cognition that show one initial way of crossing the boundaries between the different understandings of group cognition by incorporating aspects of both cognitive and socio-cultural perspectives.

The analysis reveals the complementary makeup of the two basic perspectives on group cognition, cognitive and socio-cultural; the drawback of the one perspective seems to be exactly what is essentially highlighted by the other perspective. The cognitive tradition looses sight of the intrinsic nature of the complex system as a whole, and can only learn about it through the aggregation of the properties of subsystems. The shortcoming of this is that, in the end, groups are understood as some sort of sum of its members. In contrast, the socio-cultural tradition looses sight of the intrinsic nature of the subsystems, and learns about them only through the perspective of the system of which they are part.

The studies that are identified as boundary crossing show some initial ways of combining insights from the two perspectives, however they failed to fully account for the two perspectives. Based on these experiences and from theoretical reflections in the literature, the review concludes that a full integration of the perspectives, and thus

striving for a coherent theory on group cognition, is not possible. However, given the complementarities of the two basic perspectives, it is advisable to start a true dialogical engagement. We agree with Greeno (1998), that a first step to bring together the values of both the cognitive and the socio-cultural perspective is for each perspective to extend itself to include some of the explanations offered by the other perspective.

The results of the review helped to design the empirical studies, both conceptually and methodologically. It becomes clear that the ideas developed in this dissertation are fundamentally based on a cognitive perspective. Also the methodological choices that are made to grasp group cognition as conceptualized in this dissertation are clearly founded on a cognitive perspective. However, if we take a look at the complete conceptual model, it also shows that we stretch this cognitive perspective and try to include other -social- aspects of the situation. In the empirical research that we present in this dissertation, investigation of cognition as structures within the individual mind is complemented with examination of situated factors and processes through which information is processed. In this way, the empirical studies presented in this dissertation start from the cognitive perspective and build toward a broader theory by incrementally developing analyses of additional components of situations that are considered as contexts for cognitive processes. The following paragraphs present the conclusions that can be drawn from the various empirical studies.

Empirical studies

Three empirical studies investigate the hypotheses that can be deduced from the conceptual framework as presented. The first empirical study is an overall test of most of the relations proposed in the conceptual model. The second builds on the result of the first study and focuses on some of the aspects that showed crucial, and also deals with some methodological challenges that were not yet completely tackled in the first study. The third and final empirical study returns to our initial questions by focusing on the aspect of multi-disciplinary composition of teams.

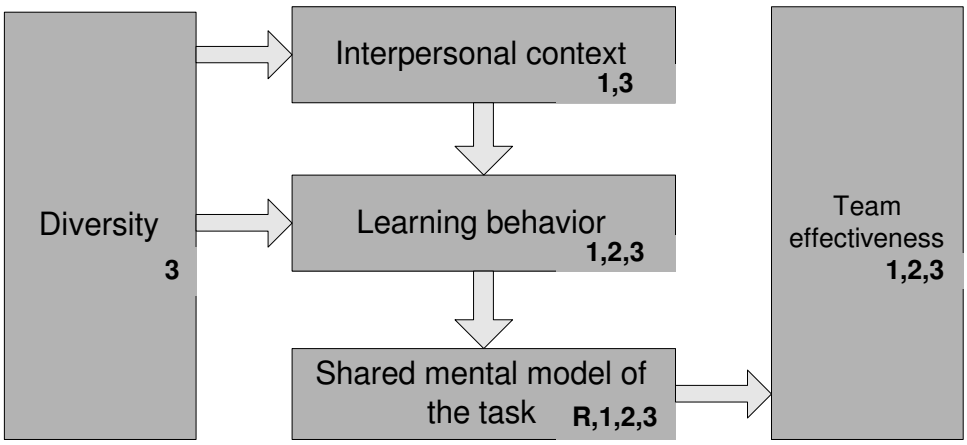


Figure 2: Team effectiveness framework with indication of the models of the different studies
(Bold numbers indicate the studies in which this variable is part of the research design: R=review; 1=empirical study 1; 2=empirical study 2; 3=empirical study 3)

We decided to conduct our research in both educational and organizational contexts. This seems legitimate and even indispensable since both working teams in organizations as learning groups in schools are confronted with the issues of establishing common frames of reference, resolving discrepancies in understanding, and coming to joint understanding (Barron, 2000; Roschelle, 1992). This is not to say that both contexts are equal, but we argue that the processes identified play a crucial role in both contexts.

1. Social and cognitive factors driving teamwork in collaborative learning environments

The aim of the first empirical study is to do a first overall test of the identified mediating factors and processes, and their effect on team effectiveness. The study explores the relations between the interpersonal context emerging in the team and the learning behaviors that take place. Furthermore, we question what the influence is on the development of mutually shared cognitions in the team. This study investigates these relations in teams of students in a collaborative learning environment.

The results support the model as proposed. The analyses indicate that both interpersonal factors and socio-cognitive processes have to be taken into account to understand the formation of mutually shared cognition, resulting in higher perceived team performance. Interdependence, task cohesion, psychological safety, and group potency, as aspects of the interpersonal context, appear to be crucial for the engagement in team learning behaviors. The identified team learning behaviors, in turn, give rise to mutually shared cognition. Also it is found that mutually shared cognition is an important factor to understand perceived team effectiveness.

Although promising, some limitations of this study are acknowledged. The study is founded on the perceptions of team-members. This is not a problem when it concerns the measurement of interpersonal beliefs and team learning behaviors, since it can be argued that the team-members are the primary observers in these cases. However, with regard to shared mental models it is recommended to look for methodology that accomplishes a more direct measurement that does not rely on the perceptions of team-members. Also it can be argued that concerning team effectiveness a sole reliance on self-assessment needs to be complemented with more objective measures. Moreover, this study focuses only on groups of students in an educational context.

2. A study on team learning and its effect on shared mental models

The second empirical study copes with the limitations of the first study and looks into aspects of the conceptual model more closely.

The research is conducted using a business simulation game. The simulation offers a challenging environment that shares basic characteristics with the situation management teams are confronted with, and at the same time it provides a controlled research setting for examining critical factors influencing team learning and effectiveness (Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Additionally, the simulation game offers objective measures of team performance, presenting the effect of team decisions on the mean equity and goodwill of the company the team was managing. Important to

notice is that this study questions the relation between shared mental models and performance in strategic decision-making teams. This in contrast with most previous research on shared mental model which is mainly conducted in so-called action teams (e.g., Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Furthermore, the study considers in-depth the measurement issue of shared mental models in teams, leading to the use of a methodology based on cognitive mapping. This approach makes it possible to capture the idiosyncratic content and structure of the mental models.

The results of the study shed light on a complex relation between team learning behaviors and the development of shared mental models in a team. Constructive conflict is found to be a critical in the process of building shared mental models; only if there is a critical stance regarding each other contributions, if there is thorough consideration of each other ideas and comments, and if team members address differences in opinion and can speak freely, there will be construction of a shared mental model. Furthermore, this study shows that the development of a shared mental model results in substantially better team performance. The results of a company increase if the management team has developed a higher level of shared mental model of their environment. Moreover, the development of shared mental model mediates the relation between team learning behavior and (objective) business performance. Indicating that team learning has its effect on actual team performance through the development of a shared cognitive framework to comprehend the situation.

3. Harvesting diversity

We stated that one of the main reasons for implementing teams is the belief that they have the potential to bring a diversity of knowledge bases, professional orientations and/or disciplinary backgrounds to bear on a problem. The third and last empirical study in this dissertation focuses on the aspect of diverse composition of the team and its effects on team performance and on mediators that are identified as crucial in the previous studies. In this way, also a further validation of the mediators that are proposed in this dissertation is strived for. This is done by considering both constructive conflict and task conflicts as processes involved. Task conflicts are disagreements on task-issues and are proposed as mediator in diversity research from an information/decision-making perspective.

This research is conducted in an educational as well as in an organizational setting (insurance company). Again we examine the development of shared mental models as a crucial mechanism in explaining team effectiveness. Also we put forward psychological safety as important variable in the interpersonal context, grasping if the environment is characterized by trust and open for diverse viewpoints.

In both settings, the results of the analysis indicate that constructive conflict, contrary to task conflict, is positively related to performance. These results add to the evidence that the potential benefits of diversity are realized through the cross-fertilization of ideas that occurs through team learning behaviors and fail to support a role for task conflict in mediating the relationship between diversity and team performance (Van der Vegt &

Bunderson, 2005). Moreover, in the educational setting, the results indicate that constructive conflicts give rise to shared mental models. This underpins the idea that constructive conflicts bring to bear the potential of the diversity of knowledge available; it leads to the integration of perspectives in a shared mental model.
Again, the importance of psychological safety for learning is established indicating that it opens the possibility to engage in learning behavior that asks team-members to 'build' on each other (Edmondson, 1999). Finally, the analyses in both settings indicate relations between different types of diversity indicators and task conflict and constructive conflict. However the results look inconsistent across the two settings. In the educational setting, informational diversity seems to give rise to task conflicts and social category diversity is related to the occurrence of constructive conflicts. Different results in the second setting showed social category diversity to be related to task conflicts.

Discussion of the General Framework

What can be learned from the empirical studies (chapter 3, 4 and 5) regarding the general conceptual model we have proposed in this dissertation?

Shared mental model

All three empirical studies examined the relation between shared mental models and team effectiveness. The results of the first two studies (chapter 3 & 4) provide evidence for this crucial role of the development of shared mental models: teams with greater levels of shared mental models are more effective than teams with lower levels. The last empirical study however showed some mixed results regarding this relation (see chapter 5). In the first part of this study a relation is established between the level of shared mental model and the team performance. However, close examination of the outcomes demonstrated that the observed relation is not direct. It seems as if shared mental models are only a by-product of the processes leading to high team effectiveness. The second part of this study indicated no relation at all between the level of shared mental model and perceived team performance.
The results of the empirical studies need to be interpreted in the light of the methodology that was used. In order to measure the idiosyncratic shared mental model of the team, we used subjective measures as well as objective measures. With respect to the latter, we implemented the methodology of cognitive mapping as operationalized by Carley (1997) and of concept mapping. This seemed to be successful in the educational setting and in the controlled environment of the simulation. However, the question is if these methods are equally valid to capture the shared mental models of (all kinds of) teams in an insurance company and in organisations in general. The selection of the most appropriate knowledge elicitation techniques should be guided by the tasks the teams are confronted with (Cooke, 1994). This will remain a challenge as no orderly relation exists between knowledge elicitation technique and the type of knowledge that results. But research on shared mental models will only reach its potential if researchers are capable of grasping the idiosyncratic knowledge of teams.
In sum, the studies deliver substantial evidence for a relation between the level of shared mental model of the task in the team and the team effectiveness. The evidence supports

the claim about the importance of group sense-making: those that do a better job will have increased competitive advantage (Nosek & McNeese, 1997). The results add to similar findings that indicate that shared mental models are related to important team outcomes (e.g., Mathieu et al., 2000; Stout et al., 1999). These previous results are mainly established in so-called 'action teams'. Our results generalize these findings for decision-making and even for educational contexts.

Learning Behaviors

The three empirical studies in this dissertation shed light on the importance of the team learning behaviors as conceptualized in our framework. The first study presented gives insight in the general effect of the learning behaviors. The results show that the learning behaviors lead to the development of shared mental models. The second study made it possible to gain a deeper insight in the role of the learning behaviors in the development of shared mental models. In this study, differentiation is made between three types of learning behaviors: construction, co-construction and constructive conflict. Constructive conflicts are identified as the key to the development of shared mental models and the improvement of team effectiveness. This major finding was taken into the design of the last study. The role of constructive conflict is further assessed by investigating it in new contexts and by 'comparing' it with other types of processes that are proposed in the literature (task conflict). Again, constructive conflict shows to be of crucial importance to team effectiveness in general and to the development of shared mental models in particular.

All these results underscore the importance of team learning behaviors as mediators for explaining team effectiveness. Moreover, our analyses suggest that important effects of team learning behaviors are indeed established through the development of shared mental models. These findings are particularly important because they provide evidence that a group learning perspective contributes to understanding the development of shared mental models. The results confirm the theoretical idea stressing the role of group learning in developing group cognitions (Mohammed & Dumville, 2001). They add to the indirect evidence within team research that interaction between team members affects mental model agreement (Rentsch & Klimoski, 2001; Walsh, 1988). This research goes beyond previous findings by identifying the kind of interactions that can be considered as team learning behavior, leading to the development of shared mental models. The concepts of co-construction and constructive conflict proved to be valuable in conceptualizing team learning behaviors. Furthermore, this research extends previous team learning research by establishing a relation between team learning behavior and the level of shared mental model (Edmondson, 1999; Wong, 2003).

Interpersonal context

This dissertation aims to identify social conditions under which teams make the effort to reach shared knowledge. Viewing teamwork as developing shared mental models, and thus as fundamentally social, stresses the need to take into account the social context in which these processes take place. Therefore, the studies focus on emerging team-level beliefs about the relations between the team members; in other words beliefs about the

interpersonal context. Two research designs, presented in chapters 3 and 5, include interpersonal beliefs. The most comprehensive account on this matter is presented in the first empirical study. This research identifies a number of powerful group-level beliefs which affect the learning behavior in teams: psychological safety, cohesion, potency and interdependence. In turn, the last empirical study investigates the role of one of these interpersonal beliefs, namely psychological safety. Again the results confirm that this interpersonal belief play an important role in fostering fruitful learning behavior. Moreover, it appears that psychological safety inhibited behaviors that were not contributing to team effectiveness. In both studies (chapter 3 and 5), the impact of these interpersonal beliefs on team effectiveness is primarily effectuated through team learning behaviors.

It can be concluded that insights in the role of interpersonal beliefs substantially add to the understanding of effective teamwork and particularly in understanding the emergence of productive team learning behavior. Team learning behaviors do not take place just by putting people together. The beliefs about the interpersonal context need to be taken into account to understand the engagement of team members to coordinate their understanding. It underpins the results of Edmondson (1999), and extends it by incorporating different interpersonal beliefs leading to a more complex understanding of the interpersonal context. These conclusions show the importance of an understanding how people belief they relate to each other; the 'cognitive side' of teamwork seems a reflection of the 'social picture' of the team.

Diversity as input

One of the starting points of this dissertation is that a diverse composition of a team results in high potential. By getting people together who have a variety of backgrounds, points of view, education, and/or expertise teams can bring multiple perspectives to bear on a problem, which allows for the rich problem conceptualization required to solve complex problems (Beers, 2005; Lomi et al., 1997; Vennix, 1996). For that reason, this dissertation considers the mediators through which diversity influences team effectiveness.

The last study (chapter 5) deals explicitly with the issue of a diverse composition of the team by depicting the informational and social category diversity of the teams. No consistent results were found between the diversity types and the identified learning behaviors (c.q., constructive conflicts). It has to be concluded that the results only partially elucidate the relation between the diversity types, processes, and performance. Probably more complex measures of diversity are necessary to reveal the influences of diversity on process and outcome. Furthermore, one should also try to get a grip on the salience of diversity attributes in groups (Van Knippenberg et al., 2004), as not all diversity attributes influence the behavior of team members at all times. Diversity only becomes 'active' through the perception of the team-members, which implies that future research attempts should try to examine how (and when) these perceptions are established and influence performance.

Outcomes: team effectiveness

In all studies presented in this dissertation, a broad approach to team effectiveness is taken. Team performance, team viability and team learning are taken as important dimensions of team effectiveness.

The first empirical study is based on perceptions of the team members. The second study uses both actual performance and team members' perceptions about performance. These data are completed with perceived team viability and perceived learning. The first of the two studies that are presented in chapter 5 uses evaluations by teachers of the products that resulted from the teamwork. No other data on team effectiveness are collected. The second study in chapter 5 relies on perceptions of the team members regarding the different team effectiveness dimensions. These perceptions are validated by evaluations of the team leaders.

Two observations regarding these team effectiveness measurements should be emphasized. First, when team members are asked to give their evaluation of the team performance, team viability and team learning, these perceptions seem to cluster; factor-analyses indicate that these three dimensions, when measured through perceptions, relate to one underlying factor. Second, different patterns appear in the analyses when team effectiveness is differently operationalized: shared mental models mediated the effect of team learning behaviors on team effectiveness when the actual business performance data were used as performance measures (study 2). However when the perceptions of the team members on the team effectiveness were used as performance measures in this study, the mediation was no longer established. Future research could elaborate on these findings by focusing on the relations between the different dimensions of team effectiveness, hereby including various sources of evidence.

Overall, substantial evidence that underscores the conceptual framework is collected by the different studies. Adding to the validity of the framework is the fact that results are replicated in different contexts: teams in educational settings, teams in a simulation of top management teams, work-teams in an insurance company. At the same time, many new questions popped up. Methodological as well as conceptual issues remain to be explored. We will discuss some of them in the next section.

Where do we go from here?

In looking for pathways guiding future research on shared mental models and its effects on teams, we will elaborate on two ideas that are crucial in this dissertation. First, this dissertation relies heavily upon the idea of shared mental models as crucial for effective team-work. It is stated that a shared mental model integrates and coordinates the perspectives of the team members. This enables the team to have a complex and rich understanding of the task environment (Nosek & McNeese, 1997). Second, the conceptual framework proposed in this dissertation conceptualizes the mediators of team effectiveness both as processes and as states. Hereby it borrows insights from complexity theory (Arrow, McGrath, & Berdahl, 2000). Both approaches have proven their value in understanding team effectiveness through the results of the different studies. But, both

ideas, if thought through, can have more advanced implications for future research. We will discuss the implications of both ideas more extensive in following paragraphs.

Shared mental models

Shared mental models are proposed in this dissertation as one of the building blocks of team effectiveness. The results of the empirical studies confirmed the high potential of this construct in understanding team effectiveness. On the other hand, the review presented in chapter 2 indicated different ways to deal with this idea and suggested that a lot can be learned from the various conceptualizations and methodologies that are out there. The review has indicated possibilities, maybe better viewed as challenges, to consider when developing a more comprehensive account of group cognition.

We learn from the review that the conceptualization of shared mental models and the corresponding methodologies, as used in this dissertation are robustly based on a cognitive perspective; shared mental models are looked at as a state of group cognition in which the individual subjectivities overlap and thus consensus is accomplished. However, this is not to suggest that the conceptualization from a cognitive perspective is superior to a conceptualization guided by a socio-cultural perspective, as shown in the review. We have argued in the review that an integration of both perspectives is not possible, but the differences between both perspectives reveal the strengths and weaknesses of each. So, future research should try to extend the understanding of group cognition.

For example, a short-sighted conclusion of a shared mental model conceptualization from a cognitive perspective would be that a complete overlap of mental models is an optimum to strive for. That conclusion seems too far-reaching. It would be time consuming and maybe even impossible for a team to develop such a complete overlap. Furthermore, an exact replication of individual mental models would reduce the availability of alternative solutions or strategies because of team members' varying perspectives and understandings, thereby resulting in decreased effectiveness (Salas, Sims, & Burke, 2005). Other perspectives can compensate for the dangers of such a restricted view and enhance team effectiveness through a constructive integration of ideas. A socio-cultural perspective on group cognition pays much more attention on the required diversity and the coordination of these differences. Also, research efforts starting from this perspective have much more attention for the dynamic character of group cognition and the fact that it always needs to be established. With this in mind, future research should also try to account, in their conceptualization and methodologies, for the dynamics of and diversity in mental models. This should lead to the development of a more integrated view on team cognition.

Teams as complex, adaptive, dynamic systems

It is stated in the first chapter that team researchers have converged on a view of teams as complex, adaptive, dynamic systems (Arrow et al., 2000). The conceptual framework of this dissertation has strongly taken into consideration some consequences from looking to teams as complex systems. For instance, it adopts the idea that teams are self-organizing systems in which global patterns emerge and structure subsequent local

action (Arrow et al., 2000). However, it takes more to fully understand them as complex, adaptive and dynamic systems. The following paragraphs elaborate some ideas on what it would entail for future research to incorporate accounts of teams as dynamic and adaptive systems.

To fully understand teams as dynamic systems it can be argued that future models should deal with the issues of time and development and that they should incorporate feedback-loops. It is important to consider that the structure and behavior of teams changes over time, yielding temporal patterns of development (Arrow et al., 2000; Arrow, Poole, Henry, Wheelan, & Moreland, 2004). This implies that to fully understand team effectiveness it is insufficient to take a single snapshot of team performance. Instead, performance should be sampled during a variety of conditions and situations (Salas et al., 2005). Also, there is a small body of literature that specifically suggests that outcome-process linkages may exist and have causal effects on future group processes (Peterson & Behfar, 2003). A cyclic theory could include previous group outcomes as inputs into the input-mediator-output chain we rely upon (Marks et al., 2001; Wittenbaum & Stasser, 2004). Including time in our models and attending to feedback-loops would add considerably to a dynamic understanding of teamwork.
Regarding the idea of teams as adaptive systems; the present research has considered teams as driven by intra-team factors and processes. However, teams never function in isolation from their context. This means that these teams are also driven by the interactions between the team and its embedding contexts (Arrow et al., 2000). It implies that research has to conceptualize teams as continuously interacting with the different embedding contexts; with other work groups and individuals within the organization; with customers and suppliers; with families and friends, as well as with a physical environment from and to which information, stimulation and resources may flow. This dissertation focuses on intra-team learning efforts. In the light of the implementation of work organizations that are team-based (West & Markiewicz, 2004), it becomes of increasing importance to have an understanding of inter-team learning. Team effectiveness will only pay off for organizations if knowledge that is developed in one team is spread out though the broader organizations. Research efforts are starting to be directed to questions that are related to these challenges.

Research that is fully capable of dealing with teams as complex, dynamic, and adaptive systems, could help in developing in-depth understanding of topics that are highly relevant for implementing effective teams and building team-based organizations. Both dynamics and adaptivity are aspects on which the framework that is presented here needs further development. This kind of research could indicate 'keys' to open the door to effective teamwork as it is presented in this dissertation.
Concerning implementation of effective teamwork in organizations, future research can link the insights of this dissertation with aspects of structure and leadership. The leading question needs to be: How can teamwork be organized so that it delivers its promises? Examples of structural and design aspects that can be considered are team design, task

design, autonomy, pay system, equipment, culture and norms of the organization, characteristics of the industry (Arrow et al., 2000; Edmondson, 1999). Leadership is generally considered as a crucial factor in creating effective teams (e.g., Edmondson, 2002). Team leaders are the primary connection to the embedding context of teams (e.g., the larger organization). Furthermore, team leader's behaviors are particularly salient in the team; team members are very aware of the behavior of the team leader (Tyler and Lind, 1992 in Edmondson, 1999). Links can be found between team leader behavior and both the social and cognitive aspects of teamwork. Through their behaviors they are likely to influence the interpersonal context and can set an example concerning team learning behavior. Moreover, they can monitor the team's functioning.

Practical implications

The research presented does not only provide stepping stones for further research, but also provides insights that have direct implications for practice. Since this research is based on samples of both student and professional work teams, it is interesting to reflect on the practical implications for both a learning and a performance context. All the more since the results show that performance benefits from a learning attitude. As collaborative learning formats are frequently used in education for the professions and teamwork is omnipresent in those professions the results of the present research suggest practical consequences for both education and professionals in teams.

The research presented in this dissertation suggests that constructing a shared mental model of the task is indeed crucial for increasing the effectiveness of those teams. To achieve this, these teams will have to pay explicit attention to their socio-cognitive processes in order to promote team learning as an avenue to shared mental models. This implies that both understanding and agreement need to be dealt with in these teams. This means that there needs to be room for construction, co-construction and constructive conflict. This can involve slowing down the interaction in order to inquire about meanings and test understandings (Argyris & Schön, 1996; Marsick, Watkins, & Wilson, 2002). Also, conflicts need to be seen as windows of opportunity instead of threats to progress. The results underline the power of disagreement or conflict (Jehn, 1994), but even more they stress the potential and need of dealing constructively with different opinions that may arise in a team.

Furthermore, team members, teachers, and managers need to pay explicit attention to the basic requirements for fostering interpersonal processes and beliefs that promote learning (e.g., Smith, 1996). This entails that students and professionals need (to learn how) to cope with these interpersonal beliefs and processes. Being able to manage this social side of learning and working should be a goal of staff and management development programs, moreover, it should be a part of each student's curriculum.

This research also identifies implications for the design of collaborative learning environments. Educational environments need to be designed in such a way that students are confronted with diverse points of views and learn how to constructively deal with them. In designing such learning environments, both the task and social dimension of the learning environment need to be considered (Arts, Gijselaers, & Segers,

in press). Tasks used in learning curricula are too often 'constructed for education' and do not require the cognitive activities that the workplace requires (Arts et al., in press). Realistic problem descriptions with a 'rich set of data' ('authentic learning environments') offer better opportunities for generating diverging ideas, perspectives and problem explanations. At the social dimension, teams of students need to be formed which provide optimal opportunity to be faced with multiple perspectives and thereby learn how to deal with this diversity and at the same time more deeply process the knowledge at hand. This entails that small groups of students are better learning units to tackle learning tasks. Larger groups impose more difficulties concerning coordination and creation of cohesion and feelings of trust (c.q., psychological safety) (Birmingham & McCord, 2002), which prevents multiple point of views to surface and to constructively deal with them. Also, the results suggest that providing time and explicitly dealing with group development to foster a beneficial interpersonal context could pay off.
Related research (Arts et al.) has shown that redesigning a learning environment according these principles resulted in increased problem-solving performance of the students.

In closing

The research presented here aims to further understanding of how teamwork can be described from a learning behavior perspective. The results indicate that this perspective can add to the understanding of what effective teamwork entails. The different chapters display how our learning perspective is supported by an integration of cognitive, socio-cognitive and social approaches. By this, it shows the potential of integrating these perspectives. However, concerning this matter is, the presented research is only at the outset of what seems possible and fruitful.
This work embodies the idea that learning is not only and maybe not foremost a cognitive endeavor. In that way, the presented research is exemplary in indicating the social nature of cognition. Acknowledging this idea has fundamental implications for a science that is focusing on learning. In first instance this implies that we understand the influence of social factors on the development of cognition, but in the end it means that we will need to understand cognition as social. This implies that a learning science requires a multi-disciplinary approach, since the different ideas needed to understand learning, are developed in different research strands. This is the direction in which the learning sciences need to evolve and how it can advance insight in work, education and life. It all starts from the idea that learning is (a way/part of) life.

References

Argyris, C., & Schön, D. (1996). *Organizational learning II: A theory of action perspective*. Reading, MA: Addison Wesley.

Arrow, H., McGrath, J. E., & Berdahl, J. L. (2000). *Small groups as complex systems. Formation, coordination, development and adaptation*. Thousand Oaks, CA: Sage Publications, Inc.

Arrow, H., Poole, M.S., Henry, K.B., Wheelan, S., & Moreland, R. (2004). Time, change, and development: The temporal perspective on groups. *Small Group Research, 73*, 73-105.

Arts, J. A. R., Gijselaers, W. H., & Segers, M. S. R. (in press). Enhancing problem-solving expertise by means of an authentic, collaborative, computer supported and problem-based course. An effect outcome comparison of a traditional and a refined PBL course. *European Journal of Psychology of Education*.

Baker, M. J. (1995). Negotiation in collaborative problem-solving dialogues. In R.-J. Beun & M. Baker & M. Reiner (Eds.), *Dialogue and instruction. Modeling interaction in intelligent tutoring systems* (pp. 39-55). Berlin: Springer-Verlag.

Baker, M. J. (1999). Argumentation and constructive interaction. In P. Coirier & J. Andriessen (Eds.), *Foundations of argumentative text* (pp. 179-202). Amsterdam, The Netherlands: University of Amsterdam Press.

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

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

Beers, P. J. (2005). *Negotiating common ground: Tools for multidisciplinary teams.* Unpublished doctoral dissertation. Open Universiteit Nederland, Heerlen.

Birmingham, C., & McCord, M. (2002). Group process research: Implications for using learning groups. In L. K. Michaelsen, A. B. Knight & L. D. Fink (Eds.), *Teambased learning: A transformative use of small groups in college teaching* (pp. 73-94). Sterling: Stylus.

Cannon-Bowers, J. A., & Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behavior, 22*, 195-202.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed.), *Individual and group decision making: Current issues* (pp. 221-246). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Carley, K. M. (1997). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533-558.

Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. *International Journal of Human-Computer Studies, 41*, 801-849.

De Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*, 741-749.

Edmondson, A. C. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350-383.

Edmondson, A. C. (2002). The local and variegated nature of learning in organizations: A group-level perspective. *Organization Science, 13*, 128-146.

Greeno, J. G. (1998). The situativity of knowing, learning and research. *American Psychologist, 53*(1), 5-26.

Jehn, K. A., (1994). Enhancing effectiveness: An investigation of advantages and disadvantages of value-based intragroup conflict. *International Journal of Conflict Management, 5*, 223-238.

Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management, 20*, 403-437.

Kline, D. A. (2005). Intuitive team decision making. In H. Montgomery & R. Lipshitz & B. Brehmer (Eds.), *How Professionals Make Decisions* (pp. 171-182). Mahwah, NJ: Lawrence Erlbaum Associates.

Lomi, A., Larsen, E.R., & Ginsberg, A. (1997). Adaptive learning in organizations: A system-dynamics-based exploration. *Journal of Management, 23,* 561-582.

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26*, 356-376.

Marsick, V. J., Watkins, K. E., & Wilson, J. A. (2002). Informal and incidental learning in the new millennium: The challenge of being rapid and/or being accurate! In M. Pearn (Ed.), *Individual differences and development in organisations*. Chichester, England: John Wiley & Sons.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Cannon-Bowers, J. & Salas, E. (2005). Scaling the quality of teammates' mental models: Equifinality and normative comparisons. *Journal of Organizational Behavior, 26*, 37-56

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*, 273-283.

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*, 89-106.

Nosek, J. T., & McNeese, M. D. (1997, March). *Issues for knowledge management from experiences in supporting group knowledge elicitation & creation in ill-defined, emerging situations.* Paper presented at the AAAI Spring Symposium Artificial intelligence in knowledge Management, Stanford University.

Peterson, R. S., & Behfar, K. J. (2003). The dynamic relationship between performance feedback, trust, and conflict in groups: A longitudinal study. *Organizational Behavior and Human Decision Processes, 92*, 102-112

Rentsch, J. R., & Klimoski, R. J. (2001). Why do 'great minds' think alike?: Antecedents of team member schema agreement. *Journal of Organizational Behavior, 22*, 107-120.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*, 235-276.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "Big Five" in teamwork? *Small Group Research, 36*, 555-599.

Smith, K. A. (1996). Cooperative Learning: Making 'Group work' Work. In T.E. Sutherland, & C.C. Bonwell (Eds.), *Using active learning in college classes: A range of options for faculty*, New Directions for Teaching and Learning No. 67.

Stout, R. J., Cannon-Bowers, J. A., Salas, E., & Milanovich, D. M. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors, 41*(1), 61-71.

Van der Vegt, G., & Bunderson, J. S. (2005). Learning and performance in multidisciplinary teams: the importance of collective team identification. *Academy of Management Journal, 48*, 532-547.

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*, 1008-1022.

Vennix, J. A. M. (1996). *Group model building. Facilitating team learning using system dynamics*. Chichester, UK: Hohn Wiley & Sons.

Walsh, J. P., Henderson, C. M., & Deighton, J. (1988). Negotiated belief structures and decision performance: An empirical investigation. *Organizational Behavior and Human Decision processes, 42*, 194-216.

West, M. A., & Markiewicz, L. (2004). *Building Team-based Working*. Malden, MA: Blackwell Publishing.

Wittenbaum, G. M., & Stasser, G. (1996). Management of information in small groups. In J. L. Nye & A. M. Brower (Eds.), *What's social about social cognition* (pp. 3-28). Thousand Oaks, CA: Sage Publications Inc.

Wong, S.-S. (2003). *Collective cognition in team: The role of interactive learning and effects on team performance.* Paper presented at the Academy of Management, Seattle.

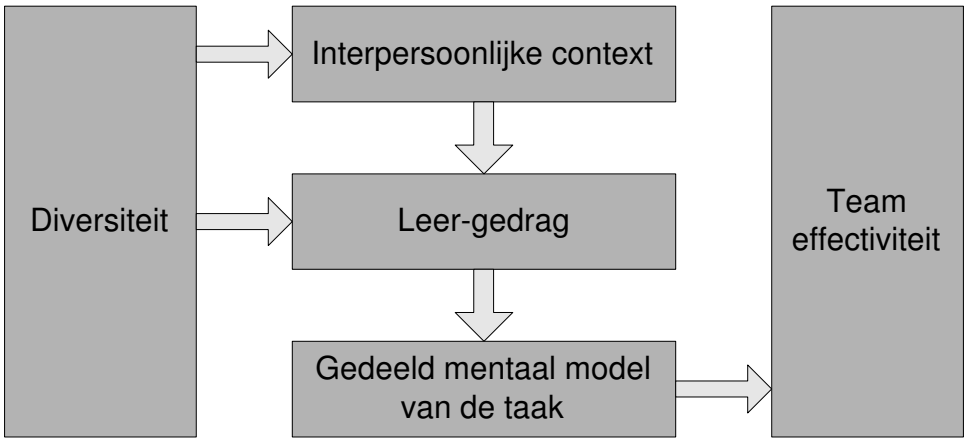
SAMENVATTING

Van teams wordt verwacht dat zij effectiever zijn in het managen van complexe problemen dan individuen, aangezien teams mensen samenbrengen die verschillende ervaringen, waarden en kennis hebben. Om problemen adequaat aan te pakken in deze teams is het nodig dat de teamleden niet naast maar met elkaar werken aan het probleem. Dit betekent dat perspectieven, die teamleden meebrengen, geïntegreerd moeten worden en gezocht moet worden naar een gedeelde interpretatie van het probleem. Dit gemeenschappelijk begrip of dit gedeeld mentaal model komt tot stand door overvloedige communicatie, discussie en onderhandeling.

In de literatuur worden de voordelen van teamwerk veelvuldig beschreven. De voortschrijdende implementatie van teamwerk in zowel scholen als organisaties zijn voorbeelden van pogingen om dit te verzilveren. Echter, zowel uit ervaringen in de praktijk als onderzoeksresultaten blijkt dat men hier niet altijd in slaagt. Onderzoek toont aan dat productieve samenwerking niet simpelweg tot stand komt door mensen met de nodige (relevante) kennis bij elkaar te brengen.
Deze dissertatie heeft als doelstelling om sociale en cognitieve factoren te bepalen die een rol spelen in het effectief functioneren van teams. De uitdaging hierbij is om inzicht te krijgen in de rol van het gemeenschappelijke begrip van het probleem en condities waaronder dit ontwikkelt. Om de mechanismen van effectief teamwerk bloot te leggen hebben we gekozen voor een multi-disciplinaire aanpak, gebaseerd op cognitief-psychologisch, sociaal-psychologisch en bedrijfskundig onderzoek. Door de integratie van cognitieve en sociale perspectieven hopen we bij te dragen aan de groeiende kennisbasis over teamwerk.

Verschillende onderzoekers beschrijven teamgedrag en verklaren team effectiviteit vanuit een cognitief standpunt, waarbij *gedeelde mentale modellen* centraal staan. Er wordt bepleit dat gedeelde mentale modellen van de taak de perspectieven op het probleem die aanwezig zijn in het team integreren en coördineren en dat ze het team in staat stellen om een complex en rijk begrip te hebben van de taakomgeving waardoor problemen beter kunnen aangepakt worden.
Vanuit socio-cognitief perspectief beargumenteren we dat gedeelde mentale modellen zich ontwikkelen door processen van constructie, co-constructie en constructief conflict, samen *leergedrag* genoemd. Eerst dient betekenis of begrip ge(co-)construeerd te worden. Dit vindt niet plaats door het simpelweg accumuleren van contributies door teamleden; de verschillende contributies moeten op elkaar voortbouwen. Ten tweede dient men 'overeenkomst' te bereiken over de voorgestelde oplossingen. De rol van conflict, voortkomend uit verschillen in mening, is in dit verband belangrijk. Een team zal enkel voordeel hebben van meningsverschillen als deze leiden tot het diepgaand verwerken van de verschillende informatie en perspectieven die aanwezig zijn in het team. Doorheen verduidelijking van standpunten en negotiatie aan de hand van argumenten

kan een team bouwen aan een integratie van meningen, zodat een gedeeld mentaal model kan ontstaan.
Vanuit sociaal-psychologisch perspectief wordt gewezen op de sociale condities waaronder teams een investering doen om gedeelde mentale modellen te ontwikkelen. Hierbij kijkt men naar de op groepsniveau ontwikkelde opvattingen over de relaties tussen de teamleden, m.a.w. opvattingen over de *interpersoonlijke context*. Het wordt verondersteld dat deze interpersoonlijke opvattingen een context vormen die de leergedragingen van het team beïnvloeden. Gebaseerd op de literatuur, identificeren wij enkele krachtige opvattingen op groepsniveau: psychologisch veiligheid, cohesie, doeltreffendheid en interdependentie. De hypothese is dat teams pas leergedragingen zullen vertonen als aan specifieke sociale condities is voldaan: er moet een gedeelde betrokkenheid zijn voor de taak (taak cohesie), men moet geloven dat men elkaar nodig heeft voor de taak (interdependentie), men moet geloven dat een teamlid niet zal aangekeken worden op het leveren van al dan niet alternatieve voorstellen (psychologische veiligheid) en men moet geloven dat het team in staat is om iets te maken van de ideeën die worden aangeleverd (doeltreffendheid).
Tot slot wordt voornamelijk in de diversiteitsliteratuur veel aandacht besteed aan de *diverse samenstelling* van teams: het potentieel van teams is voor een groot deel te wijten aan het feit dat teams mensen kunnen samenbrengen die een verscheidenheid aan achtergrond, gezichtspunten, en/of expertise hebben. Finaal is teamwerk voor elke organisatie een middel en geen doel op zich: het moet leiden tot een hogere mate van effectiviteit. *Team effectiviteit* betreft zowel prestaties, levensvatbaarheid, als het leren van het team.



Figuur 1: Conceptueel model team effectiviteit

Zoals eerder aangegeven is dit conceptueel model (Figuur 1) een integratie van verschillende perspectieven die te vinden zijn in verschillende stromingen in de literatuur. Bij het verkennen en samenbrengen van deze literatuur werd duidelijk dat er heel wat onduidelijkheid was betreffende het construct 'gedeelde mentale modellen'. Om hierin klaarheid te scheppen, is besloten om eerst een overzicht te geven/krijgen over de verschillende conceptualisaties die terug te vinden zijn in de literatuur.

Literatuurreview: cognities op groepsniveau (hoofdstuk 2)

Heel wat verschillende concepten zijn in omloop om het 'collectieve begrip' in teams te beschrijven: common ground, team mental models, shared understanding, distributed cognition en collective mind. Hierbij komt nog eens dat verscheidene studies ook een veelvoud aan conceptualisaties en methodologieën gebruiken. Deze verscheidenheid illustreert de complexiteit van wat bestudeerd wordt. Maar dit gebrek aan conceptuele helderheid is een hinderpaal voor de wisselwerking tussen en het voortbouwen op resultaten van onderzoek. Dit hindert voortschrijdend inzicht in het fenomeen groepscognitie. Het doel van deze literatuurstudie is het ontwikkelen van een conceptueel kader. Dit betekent het bestuderen van gelijkenissen en verschillen die terug te vinden zijn in de literatuur wat betreft de conceptualisering van groepscognitie en de methodologie die gebruikt wordt om grip te krijgen op dit fenomeen. Om ordening aan te brengen in de vele conceptualisaties hebben we een raamwerk gebruikt dat is gebaseerd op twee socio-genetische visies, die uitgaan van een verschillende opvatting over de sociale aard van cognitie: een cognitief en een socio-cultureel perspectief.

De analyse toont aan dat drie benaderingen kunnen worden onderscheiden. Sommige studies conceptualiseren groepscognitie als het overeenstemmen of overlappen van individuele mentale modellen. Deze studies representeren het cognitief perspectief. Andere studies benaderen groepscognitie als een proces van coördinatie van activiteiten of als een dynamische eenheid van individuele contributies in de gezamenlijke activiteit. Zij representeren een socio-cultureel perspectief. Tot slot zijn er ook enkele studies die in hun conceptualisatie van groepscognitie een begin maken van het overschrijden van de grenzen tussen de twee onderscheiden perspectieven. Zij slagen er in om zowel aspecten van een cognitief en een socio-cultureel perspectief in te bouwen in hun conceptualisatie.

Een verdere analyse van de literatuur toont de complementariteit van het cognitief en socio-cultureel perspectief op groepscognitie. Wat in de schaduw blijft bij het ene perspectief wordt net belicht in het andere perspectief. De cognitieve traditie verliest de intrinsieke complexe kwaliteit van het gehele systeem uit het oog doordat het zich enkel richt op de aggregatie van de kwaliteiten van de sub-systemen. Het grote nadeel hierbij is dat we uiteindelijk enkel iets over een groep te weten komen als een som van de leden van die groep. De socio-culturele traditie echter verliest het zicht over de intrinsieke aard van de sub-systemen doordat enkel het systeem waar ze deel van uitmaken wordt belicht.

De studies die aangeduid werden als 'grensdoorbrekend' tonen hoe de twee perspectieven zouden kunnen gecombineerd worden. Toch zijn deze studies niet in staat om volledig tegemoet te komen aan de principes van beide perspectieven. Gebaseerd op deze analyses en op de theoretische reflecties in de literatuur concluderen wij dat een volledige integratie van de perspectieven, en dus het streven naar een coherente theorie over groepscognitie, niet mogelijk lijkt. Echter, gegeven de complementariteit van de beide perspectieven lijkt het wenselijk dat er een dialoog wordt opgestart. Een eerste stap om het cognitieve en socio-culturele perspectief dichter bij elkaar te brengen, is dat ieder perspectief wordt uitgebreid door elementen van het andere perspectief mee te nemen in

de verklaring van fenomenen. De 'grensdoorbrekende studies' kunnen hierbij een gids zijn.

Drie empirische studies

Drie studies onderzoeken de hypothesen die afgeleid kunnen worden uit het team effectiviteits-raamwerk. Hierbij werd rekening gehouden met de inzichten opgedaan in de review. De eerste empirische studie is een toets van de relaties die geponeerd worden in het raamwerk. De tweede studie bouwt voort op de resultaten van de eerste studie en concentreert zich op een aantal cruciale aspecten. Alsook tracht het oplossingen te vinden voor enkele methodologische uitdagingen die resulteerden uit de eerste studie. De derde empirische studie keert terug naar ons uitgangspunt en tracht grip te krijgen op de (gevolgen van de) diverse samenstelling van een team.

Het doel van de eerste empirische studie (*hoofdstuk 3*) is om de geïdentificeerde mediërende factoren en processen en hun invloed op team effectiviteit te testen. De studie bestudeert de relaties tussen de interpersoonlijke context die ontstaat in het team en de leergedragingen die plaatsvinden. We bevragen ook de invloed van deze leergedragingen op het ontstaan van gedeelde mentale modellen. Dit onderzoek gebeurde bij studententeams in een collaboratieve leeromgeving.
De resultaten staven het model zoals wij het voorstelden. De analyses tonen aan dat interpersoonlijke factoren en socio-cognitieve processen bijdragen aan het begrijpen van het tot stand komen van gedeelde mentale modellen, uiteindelijk leidend tot hogere waargenomen team effectiviteit. De aspecten van de interpersoonlijke context, interdependentie, taak cohesie, psychologische veiligheid en doeltreffendheid, lijken cruciaal om leergedrag mogelijk te maken. Deze leergedragingen dragen op hun beurt bij aan de ontwikkeling van gedeelde mentale modellen. Deze gedeelde mentale modellen zijn een belangrijke factor in team effectiviteit.
Hoewel deze resultaten het conceptuele model lijken te bevestigen, dienen we enkele beperkingen van deze studie te erkennen. Deze studie baseert zich volledig op percepties van team-leden. Dit stelt geen probleem aangaande de meting van opvattingen over de interpersoonlijke context of het leergedrag van het team aangezien beargumenteerd kan worden dat teamleden hier de eerste en beste observatoren zijn. Echter, wat betreft de metingen van het gedeelde mentale model is het aangewezen om een meer directe maat te hanteren die niet enkel op de percepties van de teamleden terugvalt. Ook wat betreft team effectiviteit kan men opperen dat de zelf-evaluaties van de team-leden dienen aangevuld te worden met meer objectieve maten van team prestaties. Alsook dient opgemerkt worden dat we in deze studie enkel gebruik maakten van studententeams in een onderwijsomgeving.

De tweede empirische studie (*hoofdstuk 4*) komt tegemoet aan de beperkingen van de eerste studie en tracht tegelijkertijd ook diepgaander inzicht te krijgen in bepaalde aspecten van het conceptueel model. Dit onderzoek werd uitgevoerd door teams te plaatsen in een simulatie van een organisatie. Deze simulatie biedt een uitdagende omgeving die enkele sterke overeenkomsten heeft met de situatie waarin management

teams zich bevinden, en tegelijkertijd biedt het een gecontroleerde omgeving om kritische factoren te onderzoeken die team-leren en -effectiviteit beïnvloeden. Tevens biedt de simulatie de mogelijkheid om objectieve data te verzamelen aangaande de prestaties van het team. Deze studie bevraagt de relatie tussen leergedrag, gedeelde mentale modellen en prestaties in teams die aan strategische besluitvorming doen. Deze context is verschillend van het meeste onderzoek naar gedeelde mentale modellen, dat meestal plaatsvindt in zogenoemde actie-teams. Daarnaast wordt in deze studie ook ingegaan op het methodologische probleem omtrent het meten van gedeelde mentale modellen. Dit leidt tot het gebruik van de methodologie 'cognitive mapping'. Deze aanpak maakt het mogelijk om de ideosyncratische inhoud en structuur van mentale modellen in beeld te brengen.
De resultaten van de studie werpen licht op de complexe relaties tussen leergedrag en de ontwikkeling van gedeelde mentale modellen. Constructief conflict blijkt cruciaal te zijn in het proces van het bouwen van gedeelde mentale modellen; enkel als er een kritische houding ten opzicht van elkaars inbreng in het team is; als elkaars inbreng grondig wordt overwogen en als teamleden verschillen van mening openlijk bespreken, enkel dan zal er constructie van gedeelde mentale modellen plaatsvinden. Daarenboven toont deze studie dat de ontwikkeling van gedeelde mentale modellen leidt tot betere resultaten. De resultaten van een bedrijf blijken beter te zijn als het management team een groter gedeeld mentaal model heeft. Het blijkt tevens dat deze gedeelde mentale modellen het effect van teamleergedrag op de bedrijfsprestaties mediëren. Dit suggereert dat teamleren effect uitoefent op de feitelijke teamprestaties door de ontwikkeling van een gedeeld cognitief kader om de situatie te interpreteren.

Wij stelden dat een belangrijke reden waarom men teams implementeert te vinden is in de overtuiging dat ze het potentieel hebben om een diversiteit aan kennis en achtergronden bij elkaar te brengen. De derde empirische en laatste studie in deze dissertatie (*hoofdstuk 5*) kijkt specifiek naar het aspect van een diverse samenstelling van teams en de invloed daarvan op de mediërende variabelen uit het conceptueel kader en team effectiviteit. Op deze wijze levert deze studie ook een bijdrage aan de verdere validering van de factoren en processen die cruciaal bleken in de vorige studies. Procesmatig wordt gekeken naar de rol van constructive conflicten en taakconflicten. Taakconflicten zijn meningsverschillen over taakgerelateerde zaken en worden in onderzoek naar diversiteit vanuit een informatie/besluitvormings-perspectief naar voor geschoven als belangrijke mediërende variabele. Deze studie werd uitgevoerd bij twee verschillende steekproeven. De eerste bestaat uit studententeams in een onderwijsomgeving, een tweede uit professionele teams in een verzekeringsmaatschappij. Ook in deze studie wordt nagegaan of de ontwikkeling van gedeelde mentale modellen een cruciaal mechanisme is in het verklaren van team effectiviteit. Psychologisch veiligheid wordt bestudeerd als mogelijk belangrijke variabele in de interpersoonlijke context.
De analyses op beide steekproeven tonen aan dat het constructieve conflicten zijn, en niet taak conflicten, die positief gerelateerd zijn aan team effectiviteit. Deze resultaten

bevestigen de potentiële voordelen van diversiteit gerealiseerd worden door de kruisbevruchting van ideeën die plaatsvindt binnen teams. Ze ondergraven het belang van taakconflicten als mediërende variabele tussen diversiteit en team effectiviteit. Daarenboven blijkt uit de analyses in de steekproef van studententeams dat constructieve conflicten aanleiding geven tot de ontwikkeling van gedeelde mentale modellen. Dit lijkt verdere evidentie aan te dragen voor de idee dat constructieve conflicten maken dat de diversiteit van kennis die aanwezig is in het team geïntegreerd wordt in een gedeeld mentaal model. Tevens blijkt bij beide steekproeven het belang van een variabele als psychologische veiligheid voor teamleren; de aanwezigheid van psychologische veiligheid opent voor teams de mogelijkheid om tot leergedrag te komen zodat men kan 'bouwen' op elkaar. Ten slotte wijzen de analyses in beide steekproeven op een relatie tussen verschillende vormen van diversiteit enerzijds, en taakconflict en constructief conflict anderzijds.

In het algemeen kunnen we stellen dat de resultaten van de verschillende studies in deze dissertatie het conceptueel kader zoals voorgesteld onderbouwen. Het feit dat deze resultaten gerepliceerd worden in verschillende contexten (van studententeams in een onderwijscontext, over simulaties van top management teams tot professionele teams in een verzekeringsorganisatie) draagt bij tot de validiteit van dit kader.
In het zoeken naar mogelijkheden voor toekomstig onderzoek elaboreren wij twee ideeën. Ten eerste, deze dissertatie bouwt sterk voort op het belang van gedeelde mentale modellen voor effectief teamwerk. Er wordt gesteld dat gedeelde mentale modellen de perspectieven van teamleden integreren en coördineren. Dit maakt het mogelijk dat teams een complex en rijk begrip hebben van de omgeving. De review maakt duidelijk dat de studies die gepresenteerd worden in deze dissertatie vertrekken vanuit een cognitief perspectief, zowel qua conceptualisatie als qua methodologie. Gedeelde mentale modellen worden bekeken als een toestand waarin groepscognitie zich bevindt en waarin individuele subjectiviteiten overlappen en waar dus consensus is. Toekomstig onderzoek zou ook moeten proberen om het dynamische en diverse aspect van groepscognitie te belichten in de conceptualisatie en methodologie.
Ten tweede, het conceptueel kader achter deze dissertatie conceptualiseert de mediërende variabelen van team effectiviteit als processen en als toestanden. Dit leunt op inzichten vanuit complexiteits- en systeemtheorie. Om teams volledig als dynamische, adaptieve en complexe systemen te begrijpen moeten toekomstige modellen meer aandacht hebben voor het tijds- en ontwikkelingsaspect en moeten zij feedback-loops incorporeren. Verder kan gesteld worden dat aangaande de idee van teams als adaptieve systemen het gepresenteerde onderzoek teams bekijkt als gestuwd door intra-team factoren en processen. Echter, teams functioneren niet geïsoleerd van hun omgeving. Dit betekent dat teams ook bepaald worden door interacties tussen het team en de omgeving waarin dit team zich bevindt. Toekomstig onderzoek dient zich ook hier meer rekenschap van te geven.

De verschillende hoofdstukken in dit proefschrift tonen hoe een leer-perspectief ondersteund wordt door een integratie van cognitieve, socio-cognitieve en sociale

gezichtspunten. Op deze manier toont deze dissertatie het potentieel van het integreren van deze perspectieven. Niettemin is het zo dat het voorgestelde onderzoek hiermee enkel aan het begin staat van wat mogelijk en vruchtbaar lijkt.

Dit werk belichaamt de idee dat leren niet enkel en misschien zelfs niet vooral een cognitieve onderneming is. Dit erkennen heeft fundamentele gevolgen voor een wetenschap die op leren gericht is. In eerste instantie betekent dit dat we de invloed van sociale factoren op de ontwikkeling van cognities dienen te begrijpen. Maar uiteindelijk zal dit ook betekenen dat we cognitie *als* sociaal fenomeen kunnen begrijpen. Dit betekent dat een wetenschap over leren een multi-disciplinaire aanpak vergt, aangezien de ideeën die nodig zijn om leren te begrijpen ontwikkeld worden in verschillende onderzoekstradities. Dit is dan ook de richting waarin de wetenschap over leren dient te evolueren en hoe het kan bijdragen aan inzicht in onderwijs, opleiding, werk en leven.

About the author

Piet Van den Bossche (1977) obtained his Master degree ('Licentiate') in Educational Sciences at the Faculty of Psychology and Educational Sciences of the University of Leuven (Belgium).
In 2000, he started his career as a junior researcher at the department of Educational Development & Research at the University of Maastricht. During this period he was involved in several research projects concerning quality assurance and educational innovation at the faculty. He also was a part-time lecturer at a centre for adult education in Ghent (Belgium).
From 2001 to 2005, in addition to a part-time assistant professorship at the department of Educational Development & Research, Piet Van den Bossche was a Ph.D. Student. His Ph.D. project was part of a larger project, entitled "Knowledge sharing and decision-making in collaborative multidisciplinary teams with (a)synchronous computer-mediated environments" (part of the NWO research programme "Society and ICT").
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List of publications

Articles in refereed journals

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning & Instruction, 13*(5), 533-568.

Dochy, F., Segers, M., Van den Bossche, P., & Struyven, K. (2005). Students' perceptions of a problem-based learning environment. *Learning Environments Research, 8*(1), 41-66.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2003). Effects of short term implementations of problem-based learning within teacher training. *International Journal of Educational Policy, Research & Practice, 3*(4), 55-72.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75*(1), 27-61.

Gijbels, D., van de Watering, G., Dochy, F., & Van den Bossche, P. (2005). The relationship between students' approaches to learning and the assessment of learning outcomes. *European Journal of Psychology of Education, 20*(4), 327-341.

Gijbels, D., van de Watering, G., Dochy, F., & Van den Bossche, P. (2006). New learning environments and constructivism: The students' perspective. *Instructional Science34* (3), 213-226.

Gijbels, D., Van den Bossche, P., Dochy, F., & Segers, M. (2002). Effecten van probleemgestuurd onderwijs in de lerarenopleiding. *Tijdschrift voor Hoger Onderwijs, 20*(1), 60-72.

Newman, M., Van den Bossche, P., Gijbels, D., McKendree, J., Roberts, T., Rolfe, I., et al. (2004). Responses to the pilot systematic review of problem-based learning. *Medical Education, 38*, 921-923.

Segers, M., Van den Bossche, P., & Teunissen, E. (2003). Evaluating the effects of redesigning a problem-based learning environment. *Studies in Educational Evaluation, 29*, 315-334.

Van den Bossche, P., Gijselaers, W., Segers, M., & Kirschner, P. A. (2006). Social and Cognitive Factors Driving Teamwork in Collaborative Learning Environments. Team Learning Beliefs & Behaviors. *Small Group Research, 37*(5), 490-521.

Van den Bossche, P., Segers, M., Gijbels, D., & Dochy, F. (2001). Effecten van een probleemgestuurd economisch curriculum. *Tijdschrift voor Hoger Onderwijs, 19*(4), 254-277.

Under review

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., Simons, R.-J., & Kirschner, P.A. (submitted). *Reconsidering group cognition: From conceptual confusion to a boundary area between cognitive and socio-cultural perspectives?*

Van den Bossche, P., Gijselaers, W., Segers, M., Woltjer, G., & Kirschner, P. A. (submitted). *Sharing Expertise in Management: A Study of Team Learning and its Effect on Shared Mental Models*.

Van den Bossche, P., Van Gennip, N., Gijselaers, W., Segers, M., & Kirschner, P. A. (submitted). *Harvesting diversity. Unravelling mechanisms in diverse teams to yield high team performance*.

Books

Dochy, F., Segers, M., Gijbels, D., & Van den Bossche, P. (2002*). Studentgericht onderwijs & probleemgestuurd onderwijs. Betekenis, achtergronden en effecten*. Utrecht: Lemma.

Newman, M., De Virgilio, G., Engel, C., Gijbels, D., McKendree, J., Roberts, A., Rolfe, I., Smucny, J., & Van den Bossche, P. (2003*). A pilot systematic review and meta-analysis on the effectiveness of Problem Based Learning*. Newcastle: Learning and Teaching Subject Network Centre for Medicine, Dentistry and Veterinary Medicine.

Chapter in book

Van den Bossche, P., Segers, M., Gijbels, D., & Dochy, F. (2004). Effects of problem-based learning in business education: A comparison between a PBL and a conventional educational approach. In R. Ottewill, L. Borredon, L. Falque, B. Macfarlane & A. Wall (Eds.), *Educational innovation in economics and business VIII: Pedagogy, technology and innovation* (pp. 205-228). Dordrecht: Kluwer Academic Publishers.

Papers

Akkerman, S., & Van den Bossche, P. (2003). *Diversiteit in groepen als bron voor een gedeelde visie.* Paper presented at the Onderwijs Research Dagen, Kerkrade, the Netherlands.

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., & Simons, R.-J. (2005). *Shared mind in groups: Cognitive and socio-cultural perspectives.* Paper presented at the biennial conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Akkermans, M., Van den Bossche, P., Gijselaers, W., & Van de Wiel, M. (2006). *Measures for Shared Mental Models. Does Shared Expertise Really Count in Team Performance?* Paper presented at the EARLI-sig Professional Development and Learning, Heerlen, the Netherlands.

Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Van den Bossche, P. (2002). *Decision-support and complexity in decision making.* Paper presented at the JURE (Junior Researchers of EARLI) conference, Amsterdam, the Netherlands.

Beers, P. J., Kirschner, P. A., Van den Bossche, P., & Gijselaers, W. (2002, 5-6 april). *Decision support and complexity in decision making.* Paper presented at the Third European conference on Organizational Knowledge, Learning and Capital, Athens, Greece.

Beers, P. J., van Merriënboer, J., Kirschner, P. A., Van den Bossche, P., Gijselaers, W., & Boshuizen, E. (2002). *Tools for supporting policy makers: An integrated theoretical framework.* Paper presented at the Onderwijs Research Dagen, Antwerpen, Belgium.

Gijbels, D., Dochy, F., Segers, M., & Van den Bossche, P. (2000). *Effecten van studentgericht onderwijs in de lerarenopleiding.* Paper presented at the fifth VFO congres, Leuven.

Gijbels, D., Dochy, F., Segers, M., & Van den Bossche, P. (2001). *Effects of Problem-based learning in teacher education: a comparison between a PBL and a conventional educational approach.* Paper presented at the 9th biennial conference of the European Association for Research on Learning and Instruction(EARLI) conference, Fribourg, Switzerland.

Gijbels, D., Dochy, F., van de Watering, G., & Van den Bossche, P. (2005). *The relationship between students' approaches to learning and the assessment of learning outcomes.* Paper presented at the biennial conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2003). *The relation between assessment practices and outcomes of studies: The case of problem-based learning.* Paper presented at the 10th biennial conference of the European Association for Research on Learning and Instruction (EARLI), Padova, Italy.

Gijbels, D., Van den Bossche, P., Dochy, F., & Segers, M. (2001). *Effects of problem-based learning in teacher-training programs.* Paper presented at the AERA conference, Seattle, USA.

Janssen, S., Jossberger, H., Van de Wiel, M., Van den Bossche, P., & Gijselaers, W. (2006). *Deliberate practice in medicine: What work-related activities contribute to professional development?* Paper presented at the EARLI SIG Professional Learning and Development Conference, Heerlen, The Netherlands.

Kirschner, P. A., Gijselaers, W., Boshuizen, E., Segers, M., Van den Bossche, P., & Beers, P. J. (2001, October). *A multiperspective analysis of knowledge management in a complex environment.* Paper presented at the MES-SISWO conference 'ICT EN ARBEID', Amsterdam.

Newman, M., McKendree, J., Roberts, A., Smucny, J., Rolfe, I., De Virgilio, G., et al. (2003, April). *A systematic review of the effectiveness of PBL - results of a pilot study.* Paper presented at the American Educational Research Association, Annual Conference.

Newman, M., McKendree, J., Roberts, A., Smucny, J., Rolfe, I., De Virgilio, G., et al. (2003, Februari). *Pilot of a systematic review protocol: Practical and methodological issues.* Paper presented at the Campbell Collaboration Annual meeting, Stockholm.

Newman, M., McKendree, J., Roberts, T., Rolfe, I., Smucny, J., De Virgilio, G., et al. (2003). *The effectiveness of problem based learning: Results of a pilot Campbell Collaboration systematic review.* Paper presented at the 10th biennial conference of the European Association for Research on Learning and Instruction (Earli), Padova, Italy.

Newman, M., McKendree, J., Roberts, T., Rolfe, I., Smucny, J., De Virgilio, G., et al. (2002, 10-12 december). *A systematic review of the effectiveness of PBL - Results of a Campbell collaboration pilot study.* Paper presented at The Society for Research into Higher Education (SRHE) Annual Conference, University of Glasgow.

Pletinckx, J., Segers, M., Dochy, F., & Van den Bossche, P. (2001). *Evaluating problem-based learning: Looking for critical succes factors.* Paper presented at the 9th biennial conference of the European Association for Research on Learning and Instruction (EARLI), Fribourg, Switzerland.

Segers, M., Dochy, F., Van den Bossche, P., & Tempelaar, D. (2001). *The quality of co-assessment in an undergraduate problem-based learning curriculum.* Paper presented at the 9th EARLI conference, Fribourg, Switzerland.

Teunissen, E., Van den Bossche, P., & Segers, M. (2003). *The effects of supporting students' self-dependent learning in a problem-based learning environment.* Paper presented at the 10th Biennial conference Earli, Padova, Italy.

Van de Wiel, M., Van den Bossche, P., Jossberger, H., Janssen, S., & Gijselaers, W. (2006). *Deliberate practice in medicine: Relating goal orientations, learning activities and expertise.* Paper presented at the EARLI SIG Professional Learning and Development Conference, Heerlen, The Netherlands.

Van den Bossche, P., & Akkerman, S. (2004). *Considering concepts for shared views in collaboration: Two socio-genetic views.* Paper presented at the VOR-divisie Leren & Instructie; Collaboration: from individual to collective thinking?, Utrecht.

Van den Bossche, P., & Gijbels, D. (2005). *Learning in groups: Scored goals and how to play a better second half.* Keynote presentation at the 12th Educational Innovation in Business education (Edineb) conference, Antwerp, Belgium.

Van den Bossche, P., Gijbels, D., & Dochy, F. (2000). *Does problem-based learning educate problem-solvers? A Meta-analysis on the effects of problem-based learning.* Paper presented at the Seventh EDINEB Conference, Newport Beach, CA, USA.

Van den Bossche, P., Gijbels, D., Dochy, F., & Segers, M. (2001). *Effects of problem-based learning on students' learning outcomes: A meta-analysis.* Paper presented at the 9th EARLI conference, Fribourg, Switzerland.

Van den Bossche, P., Gijselaers, W., & Segers, M. (2003). *Knowledge sharing in multidisciplinary teams.* Paper presented at the 10th Annual EDINEB International Conference, Salzburg, Austria.

Van den Bossche, P., Gijselaers, W., & Segers, M. (2004). *Effects of Social Factors on Shared Cognition and Teamwork in Collaborative Learning Environments.* Paper presented at the Annual meeting of the American Educational Research Association (AERA), San Diego.

Van den Bossche, P., Van Gennip, N., Gijselaers, W., & Segers, M. (2005). *Collaborative Learning as constructive conflict: Building shared mental models.* Paper presented at the biennial conference of the European Association for Research on Learning and Instruction (EARLI), Nicosia, Cyprus.

Van den Bossche, P., Gijselaers, W., Segers, M., Beers, P. J., Kirschner, P. A., & Boshuizen, E. (2002, June 26-28). *Decision-making in complex environments. Multiple representations and multiple agents.* Paper presented at the First Professional Development EARLI-SIG Meeting, Turku, Finland.

Van den Bossche, P., Gijselaers, W., Segers, M., & Woltjer, G. (2005). *Collaboration as Learning.* Paper presented at the EDiNEB XII Conference, Antwerp, Belgium.

Van den Bossche, P., Gijselaers, W., Segers, M., & Woltjer, G. (2005). *Sharing expertise in management: A study on team learning and its effect on shared mental models.* Paper presented at the Academy of Management, Hawaii.

Van den Bossche, P., Gijselaers, W., Segers, M., & Woltjer, G. (2006). *Sharing expertise: A study on team learning.* Paper presented at the EARLI SIG Professional Learning and Development Conference, Heerlen, The Netherlands.

Van den Bossche, P., Segers, M., Gijbels, D., & Dochy, F. (2001). *Effects of problem-based learning in business education: A comparison between a pbl and a conventional approach.* Paper presented at the 8th EDINEB international conference, Nice, France.

Van den Bossche, P., Segers, M., & Teunissen, E. (2002, December 9-13). *Optimizing Students' Independent Learning in a Problem Based Learning Environment.* Paper presented at the 4th Asia Pacific Conference on Problem-based Learning, Hatyai, Songkhla, Thailand.

Van den Bossche, P., Van Gennip, N., Gijselaers, W., & Segers, M. (2005). *Effects of diversity on conflict and group performance in professional work groups.* Paper presented at the Annual meeting of the American Educational Research Association (AERA), Montreal, Canada.

Van den Bossche, P., Van Gennip, N., Gijselaers, W., & Segers, M. (2005, June 8-10). *Harvesting diversity: Building shared mental models by dealing constructively with conflict (poster).* Paper presented at the KNAW/EASP symposium Social Identity in Organizations, Amsterdam, The Netherlands.

Van Gennip, N., Van den Bossche, P., Gijselaers, W., & Segers, M. (2004). *Team Learning: Dealing with Diversity.* Paper presented at the 11th Educational Innovation in Business Education (EDiNEB) international conference, Maastricht, The Netherlands.