Fostering Argumentation-Based Computer-Supported Collaborative Learning in Higher Education

Omid Noroozi

Fostering Argumentation-Based Computer-Supported Collaborative Learning in

Higher Education

Omid Noroozi

Thesis

Submitted in fulfilment of the requirements for the degree of doctor

at Wageningen University

by the authority of the Rector Magnificus

Prof. dr. M.J. Kropff,

in the presence of the

Thesis Committee appointed by the Academic Board

to be defended in public

on Friday 11 January 2013

at 4 p.m. in the Aula.

Dedication

To my beloved family,

Your unconditional love means the world to me.

Preface

The initial spark out of which this thesis grew came five years ago when I heard from doctors that due to severe knee surgery I would have to quit my beloved sport, football, at least at the professional level. I must admit that being forced to stop playing football and competing in top-level sports has been one of the worst experiences of my life. After struggling with this incident, I decided to play another challenging game at top level with the encouragement of my loved ones. This game did not require a fully stable knee nor strong physical stamina but a fresh mind, passion, and a professional support team. This game was to complete a PhD in the domain of educational research. This PhD project, with its own joyous moments as well as hurdles, would have never been completed without the support of Almighty God and the guidance of many people who have given me strength, courage, and unfailing help. Therefore, I would like to take this opportunity to thank those to whom I am indebted.

Above all, I would like to thank great God, who granted me good health and the strength to carry out this PhD research, which was full of ups and downs.

I am deeply grateful to my promotor, Prof. Martin Mulder. Martin, you introduced me to a very interesting topic of research that was very new to me at the time. Despite my limited knowledge on technology-enhanced learning environments, you always had faith in my capability and never stopped believing in my potential to carry out and deliver high-quality research in this topic. In order to bridge the gap between my educational backgrounds, you provided me with a wealth of networking opportunities with international academia. You guided me throughout the process of developing confidence and competence as an independent researcher. In our meetings, I have always been impressed with your broad knowledge, diplomacy, inquisitive and creative mind, scientific inputs, uncompromising integrity, enviable ability, and managerial competencies. I would like to express my sincere appreciation for your patience, guidance, encouragement, criticism, and faith. I also will never forget that at a time when I was homesick you invited me to your house and showed me your beautiful hometown. You and your gracious wife even surprised me with a delicious Iranian-Dutch meal, which certainly made me feel at home. Martin, thanks for all your support, kindness, hospitality, and friendliness throughout my PhD project. I am very pleased that I will be able to continue working with you and your chair group and will do my utmost to justify the confidence placed in me by translating your appreciation into high-quality research that will hopefully benefit and be recognised by the learning sciences community.

My sincere gratitude also goes to my co-promotor, Dr Harm Biemans. Let me just make it clear that without your support this PhD project would never have been accomplished. Your friendly personality, good nature, and exceptional sense of humour coupled with in-depth knowledge on learning theories and a critical yet constructive attitude towards educational research make you a perfect example of and a role model for any supervisor of PhD students. Looking back at the first draft of my research, which was not even close to qualifying as a draft, just reminds me of your patience, support, and invaluable contribution to my professional development and learning curve as an independent researcher. When I look at my PhD book I can see your innovative, precious, and brilliant ideas throughout all chapters of the book. Your dedication and timely, detailed, critical yet constructive responses are the most important things I will always remember about our cooperation. Harm, I would like to thank you not only for your scientific contributions but also for your moral support throughout my PhD trajectory. You have not only been a co-promotor to me, but a mentor, and a dear friend with whom I could always share my concerns and worries. I am extremely happy that I will be able to work with you closely after my graduation.

This dissertation has many traces of collaboration with prestigious scholars from other institutes. Of those who helped guide my research, I must first thank Prof. Armin Weinberger. Armin, you cannot imagine how honoured I was to receive your friendly reply in which I learned that the leading expert in the online learning community would be willing to collaborate and share his knowledge with me despite my lack of a track record in this field. You have always impressed me with your passion for international collaboration, reflective scholarship, theoretical inputs, and in-depth knowledge on constructive learning theories. Your creative and innovative ideas reflected in various projects on technology-enhanced learning environments have been well recognised worldwide. Undoubtedly, you are one of the most influential researchers in the learning sciences community and your highly ranked publications have swiftly become fundamental in this field. You have recently built up your own chair group at Saarbrucken University and it is not surprising that it has flourished and become highly productive within such a short time. I am very pleased that you have already given the green light to me for future collaboration.

I am definitely indebted to Prof. Mohammad Chizari, whose unfailing support gave me the strength and courage to continue and press forward. Mohammad, let me just express my deepest gratitude to you for pretty much everything. As a main director, you bridged the gap between my life in professional sports and my work in the academic world. When I was a MSc student under your supervision, you were the one who encouraged me to do a PhD at Wageningen University. I am not sure whether I would be in academia now if I had not had the good fortune to meet you at the start of my graduate studies. You are definitely a role model for many students in Iran, thanks of course to your teaching competences and scientific capabilities, but also to your lovely personality, friendliness, calmness, and sense of humour. Whenever I struggled with scientific or personal concerns, you were there, ready to help solve

my problems and give me hope and encouragement. Dear Mohammad, let me just say that you have been a fabulous supervisor, mentor, and a true friend. Needless to say, I would like to always keep in touch with you.

As a visiting scholar I had the opportunity to work at the prestigious School of Information, University of Michigan, under the supervision of Prof. Stephanie Teasley. Stephanie's influence on this thesis goes further than just the invitation to visit the University of Michigan. Stephanie, during my stay at your chair group, I benefitted tremendously from your intellectual contributions, comments, and suggestions on the theoretical framework and the data analysis for my PhD thesis. You graciously did everything possible to make my stay at Michigan as productive as possible, providing me with many constructive meetings and introducing me to scholars, workshops, and colleagues at the University. With your impressive writing ability, you taught me how to write a scientifically sound yet simple scholarly manuscript. It is no surprise that your scientific contributions, including your published work in the journal *Science*, have already been well recognised in the learning sciences community. Stephanie, I hope my first visit to your chair group will not be the last, because I would love to continue our collaboration in the future.

I am also grateful to the co-author of some of my publications, Dr Cora Busstra, and her colleagues in the Human Nutrition Division of Wageningen University. Dear Cora, I would like to thank you for allowing me to implement my first empirical study in your course. I would also like to express my sincere appreciation for your detailed feedback, constructive and never-ending criticism on the various drafts of the manuscripts, which helped me publish them all in high-quality journals. I wish you continued academic and personal success.

I am grateful to Prof. Arjen Wals, not only for his valuable advice and productive discussions regarding my thesis, but also for allowing me the opportunity to have such joyous moments with young football players at the SKV club. Arjen, I am so thankful that when you learned that I am passionate about football, you invited me to train young players at your club, a great atmosphere for me to learn about Dutch culture. Training and coaching young players also gave me the privilege to entertain myself with a group of equally impassioned and talented people in a sport that I am so enthusiastic about. Arjen, thanks for making my PhD life more enjoyable, and I hope I will again be able to engage in these memorable experiences.

Although working on a PhD is a lonely endeavor, it is also not possible without a fruitful environment full of friendly and lovely colleagues. Dear cordial former and current colleagues at ECS, let me just say *hartelijk bedankt!* for everything to all of you, without mentioning you by name. I am grateful for the many opportunities to drink and eat together and share thoughts and fun. I have already expressed in my propositions how kind, friendly, helpful, supportive, tolerant, and of course critical where necessary the Dutch people are. Dear respected colleagues, over the last couple of years I have learned from your thoughts and ideas and benefited from your advice in informal and formal meetings. I would like to take this

opportunity to thank all of you and tell you that I will never forget these beautiful years working with you at ECS.

I would like to express my deepest appreciation to the ECS deputy administrator, Marja Boerrigter. Dear Marja, my sincere thanks for your timely reactions and friendly yet professional approach in carrying out administrative and financial management duties at ECS. Many thanks for your excellent support and efficient administration, which has made my life easy here at ECS. My special thanks also go to all members of the secretariat team, especially to Marissa and Jolanda, for their friendly, timely, and effective approach in handling the administrative work for my PhD project.

I would like to express gratitude to my Iranian friends and also those from other parts of the world whom I met here in Wageningen. Dear friends, thank you for being there for me and for making me feel at home far away from my country. I very much enjoyed our daily exchange of ideas and thoughts, and the fun moments spent together. Our informal gatherings, parties, camping, cooking, BBQing, and of course friendly football matches are among the events that I will never forget. I do not mention you by name, because the list would be too long and I would not want to inadvertently leave any one of you out.

I would like to thank Catharina de Kat-Reynen, the language editor who edited most of my PhD manuscripts and the thesis itself. Dear Catharina, many thanks for your timely and professional work on my manuscripts. Despite the presence of many variables in my studies you managed to keep the focus of each paper very well. Reviewers have always complimented the quality of the English in the manuscripts, which is an indicator of your good work. I am sure we will be in touch in the future.

My sincere thanks are due to the members of the evaluation committee, Prof. Jeroen van Merriënboer, Prof. Hans Tramper, Prof. Päivi Häkkinen, and Prof. Tammy Schellens for accepting to serve as the opponents and also for constructive advice regarding this thesis. Furthermore, I am grateful to Prof. Jeroen van Merriënboer as well as Prof. Jos Beishuizen, who were my teachers in the ICO Introductory Course. Many thanks for your invaluable hints and detailed suggestions on how to deal with review outcomes, which made me indeed realize the importance of peer-review as a critical part of the functioning of the scientific community, of quality control, and the self-corrective nature of science. Being open to criticism, treating critical comments as constructive, not giving up and getting discouraged when receiving non-favourable reviews are the most important guidelines I will always remember from your class.

There are several other people I would like to thank for their help that enriched this book. Primary among them are methodological experts who provided me with valuable advice throughout all chapters of the book. I am particularly grateful to Dr Hilde Tobi and Dr Jarl Kampen who have always been helpful and willing to assist me with methodological issues. I am also grateful to Steven Collins and Marca Gresnigt for their tremendous technical support

regarding the functionality of the computer-supported platform for this book. I would like to thank those people including student assistants at University of Michigan who have assisted me with coding procedure and data analysis for various chapters of this PhD book.

I am also grateful to the anonymous reviewers and editors of the journals for taking the time to read various manuscripts of this PhD book and for their helpful and valuable comments and suggestions. Their relevant points as well as critical yet constructive feedback have been of great help and have led to significant improvements of various chapters of this PhD book.

The layout and artwork of the PhD book were designed by Ms. Lura Salm, a MSc student at Wageningen University. Dear Lura, I would like to express my sincere appreciation for this design work. I also would like to express my deepest gratitude for your positive thoughts and encouragement as well as unfailing, never-ending, and unconditional support you have given me throughout my PhD trajectory.

These acknowledgments would never be complete without giving special thanks to my family. I am eternally grateful to my parents and siblings for things that I cannot put into words. You truly deserve special mention for your boundless support, dedication, unconditional love, and prayers. I would like to express my admiration and heartfelt thanks for your gentle love and caring, but also for the many sacrifices made to provide me with a good foundation with which to meet life. You are a great model of modesty, persistence, resilience, strength, and determination. Since mere expression of words does not suffice, let me just say that I am extremely proud of you and love you insanely. I am dying to see you all as soon as possible.

Wageningen, January 2013,

Omid Noroozi

Table of Content

Chapter

1

General Introduction

Abstract

Arguing, critical thinking, and logical reasoning are essential objectives in education. Students of all ages need to learn to clearly explain their informed opinions and give reasons for the way in which they carry out tasks and solve problems. Despite the fact that argumentation is shaped in social conversation and also in learners' online exchanges in daily life, learners in academic settings need to be taught to reason and argue in a way that is beneficial for knowledge sharing, domain-specific learning, and argumentative knowledge construction. Online support systems for collaboration or Computer-Supported Collaborative Learning (CSCL) environments in which learners argue in teams have been found to support the sharing, constructing and representing of arguments with the aim of learning. This type of learning arrangement is called Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) and it is seen as a promising environment in which to facilitate collaborative argumentation and learning. The most prominent instructional approach in CSCL that facilitates collaborative argumentation and argumentative knowledge construction is the use of computer-supported collaboration scripts. The conceptualization and operationalization of such scripts and the way in which they manifest themselves in relation to argumentative knowledge construction and domain-specific learning in multidisciplinary problem-solving settings are addressed in this thesis.

Introduction

With the arrival of the knowledge-based era, the swift growth of information and communication technology, and the rapid growth and widespread accessibility of the WorldWideWeb, it is inevitable that professionals in all fields will be confronted with rapidly changing global problems and complex issues. These complexities call for appropriate specialization of domain knowledge in which qualified professionals and experts from different disciplines need to collaborate in new learning and working contexts. This reality has consequences for education, especially for providing students with ample experience working in multidisciplinary groups. Well-designed educational settings have the potential to prepare and train students to become capable and qualified professionals, who can analyse, conceptualize, synthesize, and cope with complex and authentic problems. For example, engaging in collaborative discussion and argumentation is important for students to manage today's complex issues and actively participate in the knowledge society. Engaging in argumentative activities requires students to build arguments and support a position, to consider and weigh arguments and counter-arguments, to test, enlighten, and clarify their uncertainties, to elaborate on the learning materials, and thus achieve understanding about complex ill-structured problems (Aleixandre-Jimenez, 2007).

Despite all the advantages of collaborative argumentation in educational settings (see Van Amelsvoort et al., 2007), telling learners to argue with each other is not a sufficient way to attain collaborative argumentation's potential and hence it does not entirely guarantee successful learning (Baker, 1999; Van Amelsvoort, 2006). Technology-enhanced learning environments such as online support systems for sharing, constructing, and representing of arguments known as Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) have been found to facilitate argumentative knowledge construction and learning. This PhD thesis contributes to the existing body of knowledge in ABCSCL literature by providing an overview of this field and exploring the knowledge construction processes and outcomes in relation to collaborative argumentation. Furthermore, this PhD thesis pays explicit attention to the design and implementation of computer-supported collaboration scripts as the most prominent instructional approach that can facilitate argumentative knowledge construction and learning. This thesis is composed of a systematic literature review and two empirical studies, one of which is an exploratory study in a real educational setting, and the other an experimental study in a laboratory setting, intended to contribute to

the advancement of the use of CSCL systems for facilitation of collaborative argumentation and argumentative knowledge construction with the aim of learning.

Problem statements

Argumentation is an essential aspect of scientific thinking, which is central to the process by which science advances (Kuhn, 1993; Kuhn et al., 2008). Despite the fact that argumentation is shaped in social conversation and also in learners' online exchanges in daily life (e.g. Beach & Doerr-Stevens, 2009), learners need to be taught to reason properly and generate well-established interactive argumentation that is beneficial for collaborative learning in an academic context (see Kuhn, 1991, 1992, 2005, & 2009). There could be several reasons for the need of instruction on how to argue in academic settings. First, learners may ignore or not accept the opposing views of learning partner(s) due to incompatibility with their own ideas on the issue at stake (Jonassen & Kim, 2010). Second, learners typically avoid generating counter-arguments against learning partners(s)' arguments. This could be due to a lack of knowledge about the opposing views (Leitão, 2003) or to a fear of losing face or getting into a fight with the learning partner(s) (Andriessen, 2006). Third, learners may perceive critiques and counter-arguments as personal attacks rather than constructive feedback (Rourke & Kanuka, 2007). Last but not least, learners tend to support their own points of views instead of producing counter-arguments against the opposing views since they think that providing counter-arguments against opponents' arguments make their own arguments less persuasive (Nussbaum & Kardash, 2005; Stein & Bernas, 1999).

Various approaches have been applied in educational settings to facilitate collaborative argumentation by teaching students how to argue properly. The most prominent recent approach is the use of online support systems to scaffold collaborative argumentation. Online support systems allow for scaffolding of critical discourse and argumentation processes by means of a variety of approaches. Examples include graphical design-based approaches to support argumentation process, discussion-based tools to support dialogical argumentation, and knowledge representation tools to support construction of rhetorical argumentation. These types of learning environments are called Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) (sometimes other names for this approach are used such as Computer-Supported Collaborative Argumentation, Argumentative Computer-Supported Collaborative Learning, Computer-Supported Argumentation-Based Learning, Computer-Supported Argumentative Learning, etc.). Many studies have shown the benefits and

advantages of ABCSCL settings in terms of constructing knowledge, knowledge transfer and sharing, gaining a comprehensive understanding, cognitive development, and solving complex problems (e.g. Andriessen et al., 2003; Kirschner et al., 2003; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013).

Despite the use of a variety of instructional approaches available to support collaborative argumentation, students may still have difficulty arguing in rich ABCSCL environments (Van Amelsvoort, 2006; Kirschner, 2002; Van Bruggen & Kirschner, 2003). Firstly, since an argument or the nature of an argument is complex and not linear (Toulmin, 1958), it is not a simple task to broaden and deepen the space of debate during sequential linear discussion (McCutchen, 1987). Secondly, the lack of social context cues such as physical form, accent, tone of voice, eye contact, and group identity may reduce the interest and willingness of learners to discuss and argue, thereby leading to process losses in ABCSCL (Coffin & O'Halloran, 2009). Thirdly, ABCSCL may create an additional burden for learners because of complexities and demanding tasks that are created by instructional requirements (Van Bruggen, 2003). Furthermore, learners rarely respond to one another's points and tend to repeat points already constructed by others (Koschmann, 2003; Veerman, 2003); they may thus refuse to challenge arguments made by their peers (Nussbaum, 2002), resulting in narrow discussions with low quality (Pena-Shaff et al., 2001) and low consistency (Brooks & Jeong, 2006). All these difficulties imply that for facilitation of argumentative knowledge construction consideration must be given to developing influential factors and learning environment facilities that will enable learners to engage in well-established and interactive argumentation which is beneficial for collaborative learning. Therefore, there is a need for investigating factors that influence and constitute the results of ABCSCL.

Another crucial issue in CSCL research for collaborative discussion is the relation between learning processes and learning outcomes. Do successful and less successful students in terms of learning outcomes in CSCL differ with respect to their learning processes and the way they engage in argumentative knowledge construction? Some empirical studies (e.g. Clark et al., 2007a & 2007b; Munneke et al., 2007) have revealed that there are qualitative differences among students in terms of specific aspects of the learning processes and activities in CSCL environments in relation to argumentative knowledge construction. These studies, however, have not explicitly unraveled the differences in learning processes between successful and less successful students in CSCL in terms of performance such as domain-specific learning and argumentative knowledge construction. In-depth analysis of the student learning

processes in relation to the learning outcomes in a CSCL environment could reveal the connectivity between the collaborative argumentation and the actual learning. There is therefore a need for empirical research to reveal the connectivity between student learning processes and outcomes in a CSCL environment.

Furthermore, scientific evidence reveals that difficulties in collaborative argumentation and discussion can be even more problematic in multidisciplinary than monodisciplinary collaborative learning (see Barron, 2003; Noroozi & Weinberger et al., 2012). This is an important issue since for solving many of today's complex problems, professionals need to collaborate and argue in multidisciplinary teams. Although considering a problem from various viewpoints can be productive, multidisciplinary groups do not always produce good problem solutions (Vennix, 1996). For two reasons, multidisciplinary groups of learners may have difficulties engaging in collaborative discussion and argumentation:

First, individual members of multidisciplinary groups need to establish common ground, which is vital to team performance but can be difficult and time consuming to achieve (see Beers et al., 2005). Group members may engage in non-productive discussions of information that may already be known to all members (Stasser & Titus, 1985). As a consequence, some groups may work together for extended periods before actually starting to work efficiently on pooling their unshared knowledge. This outcome is striking since in order for collaborative problem-solving to succeed, group members need to effectively pool and process their unshared information rather than engage in discussion of the information that is already shared among them from the start (e.g. Rummel & Spada, 2005; Rummel et al., 2009).

Second, due to divergent domains of expertise, group members may have difficulties building arguments for and against those being put forward by their learning partner(s); and therefore they may avoid engaging in transactive discussions. In order to make decisions for joint solution(s) in collaborative problem-solving settings, learning partners need to engage in transactive discussion and to critically evaluate the given information from different perspectives on the basis of their domains of expertise (Rummel & Spada, 2005; Rummel et al., 2009) before they reach an agreement and consensus about solution(s). Transactivity is a term derived from Berkowitz and Gibbs (1983) and introduced to collaborative learning by Teasley (1997) meaning "reasoning operating on the reasoning of the other". Transactivity indicates to what extent learners build on, relate to, and refer to what their learning partners have said before. When learners coordinate their interactions by operating on the reasoning of

their peers, they are more likely to elaborate on the learning materials, to take advantage of the knowledge of their partners, and to arrive at a shared understanding (see Teasley, 1997; Weinberger, 2011; Weinberger & Fischer, 2006).

Speeding up the process of pooling unshared information is best achieved when group members have meta-knowledge about the domain expertise and knowledge of their learning partners (Rummel & Spada, 2005; Stasser et al., 1995). This process can be described as developing a transactive memory system (TMS; Wegner, 1987 & 1995). Facilitation of transactive discussions can be best achieved when group members are guided in such a way that they elaborate, build upon, question, construct arguments for and counter-arguments against the contributions of their learning partners in order to reach the shared solution(s) for the learning task (Stegmann et al., 2007; Weinberger et al., 2005a). Taken together, there is a need for empirical research to realize the CSCL system's potential for construction of a TMS and for fostering transactive discussion and argumentation in a multidisciplinary setting.

Computer-supported collaboration scripts are amongst the most prominent instructional approaches that can be used to facilitate coordination of the distributed knowledge and transactive discussion and argumentation in CSCL settings. Various forms of such scripts have been designed as stand-alone instructional tools or scaffolds to guide learners to engage in specific activities in CSCL. Collaboration scripts provide detailed and explicit guidelines for learning groups to clarify what, when, and by whom certain activities need to be executed (Weinberger et al., 2007b). To prevent split attention of the learners, CSCL scripts have often been realized through prompts (Baker & Lund, 1997). Prompts can take the form of sentence starters or question stems and provide learners with guidelines, hints, and suggestions that facilitate the enacting of scripts (Ge & Land, 2004; Weinberger et al., 2005a).

Despite positive effects of various CSCL scripts on the argumentative knowledge construction, these scripts have not all fostered the acquisition of domain-specific knowledge (see Kollar et al., 2007; Stegmann et al., 2007 & 2012). Stegmann and colleagues (2012) show that argumentative scripts demand that learners allocate a considerable part of their time and cognitive capacity to constructing formally adequate arguments, at the cost of operating on contributions of learning partners and jointly elaborating diverse aspects and multiple perspectives on what is to be learned. This is striking, since evidence shows that cognitive elaboration of the learning materials is positively related to knowledge acquisition (see Stegmann et al., 2011; Stein & Bransford, 1979). Facilitating argumentative knowledge

7

construction may, therefore, not only be a question of supporting process categories of argumentative discourse activities, but also of fostering elaboration of the learning materials for enhanced domain-specific knowledge acquisition. There is therefore a need for empirical research to study how scripts can be designed to facilitate argumentative discourse activities in such a way that also foster domain-specific knowledge acquisition in a CSCL setting.

Research questions and overview of the thesis

Up until now, limited attempts have been made to synthesize factors that influence and constitute the results of ABCSCL and thus no overview of this research is available. Therefore, the first aim of this thesis is to provide an overview of this field, synthesize the findings, propose a tentative framework for factors that influence and constitute the results of ABCSCL, and suggest areas in which more research is required. This accounts for the first research question in this thesis that is addressed in chapter 2, which reads as follows: *Based on the current state of the art, what factors influence and constitute the results of ABCSCL?*

In view of this, a systematic search strategy was used based on four concepts that overlap in ABCSCL, namely learning, argumentation, collaboration, and computer support. A wide variety of computerized databases (ERIC, Scopus, Web of science) were searched and the relevant publications selected based on specific inclusion criteria. Furthermore, the snowball method was employed to identify additional relevant publications. Overall, 108 publications (89 empirical studies and 19 conceptual papers) dating from 1995 through 2011 were studied to highlight the foci of the past 15 years. Building on Biggs' (2003) model, the ABCSCL publications were systematically categorized with respect to student prerequisites, learning environment, processes, and outcomes. Based on the quantitative and qualitative findings, a tentative framework is proposed in the second chapter of this thesis consisting of the four interconnected components "student", "learning environment", "learning process" and "learning outcomes", each of which is divided into sub-components in ABCSCL. Furthermore, each of these interrelated components is discussed in relation to various aspects of the learning outcomes in ABCSCL followed by suggestions for future research.

Up until now, the number of empirical studies explicitly examining the relations between learning processes and outcomes for collaborative argumentation and argumentative knowledge construction in CSCL has been rather limited. Furthermore, the majority of the research studies have focused on specific aspects of learning processes in CSCL, and not on a

8

combination of learning process variables. This is a crucial issue since scientific evidence suggests that in order to truly understand the learning that takes place, research on CSCL should be both process-focused and result-focused (Koschmann, 1996; Palincsar & Brown, 1989; Veldhuis-Diermanse, 2002). Therefore, the second aim of this thesis is to explore the relations between learning processes and learning outcomes to reveal the connectivity between the two. This accounts for the second research question in this thesis, which is addressed in chapter 3 and reads as follows: *What are the differences in learning processes between successful and less successful pairs of students in terms of argumentative knowledge construction in CSCL environments?*

In view of this, an empirical study (exploratory nature) was conducted in a real educational setting with 44 students in the field of human nutrition and health at Wageningen University. A pre-test, post-test design was used in this exploratory study. As part of a course "Exposure assessment in nutrition and health research", students were asked (as an individual pre-test) to design and analyse a study which evaluates a certain dietary assessment method. Subsequently, they were asked to discuss their evaluation studies in randomized pairs using a CSCL platform. As an individual post-test, students were asked to re-design and re-analyse the same evaluation study. The students' learning outcomes were assessed based on the quality of knowledge construction in both tests. Moreover, to analyse the students' learning processes in relation to knowledge construction, important aspects of learning processes were taken into account (relevance, correctness, width and depth of discussion, as well as justification and reasoning). The student learning processes and outcomes were reported separately in relation to argumentative knowledge construction. Based on their learning outcomes (quality of argumentative knowledge construction), pairs of students were divided into two subgroups: successful and less successful students. Next, the learning processes of these subgroups were compared. The findings of this exploratory study along with the results of the systematic review were used as guidelines for the design of the computer-supported collaboration scripts in the main empirical study, of which different aspects of the argumentative knowledge construction are presented in chapters 4, 5, and 6 of this thesis.

Based on the literature review and the results of the exploratory study, there seems to be two types of collaborative mechanisms that support group learning: First, effective collaborative learning is related to the process by which students gain meta-knowledge about the domain expertise of their partners and use this knowledge to pool and process unshared information, thus establishing a TMS. Second, effective collaborative learning depends on how students

engage in transactive discussion when they elaborate, build upon, question, construct arguments, and give counter-arguments against the contributions of their learning partners. Computer-supported collaboration scripts are used to facilitate the construction of a TMS and transactive discussions and argumentations since scripts have shown to be a promising approach to orchestrate various roles and activities of learners in CSCL environments. Therefore, the third aim of this thesis is to facilitate multidisciplinary learning using scripts supporting transactive memory and discussion in a problem-solving CSCL setting.

In view of this, an empirical study was conducted in a laboratory setting with 120 university students who were randomly assigned a partner based on their disciplinary backgrounds. Participants were paired so that each partner had a water management disciplinary background and the other had an international development disciplinary background. These partners were then randomly assigned to one of four conditions: transactive memory script, transactive discussion script, both scripts, or non-scripted (control). Learning partners were asked to analyse, discuss, and solve an authentic problem case that required knowledge of both their domains (i.e. applying the concept of community-based social marketing in fostering sustainable agricultural water management). The results of this empirical study are presented in chapters 4, 5, and 6 of this thesis. Specifically, the effects of each respective script on various aspects of learning processes and outcomes in a multidisciplinary CSCL setting are presented separately in chapter 4 (transactive memory script) and five (transactive discussion script). The combined effects of these scripts on respective dependent variables are presented in detail in chapter 6.

Chapter 4 describes how construction of a TMS is essential for learning groups, especially when they are multidisciplinary and collaborate online. The reasoning is that multidisciplinary learners suffer from having little knowledge about how expertise is distributed within a group (Rummel et al., 2009; Stasser et al., 1995) and this lack of knowledge about the partner(s) can negatively affect the exchange and distribution of unshared information and knowledge in the group (see Stasser et al., 2000). Following Wegner's (1987 & 1995) ideas, establishing a TMS in a group involves three interdependent processes: encoding, storage, and retrieval. In collaborative learning settings, group members work best when they first discover and label information and knowledge distributed in the group (encoding), then store that information with the appropriate individual(s) who has/have the specific expertise, and finally retrieve needed information from each individual when performing the task some time later (Rulke & Rau, 2000; Wegner, 1995). Therefore, a transactive memory script is developed to facilitate

encoding, storing and retrieval of information for establishing a TMS in a multidisciplinary setting with the aim of learning. The third research question of this thesis, which is addressed in chapter 4, reads, therefore, as follows: *What are the effects of a transactive memory script on the construction of the TMS, transactive knowledge sharing and transfer, as well as quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?*

As part of the already explained laboratory experiment, 60 university students with different disciplinary backgrounds were assigned at random to a scripted (experimental) or non-scripted (control) condition. Building on Wegner (1987) for establishing a TMS in a group, a transactive memory script was developed that spans three interdependent processes: encoding, storage, retrieval. Chapter 4 of this thesis explains how each of these interdependent processes of the TMS (encoding, storage, retrieval) can be facilitated through the transactive memory script. The extent to which this transactive memory script impacts the construction of the TMS, transactive knowledge sharing and transfer as well as the quality of joint and individual problem solution plans is also presented in chapter 4. Furthermore, the mediating effects of the TMS on the impacts of the transactive memory script on the quality of learners' joint and individual problem solution plans are studied, followed by in-depth explanations for these results, implications, limitations, and recommendations for further research.

Chapter 5 of this thesis explains that facilitating argumentative knowledge construction may not only be a question of supporting process categories of argumentative discourse activities, but also of fostering elaboration of the learning materials for enhanced domain-specific knowledge acquisition. Therefore, alternative instructional information in how to design CSCL scripts is needed if learners are to construct sound arguments and engage in argumentation sequences in such a way as to also benefit from argumentative activities as an approach for enhanced domain-specific knowledge acquisition. Both argumentative discourse activities and also domain-specific knowledge acquisition could be facilitated if learners sufficiently elaborate on the learning materials in a transactive manner when making analyses of the argument(s) being put forward by their partners and constructing arguments that relate to already externalized arguments. Therefore, a transactive discussion script is developed to balance argumentative discourse activities and cognitive elaboration of the learning materials for enhanced domain-specific knowledge acquisition. This accounts for the fourth research question in this thesis, which is addressed in chapter 5 and reads as follows: *What are the effects of a transactive discussion script on the processes and outcomes of argumentative*

knowledge construction, domain-specific knowledge as well as the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?

As part of the already explained laboratory experiment, 60 university students with different disciplinary backgrounds were assigned at random to a scripted (experimental) or non-scripted (control) condition. The design of the transactive discussion script builds on the coding scheme from Berkowitz and Gibbs (1983), which provides an extensive categorization of transactive contributions that have been regarded as important tools for learning (see Teasley, 1997). Accordingly, four types of question prompts (i.e. for argumentation analysis, feedback analysis, extension of the argument, and construction of argumentation sequences) were developed to facilitate argumentative knowledge construction. Chapter 5 of this thesis explains how each of these question prompts can facilitate transactive discussions and argumentations for enhanced domain-specific knowledge acquisition. The effects of this transactive discussion script on argumentative discourse activities (construction of single arguments and argumentation sequences) are presented in chapter 5 of this thesis. Furthermore, the extent to which this transactive discussion script impacts collaborative and individual domain-specific knowledge acquisition as well as knowledge on argumentation is presented in chapter 5 followed by in-depth explanations for these results, implications, limitations, and recommendations for further research.

Chapter 6 of this thesis studies the combined effects of transactive memory and discussion scripts in a 2×2 factorial-design on various aspects of argumentative knowledge construction processes and outcomes. In a multidisciplinary setting, not only meta-knowledge about the learning partners for coordination of the distributed knowledge, that is TMS (Wegner, 1997), but also the extent to which learners operate on the reasoning of their peers, that is transactivity (Teasley, 1997), can be crucial. This accounts for the final (fifth) research question in this thesis, which is addressed in chapter 6 and reads as follows: *To what extent are transactive knowledge sharing and transfer, as well as quality of problem solution plans affected by a transactive memory script, a transactive discussion script, and their combination in a multidisciplinary CSCL setting?*

While chapters 4 and 5 of this thesis study the separate effects of the transactive memory and discussion scripts, chapter 6 presents findings on how these two scripts interact with one another in relation to argumentative knowledge construction processes and outcomes. Therefore, the extent to which these two scripts in combination impact transactive knowledge

sharing and transfer as well as the quality of joint and individual problem solution plans is presented in chapter 6 followed by in-depth explanations for these results, implications, limitations, and recommendations for further research.

Finally, in the last chapter of this thesis the overall conclusions are described and discussed. This chapter opens with a summary of the main findings, followed by discussions of all chapters in concert. Next, the strengths and weaknesses of the studies are discussed along with methodological and theoretical issues. Chapter 7 concludes the thesis by presenting some of the limitations of this PhD research, challenges and recommendations for future research, and implications for theory and practice. Figure 1.1 shows how the five studies reported in chapters 2, 3, 4, 5, and 6 come together along with their corresponding variables. These five chapters of the thesis can be read independently and have already been published as separate articles in international peer-reviewed scientific journals. Furthermore, figure 1.1 gives a summary of the different phases and the main variables of the PhD book.

Overview of the field

Factors that influence learning in ABCSCL based on Biggs' model

Suggestions for future research

Literature review and theoretical framework (CH2)

Transactive memory system (TMS)

Quality of joint and individual solutions

Triangulation between TMS, transactive memory script and solution plans

Transactive memory script (CH4)

Combined scripts (CH6)

Empirical study 2

(Experimental study)

Transactive knowledge sharing

Transactive knowledge transfer

Quality of joint and individual solutions

General discussion (CH7)

Empirical study 1 (Exploratory study) (CH3)

Transactive discussion script (CH5)

Knowledge construction processes

Knowledge construction outcomes

Relationship between knowledge construction processes and outcomes

Argumentative knowledge construction processes

Domain-specific knowledge acquisition
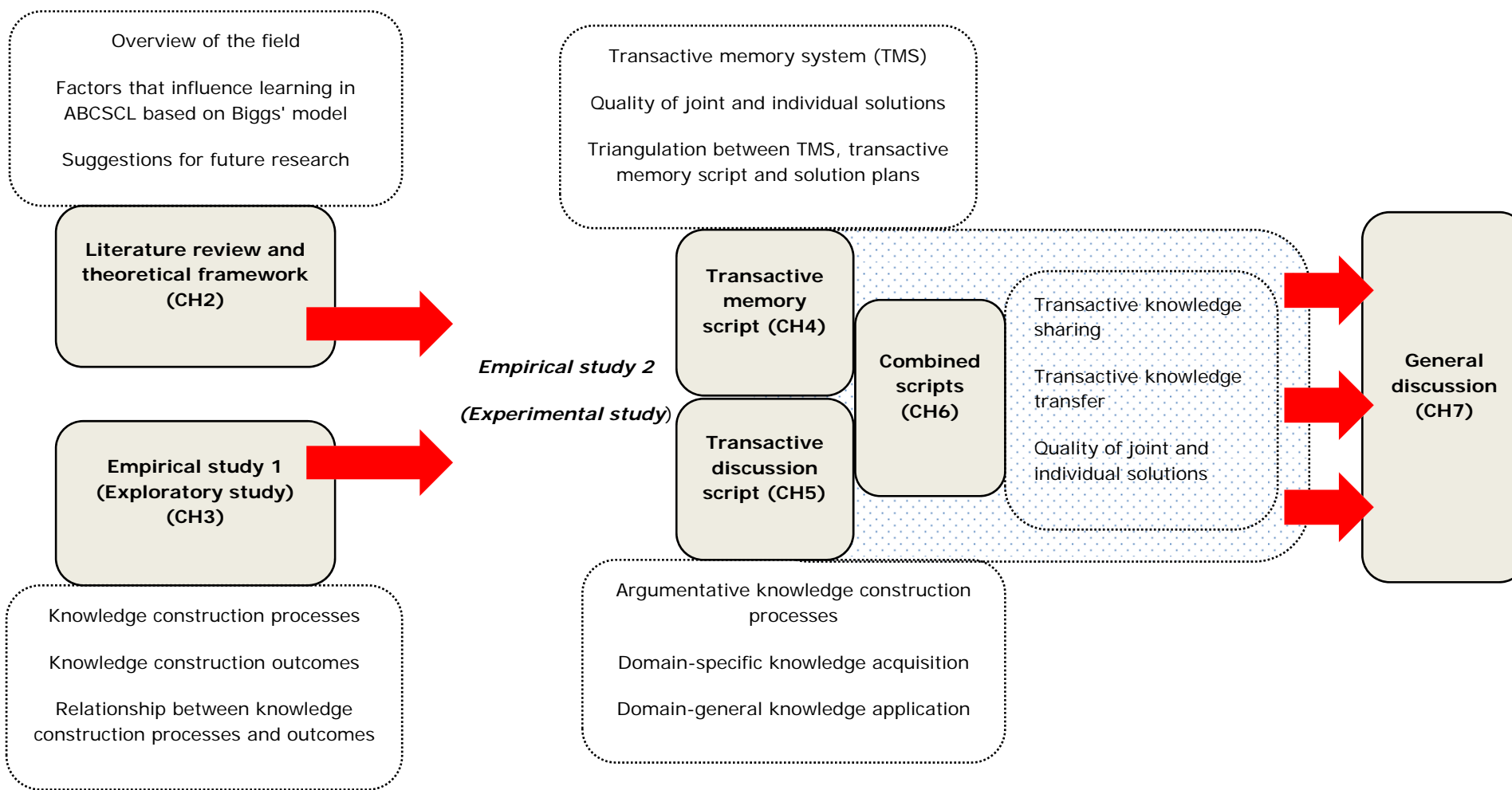
Domain-general knowledge application

Figure 1.1. Core foci of this thesis and the different studies represented by chapter numbers.

Chapter

2

Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL). A Synthesis of Fifteen Years of Research*

Abstract

Learning to argue is an essential objective in education; and online environments have been found to support the sharing, constructing, and representing of arguments for what has been termed Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL). The purpose of this review is to give an overview of this field of research, synthesize the findings, propose a tentative theoretical framework for factors that influence and constitute the results of ABCSCL, and suggest areas in which more research is required. For this review, 108 publications (89 empirical studies and 19 conceptual papers) on ABCSCL research dating from 1995 through 2011 were studied to highlight the foci of the past 15 years. Building on Biggs' (2003) model, the ABCSCL publications were systematically categorized with respect to student prerequisites, learning environment, process, and outcomes. Based on quantitative findings, ABCSCL studies varied in terms of research focus (learning processes and/or outcomes), mode of communication platforms (synchronous or asynchronous), research method (qualitative and/or quantitative), design (quasi-experimental or controlled-based), group size (dyads, triads, small and large groups), educational level (primary or secondary schools or universities), curricula (hard and/or soft subjects), and geographic location with a strong emphasis on western countries. This wide variety shows the importance and growing nature of this body of scholarship. Based on qualitative findings, a tentative framework is proposed consisting of the four interconnected components "student", "learning environment", "learning process", and "learning outcomes", each of which is divided into sub-components in ABCSCL. Furthermore, each of these interrelated components is discussed in relation to various aspects of the learning outcomes in ABCSCL environments followed by suggestions for future research.

Introduction

Arguing, critical thinking, and logical reasoning are essential objectives in education. The ability to argue is a key skill in approaching complex problems as well as in collecting observational data and applying rules of formal logic (Voss & Van Dyke, 2001). Engaging learners in dialogic argumentation in what has been called Collaborative Argumentation-Based Learning (CABLE) is an educational approach for preparing learners to manage today's complex issues and actively participate in knowledge societies (Jeong & Frazier, 2008; Van Amelsvoort et al., 2007). CABLE requires learners to build arguments and support a position, to consider and weigh arguments and counter-arguments, to test, enlighten, and clarify their uncertainties, and thus achieve understanding about complex ill-structured problems (Aleixandre-Jimenez, 2007; Cho & Jonassen, 2002). Although literature reports positive effects of CABLE on a variety of learning mechanisms, telling learners to argue with each other is not a sufficient way to attain CABLE's potential and hence it does not entirely guarantee successful learning (Baker, 1999; Van Amelsvoort, 2006 & 2007).

In the last 15 years, online support systems for collaboration or Computer-Supported Collaborative Learning (CSCL) environments in which learners argue in teams have been found to support the sharing, constructing and representing of arguments with the aim of learning. This type of learning arrangement is called Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) and it is seen as a promising context to facilitate CABLE (Scheuer et al., 2010; Noroozi & Weinberger et al., 2012). Much research has been done in the field of ABCSCL (sometimes using other names for the approach e.g. Computer-Supported Collaborative Argumentation, Argumentative Computer-Supported Collaborative Learning, Computer-Supported Argumentation-Based Learning etc.), but no overview of this research is currently available. Whereas Scheuer et al. (2010) and Clark et al. (2010) provide extensive overviews of the technological environments supporting ABCSCL, this review aims to provide an overview of this field of research, synthesize the findings, propose a tentative theoretical framework for factors that influence and constitute the results of ABCSCL, and suggest areas in which more research is required.

Argumentation

Argumentation is an essential aspect of scientific thinking in education which is central to the process by which science advances (Kuhn, 1993; Kuhn et al., 2008). Argumentation is not

restricted to one discipline and has been the subject of study in various fields, being apparent in linguistics, philosophy, psychology, education, and also recently interdisciplinary domains (Noroozi & Weinberger et al., 2012; Van Eemeren et al., 1987 & 1996). Argumentation has been defined in various ways in the literature. For example, Walton (1992, 1996, & 2006) defines argumentation as a goal-oriented and interactive dialogue in which participants reason together to advance arguments by proving or disproving presumptions. Van Eemeren et al. (1987 & 1996) view argumentation as a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of one or more propositions to justify this standpoint. Merriam-Webster's Online Dictionary defines argumentation as the act or process of forming reasons, making inductions, drawing conclusions, and applying them to the case in discussion. The common characteristic of all these definitions is the use of argumentation as a means to rationally resolve differences of opinion, questions, and issues in critical discussions (Jonassen & Kim, 2010).

Argumentation Theory

Although it is not entirely clear how the fundamentals of argumentation theory have matured over time, the most prominent work on argumentation is built upon Aristotle's theory (Van Eemeren et al., 1996). Aristotle assumed that all knowledge, insights, and opinions that arise in a rational thought are based on existing knowledge, opinions, and insights (Van Eemeren et al., 1987 & 1996). Based on this assumption, he distinguished between various purposes or functions of argumentation including didactic (apodictic), rhetoric, and dialectic (Andriessen, 2006). Didactical argument refers to the foundational structure of knowledge or science, which is self-reliable based on apodictic evidence which could lead to absolutely certain and reliable knowledge (Jonassen & Kim, 2010). Rhetorical argument refers to a dialogue between arguer and a real or imaginary audience with the aim of persuading or convincing others of a claim or proposition that the arguer believes in (Jonassen & Kim, 2010). The most prominent application of rhetorical argumentation was represented in Toulmin's (1958) model, which is based on the "grammar" of argument, by analogy with the syntax of the structure of a well-formed sentence. Toulmin's model is an alternative to the standard interpretation of formal logic for analysing real-world argumentation in natural language.

Despite the influential role of Toulmin's model in the field of argumentation theory (e.g. in the analysis of written argumentation, line of reasoning, and inquiry), the application of this model in collaborative discourse is considered to be problematic. First, one can hardly find

explicit and valid inferences according to the standards of formal logic argumentation (Leitão, 2003). For example, it is difficult to distinguish warrant (which is mostly implicit) from backing. Second, when considering argumentation as collaborative discourse phenomena, Toulmin's model only considers the proponent's side and ignores the role of an opponent in the process of argumentation (Andriessen, 2006). Therefore, the development of multiple perspectives, the pro and the contra, on the topic, which is the fundamental nature of argumentative discourse (Schwarz et al., 2000a), is underestimated in Toulmin's model (Voss et al., 1983). For this reason, the dialectical form of argument known as dialogical or multi-voiced argument has been given more attention than rhetorical argument in the learning sciences. Dialectical argument refers to the situation in which proponents of alternative claims resolve differences of opinions in critical discussions through dialogue by convincing opponents (Jonassen & Kim, 2010) or compromising on multiple claims (Driver et al., 2000).

A variety of dialectical models of argumentation has been introduced in the learning sciences. Sequential-dialectics (Leitão, 2000) describe argumentation as the dynamic macro-level of argumentative dialogue including arguments, counter-arguments, and integrations to promote the construction of valid knowledge in a collaborative discourse. Formal-dialectics (Barth & Krabbe, 1982) view argumentation as a dialogue between a proponent and an opponent around a certain topic. Pragma-dialectics (Van Eemeren & Grootendorst, 1992 & 1999; Van Eemeren et al., 2008) describe argumentation as interaction between two parties to resolve differences of opinion by critically testing the acceptability of the standpoints at issue. Dialogue theory (Walton, 2000) views argumentation as the necessary steps of a dialogue (i.e. persuasion, inquiry, negotiation, information-seeking, deliberation, and eristic) that a proponent and an opponent may follow for reasoning together. The common feature of these dialectical models is that they give just as much weight to counter-arguments as to the original argument. As stated by Osborne (2010, p. 463), "knowing what is wrong matters as much as knowing what is right". This is why dialogic forms of argumentation have been considered to be more applicable in the learning sciences (Jonassen & Kim, 2010) than rhetorical argumentation, which mostly covers areas such as theoretical linguistics, psycholinguistics, and computational linguistics (Taboada & Mann, 2006a & 2006b).

Collaborative Argumentation-Based Learning

Advocates of dialogue theory view argumentation as a means to engage learners in a collective exploration of a dialogical space of solutions (Andriessen, 2006). In this approach,

learning partners are supposed to collectively contribute reasons and evidence from different viewpoints in order to build up a shared understanding of the issue instead of merely convincing or changing their own and each other's attitudes (Baker, 2009; Chinn & Anderson, 1998). This approach is named Collaborative Argumentation-Based Learning (CABLE), which is based on the collaborative value of arguments as a contribution to the dialogue with the goal of learning. Baker (2009) argues that the point of CABLE is not necessarily changing learners' beliefs or attitudes, but rather to broaden and deepen their views and to make them more reasoned and reasonable, which will enable them to understand each other's perspectives. When argumentation is perceived as competitive for learners, it is likely that they will merely engage in what Asterhan and Schwarz (2009) call a "debate-type win-lose situation" in which they try to refute their opponents' views and prove the superiority of their own arguments. Argumentation can effectively contribute to learning when it is not used as an adversarial means for competition and/or for convincing learning partner(s) (Andriessen, 2006; Asterhan & Schwarz, 2009). This approach is supported by literature indicating the positive effects of collaborative argumentation on various learning mechanisms such as reasoning (e.g. Kuhn et al., 1997; Reznitskaya et al., 2001), co-elaboration of new knowledge (e.g. Noroozi & Weinberger et al., 2013), conceptual learning (e.g. Asterhan & Schwarz, 2007), and problem-solving (e.g. Cho & Jonassen, 2002; Noroozi & Teasley et al., in press).

Despite the fact that argumentation is shaped in social conversation and also in learners' online exchanges in daily life (e.g. Beach & Doerr-Stevens, 2009), learners need to be taught to reason properly and generate well-established interactive argumentation that is beneficial for collaborative learning in an academic context (Kuhn, 1991, 1992, 2005, & 2009; Kuhn & Udell, 2003 & 2007). There could be several reasons for the need of instruction on how to argue in academic settings. First, learners may ignore or not accept the opposing views of learning partner(s) due to incompatibility with their own ideas on the issue at stake (Jonassen & Kim, 2010). Second, learners typically avoid generating counter-arguments against learning partners(s)' arguments. This could be due to a lack of knowledge about the opposing views (Leitão, 2003) or to a fear of losing face or getting into a fight with the learning partner(s) (Andriessen, 2006). Third, learners may perceive critiques and counter-arguments as personal attacks rather than constructive feedback (Rourke & Kanuka, 2007). Last but not least, learners tend to support their own points of views instead of producing counter-arguments against the opposing views since they think that providing counter-arguments against opponents' arguments make their own arguments less persuasive (Nussbaum & Kardash,

2005; Stein & Bernas, 1999). All these difficulties imply that when designing CABLE in educational settings consideration must be given to developing certain characteristics that will enable learners to engage in well-established and interactive argumentation which is beneficial for collaborative learning. Various approaches have been applied in educational settings to facilitate CABLE by teaching learners how to argue properly. The most prominent recent approach is the use of online support systems to foster collaborative argumentation.

Argumentation-Based Computer-Supported Collaborative Learning

Over the last 15 years, computer-support systems for CABLE known as Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) have been found to support the sharing, constructing and representing of arguments with the aim of learning. ABCSCL settings have been considered as an important instructional technology aimed at scaffolding and structuring argumentative learning (Jeong & Lee, 2008), fostering in-depth discussions (Andriessen et al., 2003), and thereby helping learners to achieve a deeper understanding and productive arguments (Buckingham-Shum, 2003). ABCSCL systems allow for scaffolding of critical discourse and argumentation processes by means of a variety of approaches (Jeong & Lee, 2008). To support learners in focusing on specific content, argumentation must be framed, scaffolded and guided by external representations (e.g. Belland et al., 2008; Mirza et al., 2007). Many studies have shown the benefits and advantages of ABCSCL settings in terms of constructing knowledge, gaining a comprehensive understanding, cognitive development, and solving complex problems (e.g. Andriessen et al., 2003; Kirschner et al., 2003; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013). A variety of scaffolding approaches (e.g. shared workspaces, game-based learning, awareness features, knowledge representations, scripts) has been developed in ABCSCL settings.

Despite the variety of instructional approaches available, learners may still have difficulty arguing in rich ABCSCL environments (Van Amelsvoort, 2006; Van Bruggen & Kirschner, 2003). For several reasons, the use of ABCSCL does not always lead to productive argumentation and discussion (e.g. Kirschner, 2002). Firstly, since an argument or the nature of argument is complex and not linear (Toulmin, 1958), it is not a simple task to broaden and deepen the space of debate during sequential linear discussion (McCutchen, 1987). Secondly, the lack of social context cues such as physical form, accent, tone of voice, eye contact, and group identity may reduce the interest and willingness of learners to discuss and argue, thereby leading to process losses in ABCSCL (Coffin & O'Halloran, 2009). Thirdly,

ABCSCL may create an additional burden for learners because of complexities and demanding tasks involved in problem-solving activities (Van Bruggen, 2003). Learners rarely respond to one another's points and tend to repeat points already constructed by others (Koschmann, 2003; Veerman, 2003); they may thus refuse to challenge arguments made by their peers (Nussbaum, 2002), resulting in narrow discussions with low quality (Pena-Shaff et al., 2001) and low consistency (Brooks & Jeong, 2006).

Given the aforementioned difficulties and complexities, achieving desired learning processes and outcomes in CABLE requires well-designed ABCSCL settings. These complexities and difficulties can be tackled or at least minimized by taking into consideration various factors that influence and constitute the results of ABCSCL. Ignoring or neglecting these factors can have a negative impact on the quality of learning processes and outcomes in ABCSCL. So far, only limited attempts have been made to synthesize influential factors in the body of ABCSCL scholarship. Therefore, this review provides an overview of this field of research, synthesizes the findings, proposes a tentative theoretical framework for factors that influence and constitute the results of ABCSCL, and suggests areas in which more research is required.

Conceptualizing the Review

A preliminary review of a number of main publications in this field (e.g. Dillenbourg & Hong, 2008; O'Donnell & Dansereau, 1992; Tchounikine, 2008) showed that no specific framework is available for analysing and synthesizing ABCSCL research. Therefore, we selected Biggs' (2003) model of teaching and learning in universities as a frame of reference in this study. Biggs' model consists of the four main categories of analysis of the teaching and learning process in higher education: student, learning environment, learning process, and learning outcomes. These factors are also pertinent for ABCSCL. As students differ, and the ways in which they navigate through ABCSCL environments differ as well, the student was taken as the first category of analysis. ABCSCL is a certain learning environment, and as diverse variations exist, we selected the learning environment itself as the second category of analysis. The learning process is envisaged by the designers of the ABCSCL environments, but the question is whether, and if so to what extent, learners follow that process. Therefore the learning process was taken as the third category. The last category, the learning outcome, is the result of interaction between student, learning environment, and learning process.

Although Biggs created his model independently from ABCSCL, the model is very useful for systematic reviews of educational research (Spelt et al., 2009). In line with Biggs' model, we consider teaching and learning to be an interactive process, whereby the components student and learning environment (presage level) and learning process (process level) determine the component learning outcomes (product level). However, instead of using presage, process, and product as in Biggs' model, we use the terms precondition, development, and product to designate levels in teaching and learning in ABCSCL environments. The components student and learning environment are seen as preconditions that need to be taken into account in ABCSCL (precondition level). Precondition requirements determine the processes and activities that students undertake to accomplish tasks (development level). At this level, students need to discuss and argue in a proper way in order to solve the given task. This argumentation and discussion leads to the learning outcomes in ABCSCL environments (product level). According to Biggs' (2003) model, effective learning takes place in a whole system when all component parts of this system support each other and are interdependent. This is in line with teaching and learning in ABCSCL environments, in which all four components need to be considered as a whole for successful and high-level learning. Such a model emphasizes the interactive nature of learning, which enables curriculum developers to gain a comprehensive understanding of teaching and learning in ABCSCL.

The purpose of this review is to synthesize factors that influence and constitute the results of ABCSCL by clustering them into Biggs's model. Using the outcome-based perspective of Biggs' (2003) theory, four research questions were formulated:

1. Which student conditions that influence ABCSCL have been investigated?
2. Which learning environment conditions that influence ABCSCL have been investigated?
3. Which learning process conditions that constitute ABCSCL have been investigated?
4. What evidence is available regarding the relationship between ABCSCL and learning outcomes?

Method

Criteria for Inclusion

For this review, we adapted a narrative analysis approach to identify current trends in ABCSCL and also to address practical implications and avenues for future research. In

narrative reviews, researchers seek to systematically integrate the state of knowledge concerning the topic of interest and to highlight important issues that research has left unresolved (Van Dinther et al., 2011). Following Slavin (1986), researchers should make the search criteria and the criteria for inclusion explicit regardless of the type of review (e.g. narrative, traditional, best-evidence synthesis). Four inclusion criteria were employed for searching and collecting relevant publications. First, publications were selected for their relatedness to ABCSCL. Second, each had to have been published in a peer-reviewed journal to obtain scientific fidelity. Third, only English publications were employed in this study, since the majority of research on ABCSCL is published in international journals in English. Finally, the time span was restricted to publications from 1995 through 2011, the period in which most ABCSCL research has been produced.

Literature Search

A systematic search strategy was used based on four concepts that overlap in ABCSCL, namely learning, argumentation, collaboration, and computer support. In a first step, we identified synonyms or related terms using Merriam-Webster's Online Thesaurus in combination with the reviews of Scheuer et al. (2010) and Clark et al. (2010). In a second step, we combined the related terms with the Boolean operators OR and the four overlapping concept areas with AND to arrive at the following search string: *Learn** AND *Argument** AND *coll** OR *coop** OR *group** AND *CSCL* OR *online* OR *computer* OR *hypermedia* OR *technology-enhanced learning.* A wide variety of computerized databases was searched, namely Educational Resources Information Center (ERIC), Scopus, the Science Citation Index Expanded (SCI-EXPANDED), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (A&HCI), the latter three of which were provided by the Web of Science® (see Noroozi & Weinberger et al., 2012).

Identification of Relevant Publications

This search yielded more than 300 publications. After screening titles, abstracts, and if necessary the full text of the articles, a number of publications were removed that did not: (1) *address collaborative learning*, i.e. studies focused on computer-assisted/aided/mediated/supported/based instruction and other forms of learning (e.g. digital learning module) in which individuals interacted only with the computer; (2) *address educational purposes*, i.e. studies on online argumentation or discussions with no clear

educational purpose or studies on the use of computer networks for simple chatting and discussions; (3) *investigate learning processes or outcomes*, i.e. studies with a technical focus on educational platforms.

Further screening was carried out to distinguish between publications focused on mere collaborative learning and collaborative argumentation. Since dialogical forms of argumentation could be more applicable than others in educational settings (see Andriessen, 2006; Baker, 2009; Jonassen & Kim, 2010), we included any study in which argumentation was used by learners as a means to collectively resolve differences of opinion in critical discussions through dialogue. Based on theoretical notions of collaborative argumentation, we excluded studies merely focusing on collaborative learning, in which learners only put different parts of the puzzle together instead of contributing reasons and evidence in a collective exploration of possible solutions around the topic at stake. With respect to conceptual publications, we removed publications in which argumentation was not an essential part of the theoretical background or the core of the article was not on instructional support that improves CABLE. Furthermore, since there is both theoretical and empirical evidence for the use of argumentation in non-competitive situations for learners in educational settings (e.g. Andriessen, 2006; Asterhan & Schwarz, 2009; Chinn & Anderson, 1998), we excluded studies in which argumentation was used as a means for competition to convince partners of the superiority of one's own arguments instead of using collaborative values of arguments with the goal of learning.

The identification process was carried out by two researchers independently to guarantee the inclusion of relevant and exclusion of irrelevant publications, resulting in 73 included publications at this stage. The overlap of the two researchers' decisions was sufficient (*Cohen's κ = .85*). The discrepancies were resolved through discussion. In a final step, we applied a snowball method and reviewed the reference lists of the selected publications, which resulted in 35 further publications in peer-reviewed journals to include in the review. We acknowledge that there are also important books, book chapters, and dissertations in this field but we do not know how the review process has been carried out with these publications. Therefore, in the actual review, we included only journal articles that guarantee a high level of quality through the peer review process. However, we consulted books, book chapters, and dissertations (whenever needed using the snowball method) in order to further accumulate the state of knowledge and specific issues in ABCSCL without including them in the quantitative and quantitative analyses. This review is not limited to empirical studies, since the intention

was to support the results of empirical studies with conceptual literature. Focusing on only the educational empirical studies could have yielded an incomplete picture of the state of ABCSCL research. Therefore, conceptual papers in ABCSCL research were included to produce an accurate representation of this body of knowledge under a number of research paradigms. The search strategy and identification process were not limited to a single domain of interest, however, publications related to computer science and its technical aspects were excluded as they had been previously covered in other reviews.

Quantitative Description of Scientific Research into ABCSCL

Applying the systematic search strategy, 108 publications were deemed eligible for inclusion in this review. Eighty-nine of the selected publications provide empirical data on ABCSCL phenomena, while 19 articles are conceptual, focusing mostly (about 90%) on fundamental theories to describe a variety of pedagogical phenomena under examination. The remaining conceptual publications put forward the fundamental theories to describe methodological issues for analysing ABCSCL processes and outcomes. The empirical publications outnumbered the conceptual papers for this review without any manipulation. Empirical articles on ABCSCL are mostly published in peer-reviewed journals, whereas most conceptual and theoretical works in this field are published as books and book chapters. Thus, more empirical articles were likely to be found than conceptual ones as we only included journal publications. A complete list of empirical publications is provided in table 2.1, categorized by author(s); the year reported; participants; educational level; group size; name and functionalities of the platform; and research focus on learning processes and outcomes.

The majority of relevant publications (more than 90%) were published in peer-reviewed journals in the 21st century, largely in recent issues of the journals listed in table 2.2. As expected, the *International Journal of Computer-Supported Collaborative Learning*, *Computers and Education*, and *Computers in Human Behaviour* were on top of the list due to their vast coverage of the focal point of this review. The remaining publications were found in different journals of various disciplines such as educational psychology, technology, development, and research.

Table 2.1: Overview of the various characteristics of the reviewed empirical publications (alphabetically ordered).

Author(s) and year	Participant	Group size	Educational level	Platform	Functionalities of the platform for the study	Research focus
Baker & Lund, 1997	16	Dyad	Secondary	C-CHENE	Structured and dialogue-box communication interface	Reflective interaction, problem-solving
Baker et al., 2007	60	Dyad	Secondary	DREW	Chat and diagram-based argumentative interactions	Argumentative interaction
Beers et al., 2005	51	Triad	University	NTool	Sentence openers, communicative acts, coercion	Negotiation process, common ground
Beers et al., 2007	66	Triad	Secondary	NTool	Sentence openers, communicative acts, coercion	Negotiation, common ground, load
Brooks & Jeong, 2006	30	Dyad	University	Blackboard™	Pre-designed discussion threads, message constraints, labels	Group interaction, group performance
Buder, & Bodemer, 2008	64	Large	University	VisualGroup	Text-based discussion board	Knowledge construction, group/individual learning
Cho & Jonassen, 2002	69	Triad	University	Belvédère	Displaying argumentation process, threaded discussions	Argumentation, problem-solving, essays, performance
Clark & Sampson, 2007	84	Dyad	Secondary	WISE	Personally seeded discussion, pre-structured threads	Argumentation quality and structure
Clark & Sampson, 2008	84	Dyad/Large	Secondary	WISE	Personally seeded discussion, pre-structured threads	Argument discourse, conceptual quality
Clark et al., 2009	147,111	Large/Triad	Secondary	WISE	Seeded/augmented-preset script, pre-structured threads	Quality of argument, participation, post-explanation score
Crossa et al., 2008	28	Dyad/Four	Secondary	BioBLAST	Review-routine steps, answer explanations	Quality of argumentative structures, achievement in science
De Vries et al., 2002	15	Dyad	Secondary	CONNECT	Sequential task procedure, text negotiation, construction	Argumentation, epistemic dialogue
De Wever et al., 2007	140	Large	University	-	Functional roles	Knowledge construction processes
Ding, 2009	6	Dyad	Secondary	PhysHint	Problem/drawing/chatting/answer, hint section	Joint/individual knowledge elaboration
Erkens & Janssen, 2008	69,117	Mixed	Secondary	VCRI	Source, participation, planner, reflector and co-writer tools	communicative functions
Erkens et al., 2005	290	Dyad	Secondary	TC3	Collaborative diagram, chat, writing for argumentative text	Coordination and argumentative acts
Ertl et al., 2005	86	Dyad	University	CoStructure	Collaboration and content scheme scripts	Individual and collaborative outcome
Ertl et al., 2006a	24,86,159	Dyad/Triad	University	CoStructure	Structural visualization, conceptual, socio-cognitive support	Individual and collaborative outcome
Ertl et al., 2006b	150	Triad	University	CoStructure	Collaboration and content scheme scripts	Negotiation process, collaborative outcome
Ertl et al., 2008	159	Triad	University	CoStructure	Structural visualization, collaboration and content scripts	Individual and collaborative outcome
Fischer et al., 2002	32	Dyad	University	CoStructure	Content specific and un-specific visualization graphics tool	Collaborative/individual knowledge transfer/construction
Fischer & Mandl, 2005	64	Dyad	University	CoStructure	Content specific, independent graphical mapping tool	Collaborative/convergence process, knowledge application
Gerber et al., 2005	27	Large	University	Web Forum	Instructor stance (challenging/no challenging)	Interaction quality (reasoned argument)
Golanics & Nussbaum, 2008	141	Triad	University	WebCT	Question elaboration, goal instruction	Argumentative, exploratory discourse
Ho et al., 2009	45	Four/Five	Pre-university	SL and VoR	Structured argumentation, reflection and role-play	Interaction processes
Janssen et al., 2010	124	Mixed	Secondary	VCRI	Graphical/Textual Debate-tool, representational guidance	Argumentation quality and process, knowledge performance
Jeong, 2005	32	Dyad	University	Blackboard™	Message labels/debate, linguistic qualifiers and intensifiers	Group interaction and performance
Jeong, 2006a	31	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Interaction and participation patterns
Jeong, 2006b	32	Dyad	University	Blackboard™	Conversational language, message labels	Argumentation/interaction patterns

Jeong, 2007	54	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Critical thinking process
Jeong & Davidson, 2006	19	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Interaction patterns, participation
Jeong & Frazier, 2008	72	Dyad	University	Blackboard™	Discussion threads, conflict ideas, label message	Critical discourse (argument exchanges)
Jeong & Joung, 2007	38	Dyad	Pre-service	Blackboard™	Pre-structured threads, message constrains, message labels	Interaction and argumentation patterns
Jeong & Lee, 2008	33	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Critical discourse process
Joiner & Jones, 2003	73	Four	University	Blackboard	Communication medium, conflicts of ideas, peer interaction	Argumentation quality, critical thinking
Kim et al., 2007	57	Large	Primary	Web Crossing	Non-threaded discussions, peer interaction	Participation and argument stratagems
Kirschner et al., 2008	99	Triad	Secondary	NTool	Scripting and coercion, negotiation acts	Negotiation, common ground, load
Kollar et al., 2007	90	Dyad	Secondary	WISE	Concept-specific/textual description, input text box	Argumentation processes, general/specific knowledge
Lemus et al., 2004	63	Large	University	Text-based	Peer interaction	Development of argument, right/wrong decision making
Li & Lim, 2008	80	Dyad	Secondary	-	Augmentation and written prompts, questioning/modeling	Inquiry learning
Lin & Crawford, 2007	162	Four	University	Blackboard	Assigning roles (pro and cons), conflict schemes	Group interaction, critical thinking, argumentative writing
Liu & Tsai, 2008	57	Four	University	WBLS	Collaborative discussion boards	Interaction patterns, programming scores
Lu & Lajoie, 2008	14	Large	University	Whiteboard	Argumentation tools, interactive whiteboard diagrams	Quality of discourse argumentation
Lund et al., 2007	36	Dyad	Secondary	JigaDREW	Argumentative diagrams/chat/graphs, multiple tools	Argumentative and debate patterns
Marttunen, 1997	31	Dyad	University	Email	Tutor-led and self-directed seminar modes, peer discussion	Argumentation processes
Marttunen, 1998	31	Dyad	University	Email	Tutor-led and self-directed seminar modes, peer discussion	Argumentation interaction
Marttunen & Laurinen, 2001	46	Four/Large	University	Email	Role play, panel discussion boards, peer interaction	Argumentation processes, argumentation skills
Marttunen & Laurinen, 2007	17	Dyad	Secondary	Web-tools	Collaborative chat, pre-class argumentative lessons	Argumentation processes
Marttunen & Laurinen, 2009	27	Dyad	Secondary	Web-tools	Collaborative chat, argumentative lessons, peer discussion	Collaborative completion, speech acts
McAlister et al., 2004	22	Four/Large	University	AcademicTalk	Dialogue game, structured interface, sentence openers	Argumentation processes
Mirza et al., 2007	9	Large	University	Digalo	Graphical tools, configurable ontology	Argumentative activities
Monteserin et al., 2010	39	Triad	University	SAVER	Isolated arguments, argumentation plans	Argumentation/negotiation process, knowledge acquisition
Munneke et al., 2003	126	Dyad	Secondary	TC3	Representational tools, argumentative collaborative writing	Argumentation and debate patterns
Munneke et al., 2007	175	Dyad	Secondary	TC3	Representational tools, argumentative collaborative writing	Argumentation and debate patterns
Muukkonen et al., 2005	80	Large	University	FLE	Technology tutored and non-tutored	Progressive inquiry discourse
Noroozi et al., 2011	44	Dyad	University	Drewlite	Argumentative tools, diagrams, chat	Interactive discourse, knowledge construction
Nussbaum, 2005	224	Triad	University	Web-CT	Goal instruction, question prompts	Reasoning and argumentation
Nussbaum, 2008b	45	Dyad	University	AVD	Diagrams/AVD training, argument templates, prompts	Argument-counter-argument integration
Nussbaum & Edwards, 2011	30	Dyad	Secondary	AVD	Argumentation via diagrams, critical question prompts	Critical reasoning, practical solutions
Nussbaum & Schraw, 2007	84	Dyad	University	AVD	Graphical organizer, criteria instruction and training	Integrating argument, counter-argument
Nussbaum et al., 2004	48	Dyad	University	Web-CT	Argument templates, note-starters, prompt questions	Argumentative interaction

Nussbaum et al., 2007	87	Triad/Large	University	AVD/Wiki's	Argument diagrams, templates, prompt questions	Argumentative interaction
Nussbaum et al., 2008	88	Dyad	University	Web-CT	Collaborative discussion boards, peer interaction	Argumentative interaction
Oh & Jonassen, 2006	58	Triad	University	FLE3	Scaffolded, threaded and constraint-base discussion board	Individual problem-solving performance
Overdijk & Van Diggelen, 2008	21	Triad	Secondary	Computer	Graphical shared-workspace, diagrams, labelled arguments	Social construction, participation
Prinsen et al., 2006	120	Four	Primary	Web-Forum	Collaborative discussion boards	Quality of participation and interaction
Prinsen et al., 2009	190	Four	Primary	Web-Forum	Collaborative discussion boards	Quality of participation and interaction
Rourke & Kanuka, 2007	12	Dyad	University	-	Collaboration and computer conferencing	Reasoned debate, critical thinking
Schellens & Valcke, 2005	230	Large	University	Web-tool	Collaborative threaded discussion boards, peer interaction	Cognitive processing, knowledge construction
Schellens & Valcke, 2006	300	Large	University	Web-tool	Collaborative threaded discussion boards, peer interaction	Cognitive processing, knowledge construction
Schellens et al., 2007	223,286	Large	University	Web-tool	Collaborative threaded discussion, assigning roles	Process of knowledge construction, final exam scores
Schwarz & De Groot, 2007	10	Large	Secondary	Digalo	Structured inquiry, argumentative ontology and floor control	Reasoning, argumentation components
Schwarz & Glassner, 2007	54	Large	Secondary	Digalo	Argumentative ontology and floor control	Argumentation and interaction quality
Schwarz et al., 2000b	120	Triad	Primary	Belvédère	Collaborative argumentative map, pro-con table	Nature of argument, collective and individual knowledge
Stegmann et al., 2007b	120	Triad	University	Text-based	Input text fields, question prompts	Argumentation process, general/specific knowledge
Strijbos et al., 2004b	80	Four	University	Email	Assigning functional roles	Performance in group processes
Strijbos et al., 2007	49	Large	University	Email	Assigning functional roles	Group performance and collaboration
Suthers, 2001	12	Dyad	-	Belvédère	Text, graph, and matrix, representational guidance	Collaborative learning discourse
Suthers & Hundhausen, 2003	60	Dyad	University	Belvédère	Text, graph, and matrix, representational guidance	Collaborative/individual knowledge construction
Taasoobshirazi & Hickey, 2005	15	Triad	Secondary	Village	Instructional support, peer interaction	Quality of argumentation, curriculum and standards tests
Van Amelsvoort et al., 2007	195	Dyad	Secondary	TC3	Constructed and inspected diagrams, argumentative text	Argumentative patterns and processes
Van Amelsvoort et al., 2008	46	Dyad	Secondary	DREW	Argumentative diagrams, chat, multiple tools	Argumentative knowledge structure
Van Drie et al., 2005a	72	Dyad	Secondary	VCRI	Graphical/textual debate-tool, representational guidance	Historical reasoning process, scores on individual essays
Van Drie et al., 2005b	157	Dyad	Secondary	VCRI	Graphical/textual debate-tool, representational guidance	Collaborative domain-specific reasoning, essays
Veerman et al., 2000	68	Dyad	University	NetMeetin	Reflective peer coaching, structured peer coaching	Structure and quality of the argument
Veerman et al., 2002	14	Dyad	University	Belvédère	Argumentative diagrams, critical question asking	Argumentation process
Weinberger et al., 2005a	96,86	Dyad/Triad	University	Text-based	Input text boxes, epistemic, social script, role-play	Individual knowledge acquisition
Weinberger et al., 2010	72	Triad	University	Text-based	Input text windows for construction of single argument	Argumentative elaboration, general/specific knowledge
Yiong-Hwee & Churchill, 2007	42	Large	University	Forum	Sentence-openers, threaded and visual representations	Quality and construction of arguments

Table 2.2: Overview of the reviewed publication outlet.

Name of the journal	Number of publications
International Journal of Computer-Supported Collaborative Learning	17
Computers and Education	11
Computers in Human Behaviour	10
Journal of the Learning Sciences	8
Instructional Science	6
Computer Assisted Learning	6
Educational Technology Research and Development	6
Learning and Instruction	4
British Journal of Educational Technology	3
Educational Computing Research	3
Contemporary Educational Psychology	3
International Journal of Science Education	3
Other Journals	28

Thirty-seven (of the 89) empirical publications are experimental lab studies. The remaining 52 studies were designed in quasi-experimental field settings with little or no control over the allocation of the treatments or instructional interventions being studied. The majority of empirical studies (59 publications) used quantitative methods to analyse ABCSCL processes and outcomes; only 7 exclusively used qualitative methods (e.g. surveys, interviews and observations), and 23 used both qualitative and quantitative methods. The educational context of the empirical studies varied among students in primary (4 publications) and secondary (29) schools, and students in various levels of university studies (56). ABCSCL is used in different curricula both in hard subjects (30 empirical studies) such as mathematics, chemistry, physics, medicine, and biology as well as soft subjects (59 empirical studies), namely Gamma science such as social science, humanities, psychology, and economics. Fifty-seven empirical publications reported on the learning processes and activities in ABCSCL, only 4 studies focused on outcomes, and 28 publications studied both learning processes and outcomes.

With regard to the size of the learning groups, our review shows that researchers have been mostly investigating dyads of learners (42 empirical studies). In 14 studies, triads were formed to work in ABCSCL, while in 11 studies groups of four, and in 22 studies large (more than four) or mixed groups were investigated. Fifty-two studies used synchronous modes of communication and 37 studies used asynchronous modes. The majority of studies have been conducted in the USA (28 empirical studies) and in Europe such as the Netherlands (21), Germany (11) and Finland (8 publications). ABCSCL has been studied at least once in several

other countries such as France, Belgium, Singapore, Norway, Taiwan, Canada, Argentina, Turkey, and UK. Table 2.3 summarizes these quantitative results in a table format.

Table 2.3: Quantitative data description of the reviewed empirical publications.

Variable	Item	Number of publications	Percentage
Type of publication	*Conceptual*	19	18
	Empirical	89	82
Type of analysis	*Quantitative*	59	66
	Qualitative	7	8
	Mixed	23	26
Subject	*Hard science*	30	34
	Soft science	59	66
Research focus	*Learning processes*	57	64
	Learning outcomes	4	5
	Mixed	28	31
Group size	*Dyad*	42	47
	Triad	14	16
	Four per group	11	12
	Large or mixed groups	22	25
Design	*Quasi-experimental*	52	58
	Control-based	37	42
Educational place	*Primary*	4	5
	Secondary	29	32
	University	56	63
Mode of communication	*Synchronous*	52	58
	Asynchronous	37	42
Country of experiment	*USA*	29	33
	Netherlands	21	24
	Germany	11	12
	Finland	8	9
	Others	20	22

Results and Discussion

Exploration of Research Questions

This step involved extracting factors that influence and constitute the results of ABCSCL and categorizing them into four inter-related components (student; learning environment; learning process; and learning outcomes) based on Biggs' (2003) model (see figure 2.1). The component student can be divided into characteristics brought into the ABCSCL environment by the student, including his or her traits (gender, openness to argue, learning style, willingness to argue, and internal argumentative script), prior knowledge and skills (argumentation and collaboration skills, prior knowledge, and computer skills). Each student has his/her own characteristics that are used for arguing, discussing, analysing, conceptualizing, synthesizing, and concluding while solving learning tasks in ABCSCL. At the precondition level, learning environment addresses situational characteristics in ABCSCL that are set by curriculum developers including resources and settings (learning task, group composition, group size, and CSCL platform) and instructional support (knowledge representations and scripts). At the precondition level, orchestration of successful ABCSCL environments depends on the manipulation of multiple representations of both technological settings and instructional interventions. The development level consists of learning processes (construction of single arguments and argumentation sequences) and activities (learning activities as well as learning activities and scaffolding). Learners approach tasks differently depending on the technological settings and instructional interventions. At the product level, learning outcomes are based on the expected defined goals in ABCSCL. These include knowledge construction, which can be the acquisition of both domain-specific knowledge and domain-general knowledge (e.g. knowledge on argumentation) as well as complex problem-solving. Based on the research questions, components and sub-components of the ABCSCL framework (see figure 2.1) are identified in the following paragraphs.
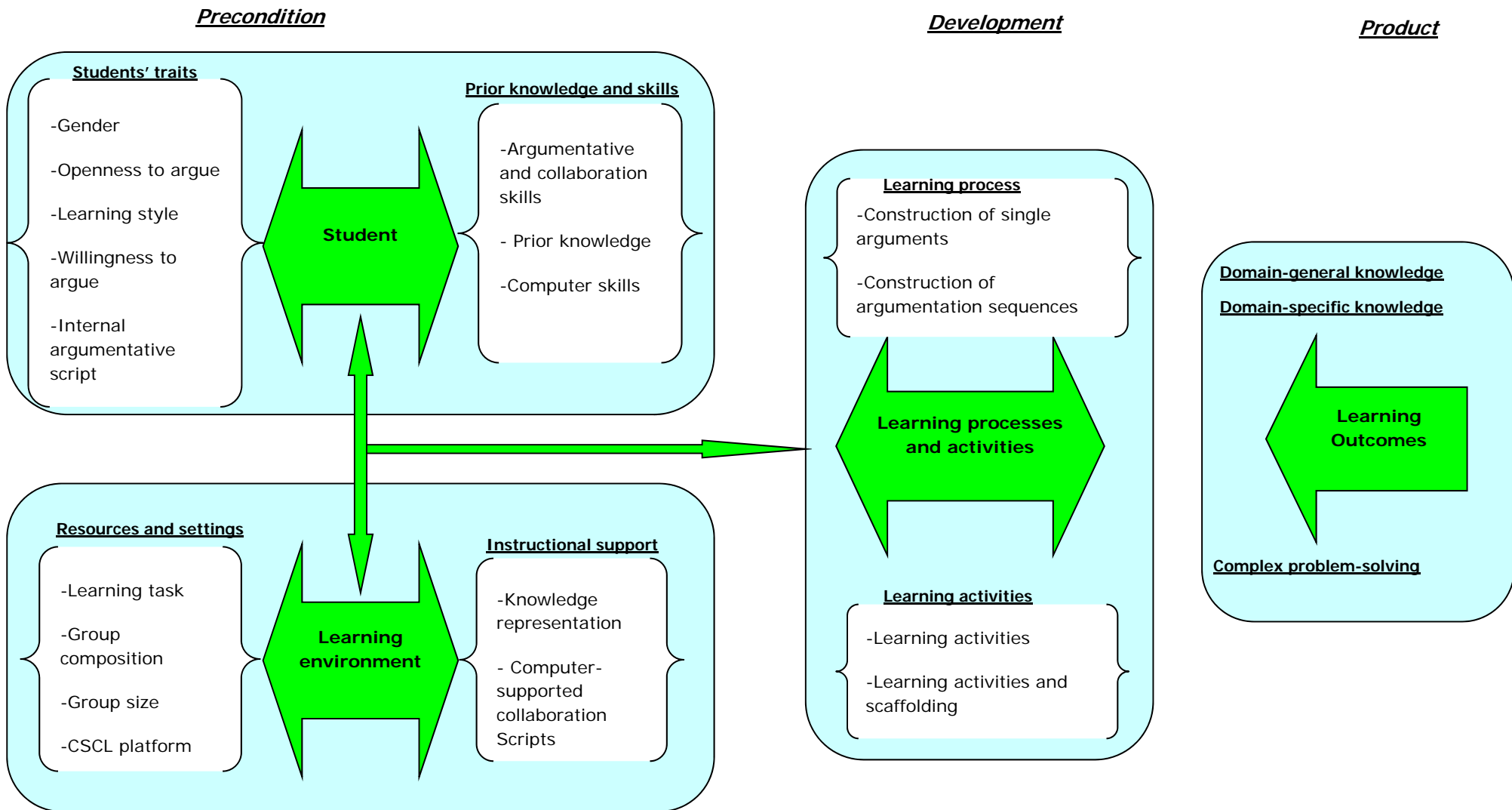
Precondition

Development

Product

Students' traits

-Gender

-Openness to argue

-Learning style

-Willingness to argue

-Internal argumentative script

Student

Prior knowledge and skills

-Argumentative and collaboration skills

- Prior knowledge

-Computer skills

Learning process

-Construction of single arguments

-Construction of argumentation sequences

Learning processes and activities

Resources and settings

-Learning task

-Group composition

-Group size

-CSCL platform

Learning environment

Instructional support

-Knowledge representation

- Computer-supported collaboration Scripts

Learning activities

-Learning activities

-Learning activities and scaffolding

Domain-general knowledge

Domain-specific knowledge

Learning Outcomes

Complex problem-solving

Figure 2.1: ABCSCL framework based on reviewed publications (adapted from Biggs, 2003).

Which Student Conditions that Influence ABCSCL have been Investigated?

This section presents findings that are related to the student in ABCSCL, including students' traits and prior knowledge and skills.

Students' traits. Students' traits in ABCSCL are gender, openness to argue, learning style, willingness to argue, and internal argumentative script.

Gender. There are mixed findings regarding the gender effects on learning processes and outcomes in ABCSCL. Some studies could not find differences between male and female learners in terms of interaction patterns in terms of participation, explanations, and counter-arguments (e.g. Jeong, 2006a), whereas in a study by Prinsen et al. (2009), males participated less than females in terms of number of words per message and elaboration of the responses. In a study by Prinsen et al. (2006), females' messages contained more words and were more "information-requesting" and less "explanation-providing" than males' messages, whereas males disagreed with others more often than females. In another study, males posted nearly twice as many rebuttals in response to critique and disagreements than females (Jeong & Davidson-Shivers, 2006). A study by Erkens and Janssen (2008) showed that females communicate differently than males do: they use more affiliative language (responsive and argumentative dialogue acts), whereas males use more assertive language (informative and imperative dialogue acts).

Openness to argue. Openness to argue refers to the extent to which a learner is curious and open to elaborating on new elements in conversation to foster deeper understanding. In ABCSCL, openness to argue is associated with how and how often learners respond to challenges and disagreements that help them generate deeper and more critical discussions (Jeong, 2007). The level of participants' openness toward argumentation plays a role in how they respond to critique and challenges. There is a connectivity among participants' characteristics (gender, openness to argue, and argumentation patterns) regarding the number of rebuttals sent in reaction to direct challenges. Gender was shown to play a key role in mediating the effects of openness while posting rebuttals in reply to critique (Jeong, 2007). The level of openness had an effect on the number of rebuttals sent in reply to critique of male participants but not of female participants (Jeong, 2007; Jeong & Davidson-Shivers, 2006). Furthermore, the more open male students posted nearly twice the number of counter-arguments than the less open male students, whereas the more open female students posted

fewer personal rebuttals to direct challenges, disagreements, and critique than less open female students (Jeong, 2007; Jeong & Davidson-Shivers, 2006).

Learning style. Learning style is associated with the characteristic affective, cognitive, and psychological behaviour that is a relatively stable indicator of how each learner perceives, interacts with, and responds to the learning environment (Keefe, 1979). There is evidence that learning style could influence the level of knowledge construction in ABCSCL. Having a strategic or deep learning style yielded a higher level of knowledge construction than having a surface approach (Schellens et al., 2007). In a study by Jeong and Lee (2008), students' learning styles affected the quality of critical discourse, process-oriented strategies and critical inquiry. Higher levels of critical discourse were achieved by students with a higher ratio of reflective to active learning styles. A review analysis showed that insufficient attention has been paid to learning styles in CSCL (Gress et al., 2010), and as a result little is known about learning styles in ABCSCL environments.

Willingness to argue. Willingness to argue refers to the extent to which learners approach or avoid arguments (Infante & Rancer, 1982). It is associated with the learners' level of assertiveness, which may determine whether they engage in or avoid critical discussions and arguments (Nusssbaum & Bendixen, 2003). Some learners may be reluctant to oppose and disagree with their peers, while others may not appreciate being challenged themselves (Nussbaum et al., 2004). The less assertive students were shown to engage less in arguments due to the competitive and disagreement aspects of argumentation (Nussbaum et al., 2008). Nussbaum et al. (2008) linked students' epistemological beliefs to specific aspects of argumentative learning, namely problem-solving, interpreting controversial information, and conceptual change related to students' willingness to engage in argumentation. In their empirical study, pairs of students were classified epistemologically as relativists (who perceive knowledge as simple, certain, and fixed), multiplists (who perceive knowledge as subjective and contextual), or evaluativists (who perceive knowledge as verified true belief) in discussions of physics concepts over a web discussion board. Multiplists were less critical regarding inconsistencies and misconceptions and less interactive with their partners than other belief groups, whereas evaluativists were more critical and active in eliciting information from their partners. Evaluativists solved one of the physics problems more accurately while tending to demonstrate fewer misconceptions. In a study by Oh and Jonassen (2006), a negative relationship between simple knowledge and individual problem-solving

performance was found. This implies that individuals who believe in simple knowledge may be less inclined to explore more solution alternatives.

Internal argumentative script. An internal argumentative script (prior procedural knowledge) is a set of knowledge and strategies that determines how a person will act in and understand particular situations such as an argumentative situation (Kollar et al., 2007; Carmien et al., 2007). In ABCSCL, for each individual this procedural knowledge is cognitively structured in the form of scripts based on prior repeated experience with argumentative situations (Kollar et al., 2007). In collaborative argumentation, the approach to measure internal argumentative scripts is based on the inter-individual differences with respect to their degree of structuredness of argumentation (Andrew & McMullen, 2000). For example, as an indicator of a highly structured internal script, some individuals may be good at giving explicit reasonable evidence and reasons in arguments (Kollar et al., 2007); others might know how to attack an argument by creating counter-arguments (Carmien et al., 2007). As an indicator of a poorly structured internal script, some individuals might not be good at backing up their arguments with evidence or examples; others might try to persuade their partner by producing arguments that do not connect to the partner's arguments (Kollar et al., 2007). Internal argumentative scripts are thus very flexible and vary between individuals (Carmien et al., 2007). In contrast, external scripts are embedded in the external surroundings of learners, not in the learners' cognitive system, with the aim of providing learners with guidelines for desired or undesired actions (Kollar et al., 2006). External scripts are likely to be either gradually internalized or they fade over time (Kollar et al., 2007). External scripts can be used in two ways: The first approach aims at the internalization of the externally scripted activities, which helps learners accomplish their tasks by being continuously accessible in the learning environment (Carmien et al., 2007). This has been termed "scaffolding approaches to scripting" (Pea, 2004) or "tools for learning" (Carmien et al., 2007). The second approach uses external aids for better understanding of complex domain concepts or processes, which persuades learners to utilize learned skills without external support being provided through fading mechanisms (Carmien et al., 2007). This has been termed "distributed intelligence approaches to scripting" (Pea, 2004) or "tools for living" (Carmien et al., 2007). Tools for learning can be regarded as tools for living if learners lack the capability to internalize external scripts (Carmien et al., 2007). An internal argumentative script must be taken into account for designing external scripts in ABCSCL. The reason is that internal scripts brought

36

into ABCSCL by different individuals can be complemented only by different external scripts (Carmien et al., 2007).

Prior knowledge and skills. The examined sub-components of students' prior knowledge and skills in ABCSCL are argumentation and collaboration skills, prior knowledge, and computer skills.

Argumentation and collaboration skills. Argumentation and collaboration skills are essential in ABCSCL for learners to assess the strengths and weaknesses of other participants' standpoints (e.g. Marttunen & Laurinen, 2001 & 2009). It is expected that learners with better argumentation skills will use more counter-arguments, produce more alternative perspectives, and engage in more critical thinking and reasoning (Kuhn & Goh, 2005). The lack of prior argumentation and collaboration skills yielded surface levels of communication and argumentation in complex problem-solving designs (Beers et al., 2007). In order to become fully engaged in ABCSCL, learners may need some prior experience with argumentation and collaboration skills. Veerman (2003) stated that less-confident learners sometimes show insufficient engagement in elaborating intricate arguments, since they lack confidence and see themselves as less knowledgeable than others. Learners with low argumentation and collaboration skills and less confidence are afraid that others may refute their opinions, and they therefore hesitate to oppose others' arguments (Andriessen, 2006; Koschmann, 2003). Furthermore, some learners have strong viewpoints but are not able to elaborate them effectively (Andriessen, 2006). A study by Marttunen and Laurinen (2001) revealed that argumentation skills can be promoted by text-based knowledge representation and that practicing develops argumentation skills. Moreover, in practicing academic argumentation via e-mail, the student-led mode was more effective than the tutor-led mode with respect to promoting argumentative dialog skills (Marttunen, 1997 & 1998).

Prior knowledge. Many publications focus on the idea that a lack of or varying levels of prior knowledge about a topic might hinder learners from arguing effectively. Andriessen et al. (2003) contented that "confronting cognitions" (i.e. prior knowledge in peer interaction) affect learning outcomes. They claimed (cited in Schwarz and Linchevski, 2007, p. 512) that "peers may disagree on the solution to a problem as a consequence of their previous different knowledge and accommodate their divergent views to elaborate new knowledge; they may co-elaborate new knowledge through collaboration if their previous knowledge does not engender contradictions; may remain stuck if their previous knowledge is not developed

enough even if they disagree, etc.". To converge various learners' levels of knowledge, additional information about the given task such as presentations and hand-out materials, should be given to learners (Clark et al., 2007a). Having adequate background knowledge of the issue could enhance the quality of collaborative argumentation (Golanics & Nussbaum, 2008). Assessing prior knowledge is important since the concept of ABCSCL is based on the assumption that individuals can take advantage of group processes and knowledge that is supposed to be distributed among partners. Learning partners are seen as additional learning resources when they contribute unshared prior knowledge to the discussion, which may eventually be shared after collaboration (Weinberger et al., 2010).

Computer skills. For working in ABCSCL, learners need a minimum level of computer proficiency, since it likely influences student willingness to work in computer-supported settings. There is not much evidence in the reviewed publications about computer proficiency in ABCSCL. However, in a study by Prinsen et al. (2006), it was concluded that learners' levels of computer proficiency is important in relation to the degree to which they participate in discussions. Rummel and Spada (2005) followed this line of reasoning when excluding learners from their study who lacked minimum technical skills. In some studies (e.g. Beers et al., 2005 & 2007), learners participated in a training and exercise session before starting real experiments in order to maximize the likelihood of success in ABCSCL.

Summary and Critique

There is a small but growing body of research focusing on learners' characteristics in ABCSCL. The results from reviewed publications are not consistent in terms of gender effects on learners' performance in ABCSCL. However, results have consistently shown that women write messages containing a higher number of words and they respond more elaborately, while men post more rebuttals in response to critique and disagreements. A student's level of openness also affects the frequency of posting rebuttals to direct challenges in ABCSCL. Gender and level of openness are thus related in this regard, especially in the sense that more open male learners construct counter-arguments and disagreements more often than less open male learners. Therefore, one should pay attention to the participants' gender while investigating the effects of level of openness on learners' performance in ABCSCL.

Few studies investigated the effects of learners' learning styles on performance in ABCSCL. Learning style was shown to influence knowledge construction, process-oriented strategies,

critical discourse and inquiry (Schellens et al., 2007; Jeong & Lee, 2008). Given the results of those two studies and the fact that each learner has his/her own learning style and strategies to perform in ABCSCL, there is thus a need for more research that systematically addresses how learners' learning styles are related to argumentative patterns. Learners may also differ in their willingness to engage in argumentation. For example, some learners appear to be reluctant to accept their peers and partners' ideas and opinions about a topic, while others may prefer to listen rather than actively participate in discussions and argumentation. There is agreement among scholars that willingness to argue affects how learners engage in argumentative activities while solving ill-structured diagnosis–solution problems. More importantly, different individuals hold different internal argumentative scripts. For some learners it might be an easy task to challenge a peer's arguments through counter-arguments, whereas for others it might be easier to back up their arguments with more reasonable evidence and logical words rather than critiquing their peers. Before scaffolding ABCSCL with external scripts, the current level of argumentative internal scripts of learners should thus be taken into consideration. Researchers agree that learners must have at least a minimum level of collaboration and argumentation skills as well as prior knowledge about the topic to be discussed in ABCSCL. Various approaches (e.g. presentation and hand-out materials, providing guidelines, training and exercises prior to discussion) can be used to compensate for the lack of learners' prior knowledge and skills. Pre-evaluation of learners' knowledge would enable course developers to provide adequate and sufficient training for learners in ABCSCL. With adequate argumentation skills and prior knowledge, learners may still fail to engage in argumentative activities in ABCSCL if they lack enough computer proficiency and skills. Few ABCSCL studies focus on computer proficiency because today's learners are generally expected to know how to work with computers.

Which Learning Environment Conditions that Influence ABCSCL have been Investigated?

This section presents findings for the learning environment condition in ABCSCL including resources and settings (learning task, group composition, group size, and CSCL platform) and instructional support (knowledge representations and scripts).

Resources and settings. The sub-components of resources and settings that have been studied are learning task, group composition, group size and CSCL platform.

Learning task. Various aspects of task characteristics and their impact on learners' performance in ABCSCL have been investigated. An ill-defined task offers learners the chance to explore the space of debate in an extensive and broad way (Van Bruggen et al., 2002 & 2003). In a study by Veerman et al. (2002), a learning task consisting of optimal open-ended questions yielded successful interaction and argumentation patterns. Ill-structured tasks require more interaction processes to establish a common ground than well-structured tasks with a pre-defined solution path. Learners are more likely to engage in argumentative interactions with tasks that require them to discuss their findings and to exchange arguments than with learning tasks that do not explicitly call for argumentation (Erkens & Janssen, 2008). Task complexity needs to be adapted to learners' levels, however. Tasks that are too straightforward and simple can lead to less motivation among students and tasks that are too complex and difficult yield less discussion and a lower level of knowledge co(construction) especially among novice students (Schellens et al., 2007). A topic of discussion which is part of a learning task should be arguable and debatable if learners are expected to express their opinions, ideas, and perspectives through reasoning, elaborating, and arguing (Felton & Kuhn, 2001). Depending on the degree of homogeneity of groups of learners in ABCSCL, topics of discussion should be designed in such a way as to maximize the likelihood of beneficial interactions for collaborative partners.

Group composition. Group composition refers to the homogeneity or heterogeneity of learners in a group based on a variety of learners' characteristics such as prior knowledge, gender, conflict ideas and opinions about the topic, learning style, and epistemic beliefs. Many more studies have focused on the quality of group work and peer interaction patterns in heterogeneous groups rather than in homogeneous ones (e.g. Ge et al., 2000; Spatariu et al., 2007) since it is likely that collaborative partners encounter wider perspectives and resources in heterogeneous than homogeneous groups. This presumably maximizes the likelihood of beneficial interactions for learning (Clark et al., 2007b).

Different criteria have been used for grouping students in collaborative learning environments. Kobbe et al. (2007) suggest that groups can be composed according to independent learners' characteristics (e.g. gender, age, nationality, educational background, prior knowledge) or a particular procedure for group formation mechanisms (e.g. number of students in class, size of group, their combination). A study by Jeong and Davidson-Shivers (2006) showed that group composition in terms of gender influences argumentative activities. For example, females posted fewer rebuttals to the disagreements and challenges of females

than males, and males posted more rebuttals to the challenges of females. Some scholars have categorized learning groups based on educational backgrounds such as knowledge, ability, and achievements (e.g. Liu & Tsai, 2008; Schellens & Valcke, 2005). Ge et al. (2000) contend that placing high-level learners together in a group may hamper their collaboration efforts because they may move quickly to the aspects of the topic that interest them most and neglect the other aspects of the topic that they are expected to elaborate on. A study by Jeong and Lee (2008) found that composing a balanced mix of active and reflective learners enhances the performance of active learners by enabling them to exchange critical messages, whereas their chance of enhancing the performance of critical discussions was not very high in groups with only or mostly active learners. In some studies, groups were composed in terms of differing opinions (a conflict schema approach known as personally seeded discussions) to ensure that multiple perspectives were present within the discussions (Clark & Sampson, 2007 & 2008; Clark et al., 2009). The results showed that personally seeded discussions successfully foster argumentation and therefore knowledge about the topic. In several studies (e.g. Beers et al., 2005 & 2007; Rummel et al., 2009), positive learning outcomes were achieved when groups of students were composed based on divergent disciplinary backgrounds. For example, a study by Rummel and Spada (2005) showed that disciplinary heterogeneous grouping helps learners acquire content-related knowledge during problem-solving activities. Here, dyads of advanced medical and psychology students were composed to jointly diagnose the patients and to develop a therapy plan making use of their complementary expertise. Students indeed benefited from one another's expertise since they could use their partner(s) as a source for clarifications and deepening of knowledge. Establishment of common ground through negotiation is crucial in such groups, however.

Group size. In addition to group composition, group size should be taken into account when designing ABCSCL environments. According to Strijbos et al. (2004a), group size influences group performance and argumentation patterns, since active participation can be much higher and common ground can be established much faster and easier in dyads than in four-person groups. In a study by Schellens and Valcke (2006), higher quantity and quality of knowledge construction as well as a higher degree of involvement were reported within smaller groups of students, whereas higher off-task activities were observed within larger groups (consisting of three or more participants). Theoretically, learners in larger groups could be exposed to a larger variety of arguments. In practice, free-riders can hinder the active participation of some learners in large groups. Furthermore, turn-taking occurs less frequently in larger groups and

41

learners in smaller groups have more time to ask critical questions from their peer(s), which in turn leads to higher levels of knowledge construction.

CSCL platform. Both conceptual (e.g. Arnseth & Ludvigsen, 2006; Hirsch et al., 2004) and empirical (e.g. De Vries et al., 2002; Lin & Crawford, 2007; Overdijk & Van Diggelen, 2008) publications focus on specific aspects of the CSCL platform and their impacts on interaction and argumentation patterns in order to justify the design principles. Strijbos et al. (2004a) suggested the following six design steps: 1) determine the learning objectives, 2) determine the expected interaction, 3) select the task type, 4) determine how much pre-structuring is needed, 5) determine group size, and 6) determine how affordances can be applied to support interaction. One needs to carefully consider the introduction of any new tool taking into account both the requirements of the task and the learning goals (Oh & Jonassen, 2006).

Many platforms have been introduced to support argumentation in ABCSCL. Asynchronous modes of communication (e.g. *ALLAIRE FORUM, KNOWLEDGE FORUM, COLLABORATORY NOTEBOOK, DUNES),* which featured in 46% of the publications in our review, provide learners with a platform for engaging in high-quality argumentative processes (Clark et al., 2007a); fostering task-oriented activities; and constructing well-conceived and accurate arguments (Munneke et al., 2007). Synchronous modes of communication (e.g. *TC3, SENSEMAKER, VCRI, DUNES, DIGALO, DREW, BELVÉD*È*RE, NetMeeting*, *DREWLITE*), which featured in 54% of the publications in our review, provide learners with a platform for coordinating and facilitating task-oriented activities (Noroozi et al., 2011; Janssen et al., 2007); fostering argumentative activities (Clark et al., 2007b); and engaging in deep and elaborated arguments (Munneke et al., 2007; Noroozi & Busstra et al., 2012). In a study by Clark et al. (2007b), asynchronous modes of communication were found to provide all learners with an equal opportunity to construct well-conceived and elaborate arguments, whereas learners using synchronous modes achieved a high degree of integration and construction of arguments and discussions. Furthermore, synchronous discussions in NetMeeting and Belvédère were found to be more argumentative than asynchronous discussions in Allaire Forums (Veerman et al., 2002). Due to the time constraint in synchronous environments, learners may jump to conclusions and ask less elaborate questions, whereas asynchronous environments provide learners with more opportunities for asking elaborate questions in order to attain a profound understanding of the problem (Veerman, 2003; Veerman et al., 2002).

Instructional support. The sub-components of instructional support that have been investigated are external knowledge representations and scripts. These have appeared in conceptual publications (e.g. Kirschner et al., 2004 & 2008) and empirical studies (e.g. Van Drie et al., 2005a). These instructional interventions have been manifested as stand-alone instructional tools or scaffolds to guide learners to engage in specific ABCSCL activities. Examples include constrained message categories with and without labels (Brooks & Jeong, 2006), conversational language (Jeong, 2006b), linguistic qualifiers (Jeong, 2005), buttons with input text fields (Baker & Lund, 1997), question prompts (Ge & Land, 2004), written prompts and argumentation template (Li & Lim, 2008), and argument map (Morgan, 2006).

Knowledge representation tools. A variety of external knowledge representation tools has been proposed to represent argumentation in ABCSCL (e.g. design-based approaches to support argumentation process, discussion-based tools to support dialogical argumentation, and knowledge representation tools to support the construction of rhetorical argumentation). IBIS (Issue-Based Information Systems) as a design-based approach was introduced to support fundamental principles for the design processes of argumentative problem-solving, including three main nodes, namely issue, position, and argument (Conklin & Begeman, 1988). Graphical IBIS (gIBIS) is a hypertext-based environment aimed at supporting and facilitating interactions and arguments between participants for issue-based communication, critical thinking, and solving complex problems (Conklin & Begeman, 1988). Application of the gIBIS model in computer-mediated settings can be seen in study done by Liu and Tsai (2008), who employed gIBIS as an argumentation tool to support small group problem-solving activities. Discussion-based tools provide a less structured and explicit shared workspace such as discussion threads, which allow learners to exchange arguments and maintain a common focus on argumentation by tracing the discussion lines and signalling the different argumentation moves by node types (Van Bruggen et al., 2002). Knowledge representation tools have been implemented in the same instructional elements with a different representational structure. They can be used in a more graphical implementation in the form of schemes (Schwarz & De Groot, 2007), tables (Suthers & Hundhausen, 2003) or visualizations (Ding, 2009; Munneke et al., 2003; Noroozi & Busstra et al., 2012) or in a more textual implementation in the form of cues, prompts, or scripts (Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Weinberger et al., 2007b). When graphical representation tools offer content-specific support by illustrating important aspects of the content (e.g. concept mapping and tabular structure), learners are asked to use the graphical

features as a cognitive tool to modify the representational context for accomplishing the learning task (Ertl et al., 2008). The other form of knowledge representation that has been called "computer-supported collaboration script" offers collaboration-specific support (see Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013).

Various types of knowledge representation tools have been introduced over the last 15 years. For example, whilst Veerman et al. (2002) emphasized the benefits of writing argumentative texts, Van Amelsvoort et al. (2007) compared the role of different external representations (diagrams, matrices, and text). In a study by Erkens et al. (2005), planning tools for writing (a shared argumentation diagram for content generation and a shared outline facility for content linearization) were shown to support the quality of argumentative text. In a study by Van Drie et al. (2005b), there was no significant difference between a graphical representation (argumentative diagram) and a linear representation (argument list) in terms of historical reasoning and outcomes. Matrix users engaged more in talking about historical changes, whereas diagram users engaged more in finding a balance in their argumentation. The expressions of opinion about arguments (for or against) can be increased by using graphs during collaborative activities (Lund et al., 2007). Diagrammatic representations were shown to improve collaborative learning but only when they are designed in such a way that students use them in a co-constructive way rather than individually (Van Amelsvoort et al., 2007). In a study by Ertl et al. (2006a), conceptual support, namely structural visualization and socio-cognitive support were positively associated with learning. In a study by Ertl et al. (2008), learners benefited more from a graphical content scheme than textually represented collaboration scripts. In a study by Janssen et al. (2010), higher-quality construction of essays, better-grounded arguments, and higher quality of knowledge construction were found with the Graphical Debate tool compared with the Textual Debate tool. There was, however, little difference between the two conditions regarding the online collaboration process. In another study, collaboration through chat discussions and argument diagrams not only encouraged students to elaborate their previous arguments but also helped them to recall and create ideas and arguments (Marttunen & Laurinen, 2007).

In a study by Fischer and Mandl (2005), learners benefited more from content-specific than content-unspecific representation regarding both the process of collaborative knowledge construction and the quality of the collaborative solution by using more appropriate knowledge resources without sharing more knowledge after collaboration. Nevertheless, for both groups a low range of knowledge convergence in terms of outcomes was achieved. The

obtained knowledge convergence was lower for factual than application-oriented knowledge. In another study by Fischer et al. (2002), no difference was found in terms of knowledge gain under the two visualization conditions. In several studies by Nussbaum and colleagues (e.g. Nussbaum, 2008b; Nussbaum & Edwards, 2011; Nussbaum & Schraw, 2007; Nussbaum et al., 2007), the effects of Argumentation Vee Diagrams (AVDs) on the quality of students' argumentation, critical discussion, and reasoning were investigated. Compared to a control group, the AVDs not only enhanced the integration of arguments and counter-arguments (i.e. compromises), but also fostered critical discussions and reasoning. They argue that the strength of an argument is a function of how well a counter-argument is approached by refuting, discounting, or accepting, or by proposing a creative solution that eliminates possible objections (see also Nussbaum, 2005 & 2008a; Nussbaum et al., 2008). Well-designed graphical tools for argumentation include evaluating and integrating both sides of an issue resulting in more elaboration of the possible arguments for and against a topic at stake.

In summary, knowledge representation tools help learners clarify their arguments (Van Bruggen et al., 2002), keep their arguments on track (Veerman et al., 2002), argue more effectively while considering all aspects and perspectives of a topic (Suthers & Hundhausen, 2003), illustrate the structure of argumentation by giving a general overview (Schwarz et al., 2000b), broaden and deepen the space of the debate (Van Amelsvoort et al., 2007 & 2008) in order to argue in a more thorough way (Munneke et al., 2007), and discover new relationships, and find patterns of evidence (Suthers, 2001).

Computer-supported collaboration scripts. Scripts are complex instructions that stipulate the type and sequence of learning activities to help group members collaborate and accomplish tasks. Scripts come in different forms (explicit or implicit; graphically embedded in a CSCL tool or included in a teacher's oral presentation; or hand-out materials) (Kollar et al., 2006) and can aim at different aspects of ABCSCL. Collaboration scripts provide detailed and explicit guidelines for collaborative partners to clarify what, when, and by whom certain activities need to be executed (Weinberger et al., 2007b). Epistemic scripts structure and sequence discourse activities with respect to the content and task strategies. Such a script provides guidelines for students to appropriately engage in task-oriented activities. An argumentative script has to do with structuring and formulating the construction of arguments. It provides guidelines for students to construct and formulate better-elaborated arguments with warranting and qualifying claims. A social script specifies and sequences learners' interactions so that they can adopt adequate interaction strategies such as eliciting (asking

critical questions to elicit information from partners) and transactivity (responding critically to partners' contributions) (see Noroozi & Weinberger et al., 2012).

In a study by Schellens et al. (2007), content-oriented (epistemic) scripts facilitated knowledge construction and induced meta-cognitive activities. The communication-oriented (collaboration) scripts facilitated interaction between participants and induced cognitive processes, which in turn influenced the meta-cognitive processes. In a study by Rummel and Spada (2005), collaboration scripts fostered the acquisition of collaborative activities and interaction skills as well as process and outcomes of problem-solving tasks. The results of two empirical studies (Weinberger et al., 2005a & 2007b) showed that epistemic and collaboration scripts facilitate collaborative learning. Students with collaboration scripts engage in more transactive discussions and thus benefit to a greater extent from the external memories available such as contributions of their learning partners (Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Teasley, 1997). In both studies, however, epistemic scripts hindered learners' cognitive engagement and individual knowledge acquisition. In studies by Ertl et al. (2005 & 2006b), collaboration scripts and content-specific schemes were beneficial to collaborative case solutions. However, both scripts had unwanted side effects. The collaboration script reduced the level of learners' content-specific negotiation and the content scheme reduced the level of strategic negotiation.

A study by Stegmann et al. (2007) showed that the argumentative scripts, namely message constraints and labels (i.e. claim, datum, and qualifier) and multiple constraints categories of response sequences (messages were automatically pre-set and labelled as argument, counter-argument, or integration) improved the formal quality of single arguments and argumentation sequences in a synchronous chat environment. However, the acquisition of knowledge on argumentation was facilitated without impacting domain-specific knowledge acquisition. It is likely that learners may have deeply focused on argumentative activities without paying enough attention to the content of the problem cases. Therefore, highly structured process-oriented interventions may cause unintended side effects with respect to the different process dimensions of argumentative knowledge construction (Weinberger & Fischer, 2006).

Conflict schema approaches. A particular class of script known as "conflict scheme" or personally seeded discussions (whereby groups of students with varied conflict perspectives describe the data using their own explanations as the seed comments for the ensuing discussion) successfully fostered argumentation structure, which in turn improved the

students' knowledge gain about the topic (Clark & Sampson, 2007 & 2008; Clark et al., 2009). Furthermore, in a study by Clark et al. (2009), students in an augmented-preset script condition (seed-comments by researchers) outperformed students in a personally-seeded script condition (students' own explanations as seed-comments) in terms of argumentation structure. A plausible explanation is that the optimal diversity of ideas as sets of preset seed-comments were provided by an expert-wise approach in the augmented preset groups and non-optimal diversity sets of seed-comments were provided by students' own explanations.

Scripted roles. Different types of scripted roles have been studied to create structure in ABCSCL and facilitate learning. In studies by Strijbos et al. (2004b & 2007), assigning functional roles resulted in more "task coordination" statements than when no roles were assigned. Functional roles stimulated coordination, which is related to the number of task-content-focused statements. Nonetheless, the number of task-content statements did not change with the increase of "task coordination" statements. Five roles (starter, summarizer, moderator, theoretician, and source researcher) were designed for students by De Wever et al. (2007). The overall conclusion was positive in the sense that students enacted the roles they were assigned without ignoring the activities related to the other roles. Furthermore, assigning roles improved the students' knowledge acquisition; however, it did not increase their level of knowledge construction. For the theoreticians and moderators, no differences emerged compared to the non-scripted groups. Unexpectedly, source researchers achieved a lower level of knowledge construction compared to the non-scripted groups. It was argued that source researchers looked at interesting websites, articles or books but failed to link them to the ongoing discussion or to discuss the supplied external sources. The authors suggested that teachers should clearly explain the roles to students and give sufficient attention to all dimensions. In a study by Schellens et al. (2007) using similar roles, only summarizers achieved higher levels of knowledge construction. Therefore, not all role assignments equally promote knowledge construction since students might get stuck to their pre-assigned roles rather than participate in the ongoing discussion. To reduce the negative effects of having only one special role, rotating roles has been recommended. In a study by Weinberger et al. (2007b), to solve three problem cases, each student had to play two roles: 1) analyst for one of the cases, namely composing initial and concluding analyses as well as responding to critique; 2) constructive critic for two other cases, namely criticizing the case analyst. These roles facilitated social and epistemic activities, as well as individual knowledge construction.

Rotating scripted roles could facilitate learning by preventing learners from getting stuck in their functional roles rather than focusing on task performance.

Prompts and sentence openers. Scripts are often realized through prompts that serve cognitive and meta-cognitive learning purposes. Prompts often take the form of sentence starters or question stems and provide learners with hints and suggestions that facilitate the enacting of scripts (Ge & Land, 2004). Serving different cognitive and meta-cognitive purposes, prompts can be procedural, elaborative or reflective (Ge & Land, 2004). In a study by Nussbaum et al. (2004), the use of prompts (note starters) increased the level of critical discussions, namely the frequency of disagreements. In a study by Yiong-Hwee and Churchill (2007), carefully developed sentence openers resulted in an effective strategy to support students' construction of arguments. In a study by Jeong (2006b), conversational language fostered high levels of critical discourse during the interaction process. Beers et al. (2005 & 2007) employed a process-specific support named NTool to facilitate the negotiation and grounding process. The more coercion was present, the better negotiation of common ground was achieved. Learners in a group need to be instructed on how to negotiate and find common ground in a collaborative task to understand one another and effectively externalize their own and elicit information from the learning partners (Kirschner et al., 2008). In a study by Brooks and Jeong (2006), pre-structured discussion threads with labels were shown to increase the frequency of argument-challenge exchanges needed to initiate critical discourse and trigger further inquiry, which in turn facilitated critical discourse and thinking. However, there was no difference in the number of counter-challenges, supporting evidence, and explanations posted in reply to challenges compared to the control group. In a comparison of constraint message categories (argument, evidence, critique, and explanation), constraint message categories with labels, and no constraint message categories, students in the former group were less likely to criticize other students and react to critique from other students (Jeong & Joung, 2007). Constraint message categories with labels can thus potentially hinder critical argumentation in discourse activities and possibly inhibit learning outcomes.

Summary and Critique

Orchestration of argumentation in ABCSCL builds on multiple representations and instructional interventions. The consensus among researchers is that learning tasks should be neither too simple and artificial, especially for professionals, nor too difficult and complicated, especially for novice learners, to prevent frustration and unintended side effects.

The topic of discussion should be arguable and debatable if learners are to delve deeply and broadly into a topic or solve ill-defined problems. As far as group composition is concerned, researchers unanimously favour heterogeneous groups. The plausible explanation is that each learner encounters a wider range of perspectives and resources in heterogeneous groups than in homogenous groups and this could likely maximize the likelihood of beneficial interactions for learning. There is no agreement among scholars about criteria for grouping learners. While many have grouped learners on the basis of learners' characteristics, recent studies have tended to group learners based on their differing opinions to ensure that multiple perspectives are present and to thus facilitate deeper and wider argumentation and discussion. Grouping learners based on their divergent disciplinary backgrounds to ensure complimentary expertise in multidisciplinary teams is a new and under-investigated trend in ABCSCL. Future ABCSCL research needs to focus on the quality of group work and peer interaction patterns in multidisciplinary groups versus in groups of learners within the same discipline. Quantitative analysis shows that small group size, namely dyads and triads, have been prioritized in ABCSCL research. This is because of the ever-present danger of free-riding and sucker influence in large groups compared to the more active participation, more turn taking, and faster establishment of common ground that is likely in small groups. A relatively large number of publications studied CSCL platforms with different functionalities and modes of communication. To synthesize, ABCSCL demands well-designed, well-scaffolded, and user-friendly platforms that take into account the type of learning task, the level of technology affordances, users' experiences, domain issues, and learning goals.

A synthesis of reviewed publications indicated that when the purpose of ABCSCL is to deepen learners' knowledge or produce productive arguments, writing tasks and argumentative texts could be the most useful (Suthers & Hundhausen, 2003). Diagrams are shown to have the most added value when the intention is to support the argumentative sequence and belief change (Nussbaum, 2008b), to maintain focus and also to broaden and deepen the discussion (Van Amelsvoort et al., 2007 & 2008). When the intention is to include relations to a topic for patterns of evidence, a matrix is considered to be a suitable tool (Baker et al., 2007), whereas graphs are useful for gathering and relating information to elaborate on a topic while keeping learners focused on the relevant aspect of the debate (Baker et al., 2007). In spite of the advantages of various forms of scripts, over-concentration on one specific process-oriented dimension of argumentative knowledge construction was shown to cause unintended side effects related to other process-oriented dimensions. Researchers still

49

need to address when, under what conditions, and which external scripts need to be performed to improve and foster argumentative knowledge construction in all its dimensions.

Which Learning Process Conditions that Constitute ABCSCL have been Investigated?

This section presents findings from publications that are related to the learning process condition in ABCSCL environments.

Learning process. The most frequently investigated sub-components of the learning process in ABCSCL are construction of single arguments and argumentation sequences. In an argumentative dialogue in ABCSCL, learners formulate single arguments (Stegmann et al., 2007) and exchange them in argumentation sequences (Baker, 1999 & 2003; Leitão, 2000).

Construction of single arguments. Construction of a single argument was proposed against Toulmin's (1958) model of argumentation (see Stegmann et al., 2012). From Toulmin's point of view, an argument consists of six interconnected parts: claim, data, warrant, backing, rebuttal, and qualifier respectively. Several researchers concurred that the complexity of the model should be reduced for use as a basis for instructional support (e.g. Stegmann et al., 2007 & 2012; Voss & Van Dyke, 2001). Hence, a simplified version of Toulmin's model was proposed comprising the components claim, grounds, and qualifications. The claim is an expression of the position that is advanced in the argument. The elements datum, warrant, and backing from Toulmin's model all fall within the term grounds. Datum is the factual information that is expressed to support the acceptance of the claim (e.g. observations). Warrant is a rule of inference that justifies the transition from the datum to the claim and reveals the relevance of the data for the claim (e.g. definitions, theories, and rules). Backing is factual information such as reasonable evidence, statistics, or expert ideas that provide a rationale for a warrant. Qualifiers and their interrelated rebuttals have to do with qualifying the relationship between claim and warrant. They both might be used in an argumentative process to limit the validity of a claim. More explicitly, qualifier has to do with expressing a potential limitation and rebuttal has to do with further explanation when the claim is not valid (Stegmann et al., 2007). Hence, based on the formal quality of argumentation, learners' knowledge construction in ABCSCL comprises five argumentative moves: 1) simple claim that refers to statements that advance a position without limitation of its validity or provision of grounds that warrant the claim; 2) qualified claim that refers to the claim without provision of grounds, but with limitation of the validity of the claim (with qualifier); 3) grounded claim

that refers to the claim without limitation of its validity, but with the provision of grounds that warrant the claim; 4) grounded and qualified claim that refers to the claim with grounds that warrant the claim and a limitation of its validity; and 5) non-argumentative moves that refer to questions, coordinating moves, and meta-statements on argumentation. Therefore, in ideal situations, a completely explicit argument would comprise a claim supported by grounds and limited by qualifications (Weinberger & Fischer, 2006).

Construction of sequences of argumentation. Construction of argumentation sequences represents the dynamic macro-level of argumentative dialogue including arguments, counter-arguments, and integrations. The ideal pattern proposed by Leitão (2000) is designed to promote the construction of valid knowledge in a collaborative discourse. Argument is a statement put forward in favour of a specific proposition. Counter-argument is an argument opposing a preceding argument or favouring an opposite proposition. Integration is a statement that aims to balance, integrate, and advance a preceding argument and counter-argument (Stegmann et al., 2007). Another pattern in terms of argumentation sequences by Baker suggests that argumentation is a form of dialogic interaction through which people propose arguments in favour of views and counter-arguments in disfavour of them. As a result of exchanging arguments, counter-arguments, and integrations, generating explicit thoughts, co-constructing new knowledge, and conceptual changes would happen in collaborative discourses (Baker, 1999 & 2003; Van Amelsvoort, 2006).

Learning activities. The most frequently examined sub-components of learning activities are learning activities as well as learning activities and scaffolding. In ABCSCL, learners approach their tasks in different ways depending on various previously mentioned factors at the level of pre-condition, namely student and learning environment. Erkens and Janssen (2008) divided learners' communicative functions into five activities: argumentative (a line of argumentation or reasoning), responsive (confirmations, denials, answers), informative (transfer of information), elicitative (questions or proposals requiring a response) and imperative (commands). Baker et al. (2007) and Van Amelsvoort et al. (2007 & 2008) divided students' activities into seven categories: outside activity, social relations, interaction management, task management, opinions, arguments, and exploration and deepening of activities. This framework points out that students not only engage in discussion and argumentation but also in off-task activities as well as social, interaction, and management activities. In a framework constructed by Weinberger and Fischer (2006), students' activities were divided into four independent dimensions for knowledge construction including

participation, epistemic, argumentative, and social modes of co-construction. The participation dimension refers to the extent to which learners participate and interact, as well as to the heterogeneity of participation, namely the (un-)equal participation of learners in the same group. The degree to which learners participate in discussions (number of words) and also the quality of interaction (elaboration of the responses) are positively associated with the learning (Prinsen et al., 2009; Schellens et al., 2007). In the epistemic dimension, students' activities have to do with construction of both problem case and conceptual space that support the understanding of the problem and the theory through relating theoretical concepts with case information and prior knowledge. In the formal argumentative dimension, micro-level activities (construction of single arguments) and macro-level activities (construction of sequences of argumentation) can be identified. In the social dimension, the extent to which learners base their reasoning on the reasoning of their partners can be analysed through different social modes (Weinberger & Fischer, 2006). Nevertheless, according to Kobbe et al. (2007), in every independent dimension, more coarse-grained or greater activities (discussion) can be decomposed to more fine-grained or lesser activities (elaborations, explanations, question asking, etc.). More fine-grained activities (asking specific questions or checking a report for mistakes, etc.) can be subsumed in more coarse-grained activities (help seeking).

Learning activities and scaffolding. Neither argumentation nor scaffolding in ABCSCL are limited to a linear sequence of activities and patterns. Both argumentation sequences and scripts may demand a series of sequential provisions that may need to be tackled through a sequence of activities with loops and branches (Kobbe et al., 2007). *Traversion* (allowing students to follow a series of the same activities with different sets of data while only one element is tackled at any given time), *rotation* (allowing students to engage in each activity by changing the order of elements in a given set), and *fading* (allowing students to work with scaffolding that is gradually increased "faded in" or decreased "faded out") are three common sequencing patterns in ABCSCL (Kobbe et al. 2007).

Depending on the degree of scaffolding, students' activities in ABCSCL might be different. For example, students with the Universanté Script (see Dillenbourg & Jermann, 2006) are supposed to follow activities such as a) analysing and elaborating the case; b) summarizing and explaining; c) analysing, comparing, and relating new information to prior knowledge; d) giving feedback and critiquing; and e) problem-solving. ABCSCL prompted with the ArgueGraph Script (Dillenbourg & Jermann, 2006) demands activities such as a) justifying opinions and constructing arguments; b) comparing, evaluating, and elaborating; c)

negotiating and constructing arguments; d) explaining and justifying opinions; and e) summarizing and making connections. ABCSCL scaffolded with a peer-review script (see Weinberger et al., 2005a) encourages students to engage in activities such as a) applying theoretical concepts to cases and constructing arguments; b) critiquing, initially scaffolded with prompts for eliciting clarification, identifying conflicting views, and constructing counter-arguments. ABCSCL scaffolded with epistemic scripts encourages learners to focus on a specific task for applying concepts and knowledge to the problem case (Clark et al., 2007a). ABCSCL scaffolded with argumentative scripts encourages learners to engage in activities that broaden and deepen their arguments (Weinberger et al., 2007b) by warranting, qualifying, or arguing against proposed solutions with reasonable and logical evidence.

Summary and Critique

Different variables in terms of learning processes and activities in ABCSCL have been investigated over the last 15 years such as interaction patterns, participation, epistemic, argumentative, and social activities, negotiation process, coordinating processes, group interaction patterns, knowledge (co)construction, as well as historical and critical reasoning processes. The central focus with respect to the learning process has been given to the construction of single arguments and argumentation sequences. The construction of a sound single argument (Baker, 2003; Spiro & Jehng, 1990) and argumentation sequences (Leitão, 2000; Stegmann et al., 2012) are presumably related to cognitive processes that may foster argumentative knowledge construction (Stegmann et al., 2012; Weinberger & Fisher, 2006). Not only the construction of single arguments but also their sequential patterns in ABCSCL can differ. Andriessen et al. (2003) argues that divergent positions or incompatible views while constructing counter-arguments could potentially induce socio-cognitive conflicts. Leitão (2000) in response argues that a counter-argument is not necessarily against the initial argument. A counter-argument could be an argument that makes the acceptability of the initial position less certain without actually opposing the initial argument. It could also represent different viewpoints on the same issue and hence widen and broaden the space of debate. Thus, a counter-argument would not always induce socio-cognitive conflicts. Furthermore, even if such a conflict occurs while counter-arguing, it could be resolved during the integration process (Nastasi & Clements, 1992) when learners elaborate and compare various possible perspectives, and decide upon the most likely solution (Stegmann et al., 2012).

The conclusion in terms of learning activities is that learners approach tasks differently depending on the technological settings and instructional interventions. Depending on the learning objectives in ABCSCL, various instructional strategies could be used to help learners construct better-elaborated, wider and deeper arguments, to keep learners' activities on the right track, and also to achieve the expected learning purposes and outcomes. There is a consensus among scholars that engaging in more relevant, sound, and on-task activities (e.g. Buder & Bodemer, 2008), making better-elaborated and justified contributions to discussions (e.g. Noroozi et al., 2011) and making broader and deeper arguments (Crossa et al., 2008; Noroozi et al., 2011), lead to better-quality learning than engaging in off-task activities and contributing less-elaborated and justified and more narrow and superficial discussions.

Which Evidence is Available on the Relationship between ABCSCL and Learning Outcomes?

Over the last 15 years, a growing body of research has shed light on the various forms of learning outcomes in ABCSCL. Some studies have reported the benefits of ABCSCL in terms of facilitation of conceptual understanding (e.g. Clark & Sampson, 2007 & 2008), cognitive and meta-cognitive development (e.g. Cho & Jonassen, 2002), as well as interaction and argumentative skills (e.g. Marttunen & Laurinen, 2001 & 2009; McAlister et al., 2004). Other have shown the benefits of ABCSCL in terms of problem-solving (e.g.Kirschner et al., 2003; Lemus et al., 2004; Lu & Lajoie, 2008; Noroozi & Teasley et al., in press), critical thinking, reasoning, and higher-order skills (e.g. Kim et al., 2007), as well as domain-general and domain-specific knowledge construction (e.g. Noroozi & Weinberger et al., 2013; Weinberger et al., 2005a & 2007b). The prominent learning outcomes in ABCSCL that have been investigated are acquisition of domain-specific and domain-general knowledge as well as complex problem-solving.

Acquisition of domain-general and domain-specific knowledge. Knowledge acquisition is one of the most important learning outcomes of ABCSCL. Both conceptual (e.g. Weinberger & Fischer, 2006) and empirical (e.g. Gerber et al., 2005; Muukkonen et al., 2005; Taasoobshirazi & Hickey, 2005) publications indicate that participation and interactions in ABCSCL can lead to knowledge construction. In ABCSCL, learners engage in specific discourse activities to elaborate on the available learning materials, to express their viewpoints and also to react to learning partner(s)' perspectives, resulting in an interactive argumentation which is beneficial for acquiring both domain-specific and domain-general knowledge (see Weinberger et al., 2005a & 2007b). ABCSCL has been used by a

considerable number of scholars to acquire domain-general knowledge, namely knowledge on argumentation (e.g. Baker et al., 2007; Clark & Sampson, 2007 & 2008; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013). ABCSCL research has also shown positive impacts on domain-specific learning including declarative, procedural, conceptual, cognitive, and meta-cognitive knowledge construction (e.g. Ho et al., 2009; Cho & Jonassen, 2002). Some researchers (e.g. Noroozi & Weinberger et al., 2013; Stegmann et al. 2007 & 2012) found positive relationships between the construction of sound (micro-level) and complete (macro-level) arguments with cognitive elaboration processes and hence knowledge acquisition. As assumed by Baker (2003), argumentation-related cognitive processing in argumentative discourse is positively related to formal quality of argumentation and acquisition of knowledge on argumentation (Stegmann et al., 2012).

Complex problem-solving. Another learning outcome of argumentation activities in ABCSCL is knowledge that can be applied to solve complex and ill-defined problems (e.g. Janssen et al., 2010; Monteserin et al., 2010). Interacting with one another and being involved in various activities (e.g. social, epistemic, and argumentative activities), learners could both individually and collectively (co)construct knowledge in ABCSCL environments while elaborating learning materials in problem-solving activities (e.g. Baker et al., 2007; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Weinberger et al., 2005a).

Summary and Critique

Scholars in the field of ABCSCL research concur that engaging in various forms of argumentative activities can facilitate acquisition of knowledge on argumentation and domain-specific knowledge that could be applied for complex and ill-defined problem-solving. Moreover, ABCSCL can promote higher-order thinking and problem-solving, and thus, can lead to deeper understanding of the topic (e.g. Van Bruggen & Kirschner, 2003). The results of this review's quantitative analysis, however, indicate that only one-third of reviewed publications investigated the learning outcomes in ABCSCL as such. Studies that do not report on outcomes seem to be based on the assumption that learning processes and activities determine the quality of learning outcomes in ABCSCL. In this view, facilitating ABCSCL processes will improve the quality of learning outcomes as well (see Noroozi et al., 2011). This review study seems to confirm such a relationship. For example, studies by Jeong and Davidson-Shivers (2006) and Jeong (2007) showed that gender (student level) could play a key role in mediating the effects of openness (student level) while posting rebuttals in reply

to critique (learning process), which in turn were shown to lead to higher quality of knowledge construction as can be seen in the learning outcomes (Weinberger et al., 2005b & 2007b). Furthermore, less open and curious learners (student level) showed a higher quality of knowledge (learning outcome) by showing more disagreement (learning process) when note starters were prompted (learning environment) compared to students who were more curious, anxious, and assertive (Nussbaum et al., 2004). To develop a more prescriptive model, future research would have to be organized not by factor but by factor-factor pairings (e.g. student-learning outcome, learning environment-learning process, learning environment-learning outcome, student-learning process etc.). Such research would not only help us understand the nature of these relationships, the optimal combination of conditions, the influence of one factor on another and the stability of such an influence, but also lead to a further understanding of what and how ABCSCL can be designed more effectively.

Conclusion and Directions for Future Work

This paper demonstrates that the design of ABCSCL environments requires a systematic approach that takes the variety of specific conditions for learning into account. Biggs' model provided a way to categorize similarities in reported studies despite the different foci. A framework was proposed here by clustering various influencing and constituting factors in ABCSCL that have been investigated over the last 15 years. This framework consists of the four inter-connected components, namely student, learning environment, learning process, and learning outcomes, each of which is divided into sub-components for pedagogic and design decisions related to teaching and learning in ABCSCL (see figure 2.1).

The quantitative analysis of 15 years of research into ABCSCL revealed that empirical publications outnumber conceptual ones, since scholars have been mostly interested in testing instructional interventions for ABCSCL. This is what we expected since conceptual publications with theoretical backgrounds can be mostly found in books and book chapters rather than journal publications. Our analysis showed that ABCSCL has not only been designed for controlled laboratory studies but also for quasi-experimental field settings that require argumentative skills in science education. Quantitative studies outnumber qualitative studies, which indicates a further need for qualitative analysis methods in ABCSCL. The educational context of the reported empirical studies varied in terms of educational level (primary and secondary schools and universities), curricula (both hard and soft subjects) and geographic location; however, there was a strong emphasis on western countries. This wide

variety shows the importance and growing nature of this body of scholarship in the 21st century. A limited number of publications reported on both learning processes and outcomes, whereas most publications in ABCSCL reported on learning processes and activities. The reason is that differences in learning outcomes result from differences in learning processes (see Noroozi et al., 2011). Therefore, in order to improve student learning outcomes in ABCSCL, explicit attention needs to be paid to the nature of the students' learning processes. Nevertheless, since direct practical relevance would only be achieved by looking at the learning outcomes in relation to learning processes and activities, we advise that future research in ABCSCL be aimed at revealing the differences in the learning processes and activities between successful and less successful learners in terms of learning outcomes. So far, small group sizes (dyads and triads) have been prioritized in ABCSCL, and the selection of group size has depended on the learning goals, time constraint, complexity of the learning task, and the technological design. Almost equal attention was paid to synchronous and asynchronous modes of communication since each has advantages and disadvantages.

One focus of ABCSCL research in the last 15 years has been on the role of external knowledge representations and various collaboration scripts. The structure of scripts for collaborative learning differs. While some researchers provide rather rough guidelines for specific activities, sequences, and roles, others may provide highly structured scripts, including detailed instructions for learners regarding what activities should be carried out, when, and by whom (Kollar et al., 2007). There is a need for more empirical research to investigate the interplay between internal and external scripts. The ongoing research aims to find the optimal balance between students' external and internal scripts in order to avoid the disadvantages of over-scripting (Carmien et al., 2007). Some evidence shows that highly structured scripts have resulted in better learning outcomes than less-structured scripts (Beers et al., 2005 & 2007). Nonetheless, overly detailed scripts or "over-scripting" has also been questioned (Dillenbourg, 2002; Tchounikine, 2008). Based on lessons learned from ABCSCL research, scripts could be faded out to avoid cognitive overload in overly scripted collaborative tasks (Kester & Paas, 2005; Dillenbourg, 2002; Jermann & Dillenbourg, 2003). One under-investigated question is how detailed and specific external scripts need to be in order to prevent frustration among students through over-scripting. Also how, when, and under what conditions should external scripts be faded out to avoid over-scripting, prevent frustration, and foster internalization of external scripts in ABCSCL. Overly rigid scripts would inhibit and spoil the richness of natural interaction, whereas overly flexible scripts

would fail to elicit the intended interaction (Dillenbourg & Tchounikine, 2007). The ongoing research focus is to determine the extent to which learners can internalize and stabilize external scripts over time taking into account their internal scripts. For how long, in what way, and under what conditions do learners need to interact using external scripts to internalize them without becoming over-scripted?

Previous research shows that various forms of collaboration scripts positively facilitate the specific activities they were aimed at (e.g. Stegmann et al., 2007 & 2012). However, in some cases unwanted side effects were found (e.g. Ertl et al., 2005 & 2006b). Providing learners with specific external scripts might cause them to deeply focus on the specific activities which are aimed to be facilitated without paying enough attention to other dimensions of collaborative argumentation with the goal of learning. Therefore, we advise that further studies be aimed at identifying the optimal combination of various external scripts while avoiding unwanted side effects.

Our review revealed that over the last 15 years considerable attention has been paid to the nature of instructional interventions in monodisciplinary teams, but only few studies have dealt with multidisciplinary teams in ABCSCL environments. More research needs to be done to compare the effectiveness of various instructional interventions in groups made up of members from the same discipline and in groups made up of member from differing disciplines. Multidisciplinary thinking is gradually becoming a major research theme in ABCSCL since grouping of learners based on different disciplinary backgrounds could help them integrate knowledge of two or more disciplines for solving complex problems. It would be a worthwhile endeavour to develop and introduce a set of scripts that could help multidisciplinary learners promptly pool and process their unshared information through establishment of a transactive memory system, and then help them engage in critical and transactive discussions aimed at reaching consensus for their joint solutions. This would also help researchers improve the technological settings and instructional strategies in multidisciplinary groups in ABCSCL environments, and thereby make the best use of learners' complementary expertise.

This literature review built on a renowned conceptual framework involving essential aspects of teaching and learning (Biggs, 2003). It is intended to contribute to a growing body of knowledge on designing ABCSCL environments. This review covered a selected time span, language, variety of relevant databases, and adopted a search strategy that provided a

sufficient representation of research carried out in this field in the last 15 years. In our review study, however, we did not report the effects of various forms of instructional support and interventions on the various components of the learning outcomes in ABCSCL. It would be insightful if another literature review focused on the empirical evidence to report the (intra) relationships between instructional interventions and learning outcomes in order to demonstrate the interactive nature of components within teaching and learning in ABCSCL. Future research therefore could focus on in-depth quantitative meta-analysis on the topic to examine how, under which conditions, and which instructional interventions in ABCSCL directly determine various components of learning outcomes within the proposed framework. This would enable researchers to draw conclusive conclusions on whether and how a particular type of intervention has a real effect on the intended dependent variable. Furthermore, future research studies could aim at answering specific questions with respect to each particular dimension of argumentation-based learning. For example, future review studies should categorize and then analyse ABCSCL publications on the basis of their argumentation focus (e.g. quality of single argument, argumentation sequence, reasoning, argumentative discourse, and interactions) to draw conclusions on the effects of collaborative argumentation on various types of learning achievements: problem-solving, knowledge construction, higher order skills, learning of subject contents, etc. This would help us understand how collaborative argumentation leads to learning in ABCSCL environments.

Acknowledgments

Chapter

3

Differences in Learning Processes between Successful and Less Successful Students in Computer-Supported Collaborative Learning*

Abstract

This study explores the differences in learning processes between successful and less successful pairs of students in Computer-Supported Collaborative Learning (CSCL) in the field of human nutrition and health. As part of the course "Exposure assessment in nutrition and health research", which is compulsory for MSc students of nutrition and optional for BSc students at Wageningen University, 44 students were asked (as an individual pre-test) to design and analyse a study which evaluates a certain dietary assessment method. Students were asked to discuss their evaluation studies in randomized pairs using a CSCL platform. As an individual post-test, students had to re-design and re-analyse the same evaluation study. The quality of students' knowledge construction in both tests and characteristics of their learning processes were assessed. Based on their learning outcomes (quality of knowledge construction), pairs of students were divided into two subgroups: successful and less successful students. Next, the learning processes of these subgroups were compared. This study revealed that the learning processes of successful and less successful students in the CSCL environment differ in terms of relevance, width and depth of discussion, as well as justification and reasoning. Based on these findings, recommendations for further research and educational practice are formulated.

Introduction

In Computer-Supported Collaborative Learning (CSCL), learners are encouraged to discuss ideas, concepts and problems from different perspectives and viewpoints (Van Bruggen, 2003) in order to re-construct and co-construct (new) knowledge (Veldhuis-Diermanse et al., 2006). CSCL provides an educational environment that prepares students to cope with authentic problems and issues (Jacobson & Wilensky, 2006), facilitates knowledge sharing, transfer, and (co)construction (Noroozi & Biemans et al., 2013; Noroozi & Busstra et al., 2012), and also supports students' learning processes and outcomes (Claudia et al., 2004; Ellis & Calvo, 2004; Hung et al., 2005; Wang & Woo, 2007).

Students' learning processes and outcomes in CSCL environments have been subjects of interest to many researchers (see Noroozi & Biemans et al., 2013; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013). However, in many cases, learning processes and outcomes of CSCL have been studied separately, even though many authors have argued that differences in learning outcomes are related to differences in learning processes and activities (e.g. Koschmann, 1996; Reimann, 2007; Russell, 1999). Therefore, it is important to study learning processes in relation to learning outcomes to reveal the connectivity between the two (Andriessen et al., 2003; Joiner & Jones, 2003). This implies that to truly understand the learning that takes place, research on CSCL should be both process-focused and result-focused (Koschmann, 1996; Mcdonald, 2003; Palincsar & Brown, 1989; Stegmann et al., 2007; Veerman, 2000 & 2003; Veldhuis-Diermanse, 2002).

Many aspects of learning processes and activities in CSCL have been studied in the past decade. For example, Veldhuis-Diermanse (2002) focused on the cognitive, affective, and metacognitive learning activities. Baker et al. (2007) and Van Amelsvoort et al. (2007) investigated students' learning processes and activities in terms of outside activity, social relations, interaction management, task management, opinions, arguments, exploration, and deepening of discussions. Their work showed that students engage not only in discussions and arguments in CSCL environments, but also in off-task activities as well as social interaction and management activities. Weinberger and Fischer (2006) mentioned that in order to construct knowledge in CSCL, students engage in four independent dimensions of collaborative learning: participation, epistemic, argumentative, and socio-modes of co-construction. In addition, Mcdonald (2003) studied specific aspects of learning processes in CSCL including consideration of other teammates' opinions, negotiation of meaning,

demonstration of mutual understanding, achievement of consensus, problem-solving, and time and task management issues.

Studies regarding the learning outcomes of CSCL have focused mainly on (quality of) knowledge construction. Both empirical and theoretical studies indicate that CSCL can facilitate and foster knowledge construction (e.g. Andriessen et al., 2003; Kanselaar et al., 2000; Kirschner et al., 2003; Noroozi & Biemans et al., 2013; Noroozi & Busstra et al., 2012; Weinberger & Fischer, 2006). Students construct not only cognitive knowledge but also metacognitive knowledge in CSCL environments (e.g. Oestermeier & Hesse, 2000; Veldhuis-Diermanse, 2002). Moreover, it has been demonstrated that CSCL can promote higher-order thinking and problem-solving and, thus, can lead to deeper understanding of the topic (De Jong et al., 2002; Noroozi & Biemans et al., 2013; Noroozi & Busstra et al., 2012; Noroozi & Weinberger et al., 2013; Van Bruggen, 2003; Van Bruggen & Kirschner, 2003; Veerman, 2000 & 2003; Veldhuis-Diermanse, 2002).

As mentioned earlier, a crucial issue in CSCL research is the relation between learning processes and learning outcomes. In other words, do successful and less successful students in terms of learning outcomes in CSCL differ with respect to their learning processes? Several empirical studies have focused on qualitative differences in students' learning processes, but these studies have mainly been aimed at specific aspects of learning processes and not at studying the learning process as a whole (i.e. taking different learning process variables into account in combination) and have not explicitly assessed and analysed the students' learning outcomes. These research studies revealed that there are qualitative differences among students in terms of specific aspects of the learning processes and activities in CSCL environments: the degree to which students discuss and share relevant information while approaching the learning task (Buder & Bodemer, 2008; Barron & Sears, 2002; De Wever et al., 2007); the degree to which students focus on both on-task and off-task activities (Buder & Bodemer, 2008; Newman et al., 1995; Van der Pol et al., 2008); the number of messages shared by students while discussing a topic for mutual understanding (Clark et al., 2007a & 2007b; Jeong & Chi, 1997; Munneke et al., 2007); the degree to which students broaden and expand their shared knowledge (Baker et al., 2007; Barron & Sears, 2002; Jeong & Hmelo-Silver, 2008; Munneke, 2007; Van Amelsvoort et al., 2007); and the degree to which students provide evidence and examples to support and justify their statements and points of view (Baker et al., 2007; Munneke, 2007; Munneke et al., 2007). Moreover, successful students in terms of learning processes and activities engage more in dividing the task into subtasks and

focus more on relevant and on-task activities than less successful students in CSCL environments (Joiner & Issroff, 2003); they also engage in more elaboration activities and make more attempts to resolve conflicts in understanding through elaborated responses (Andriessen, 2006; Barron & Sears, 2002; Munneke et al., 2007; Victor, 1999); they use broader and deeper argumentations in their discussions (Baker et al., 2007; Jeong & Hmelo-Silver, 2008; Munneke, 2007; Van Amelsvoort et al., 2007; Victor, 1999); and they justify their statements and problem solutions in a more logical and reasonable way (Andriessen, 2006; Clark et al., 2007a & 2007b; Munneke et al., 2007; Van Amelsvoort et al., 2007). These studies, however, have not explicitly unraveled the relations between learning processes and outcomes in CSCL by examining differences in learning processes between successful and less successful students in terms of learning outcomes.

To summarize: (1) up until now, the number of empirical studies explicitly examining the relations between learning processes and outcomes in CSCL has been rather limited; (2) the majority of the studies on CSCL has focused on specific aspects of learning processes in CSCL and not on learning process variables in combination. For these reasons, a comprehensive picture of the relations between learning processes and outcomes in CSCL is still lacking. Moreover, in most studies, the level of analysis considered the utterances of individual students and not the utterances of pairs or groups of students learning together in CSCL environments (the joint contributions of the students in a pair or group) (De Wever et al., 2007; Hox & Maas, 2002; Stahl, 2002). Using the joint utterances of the students in a pair or group as the unit of analysis makes it possible to analyse their joint learning processes as building shared understanding (Cress, 2008).

This article seeks to contribute to the existing literature on CSCL by comparing the learning processes of pairs of students who are successful and less successful with respect to the quality of knowledge construction. As mentioned earlier, in CSCL research it is common to operationalize learning outcomes in terms of knowledge construction. To construct a comprehensive picture of learning processes and to analyse their nature and quality in-depth, several process variables will be taken into account in combination: relevance, correctness, width and depth of discussion, as well as justification and reasoning. The research question is: what are the differences in learning processes (in terms of relevance, correctness, width and depth of discussion, as well as justification and reasoning) between successful and less successful pairs of students (in terms of knowledge construction) in CSCL environments?

Method

Context and Participants

The study took place at Wageningen University in the Netherlands, which focuses on the Life Sciences, especially food and health, sustainability, and the healthy living environment. Students at this university are stimulated to combine natural and social sciences: from plant sciences to economics and from food technology to sociology. Forty-four students from a human nutrition and health programme at Wageningen University in The Netherlands participated in this study. All subjects were enrolled in a 168-h course "Exposure assessment in nutrition and health research", a compulsory course for MSc students and a restricted optional course for BSc students. In this course, students acquire insight into the methodology of assessment of food and nutrient intake: students are expected to gain insight into the relation between the following research design components: potential systematic and random errors in exposure assessment and the purposes, design, analysis, and interpretation of studies that aim to evaluate dietary assessment methods.

Procedure

As a pre-test to assess the quality of their prior knowledge, students were given 45 minutes to individually design and analyse the essential aspects of an evaluation study (purposes, the required type of information, the potential systematic and random errors, and the design of the evaluation study), which aimed to evaluate a certain dietary assessment method (a 24-h recall) that was used to assess vitamin D intake in a population of immigrants. After this pre-test, students were randomly assigned to pairs and given 90 minutes to discuss in the CSCL environment (see next section for more details) the essential aspects of the evaluation studies developed by both students. Before carrying out this task, students were given a 20 minutes introduction to the CSCL environment. Next, students had to do an individual post-test to assess the quality of knowledge construction after collaborative learning: they had to re-design the same evaluation study individually within 45 minutes based on what they had learned during collaborative phase.

CSCL Platform

In this study, students used the platform DREWLITE (see figure 3.1). This is a simplified version of DREW, which was developed within the SCALE project to support argumentation

in CSCL (Corbel et al., 2002). The "lite" version is less advanced in managing sessions and traces, which was irrelevant in our study. The platform comprises different tools for communication, collaboration, and argumentation such as chat, graph, text board, view board, and multimodules. DREWLITE modules can be used both individually and collectively. For the present study both individual (for the pre-test and the post-test) and collaborative versions (for the collaborative task) were used. During the pre-test and the post-test, individual students used the graph module to construct a representation of the essential aspects of the evaluation study (purposes, the required type of information, the potential systematic and random errors, and the design of the evaluation study): students did so by entering text in boxes (see figure 3.1). Moreover, each student could individually provide textual comments and express his or her own opinion in favour of or against given arguments. Figure 3.1 shows how students related graphs and textual comments during pre-test and post-test. For the collaborative task, a chat module was used which allowed pairs of students to discuss the essential aspects of the evaluation study and to compose a collaboratively written text (see figure 3.2). The students' contributions were automatically recorded in a log-file.

Instruments, Measurements, and Data Sources

Two coding schemes were used to analyse the students' learning processes and outcomes in CSCL. For analysing the quality of the students' learning outcomes, an already available content analysis instrument was used. This coding scheme had already been tested on the criteria completeness, clarity, applicability, accuracy, precision, objectivity, validity, reliability, and replicability (see for more details Veldhuis-Diermanse, 2002). To measure all learning process variables, a new coding scheme had to be developed since no such instrument was available. Both instruments will be described in the next paragraphs.
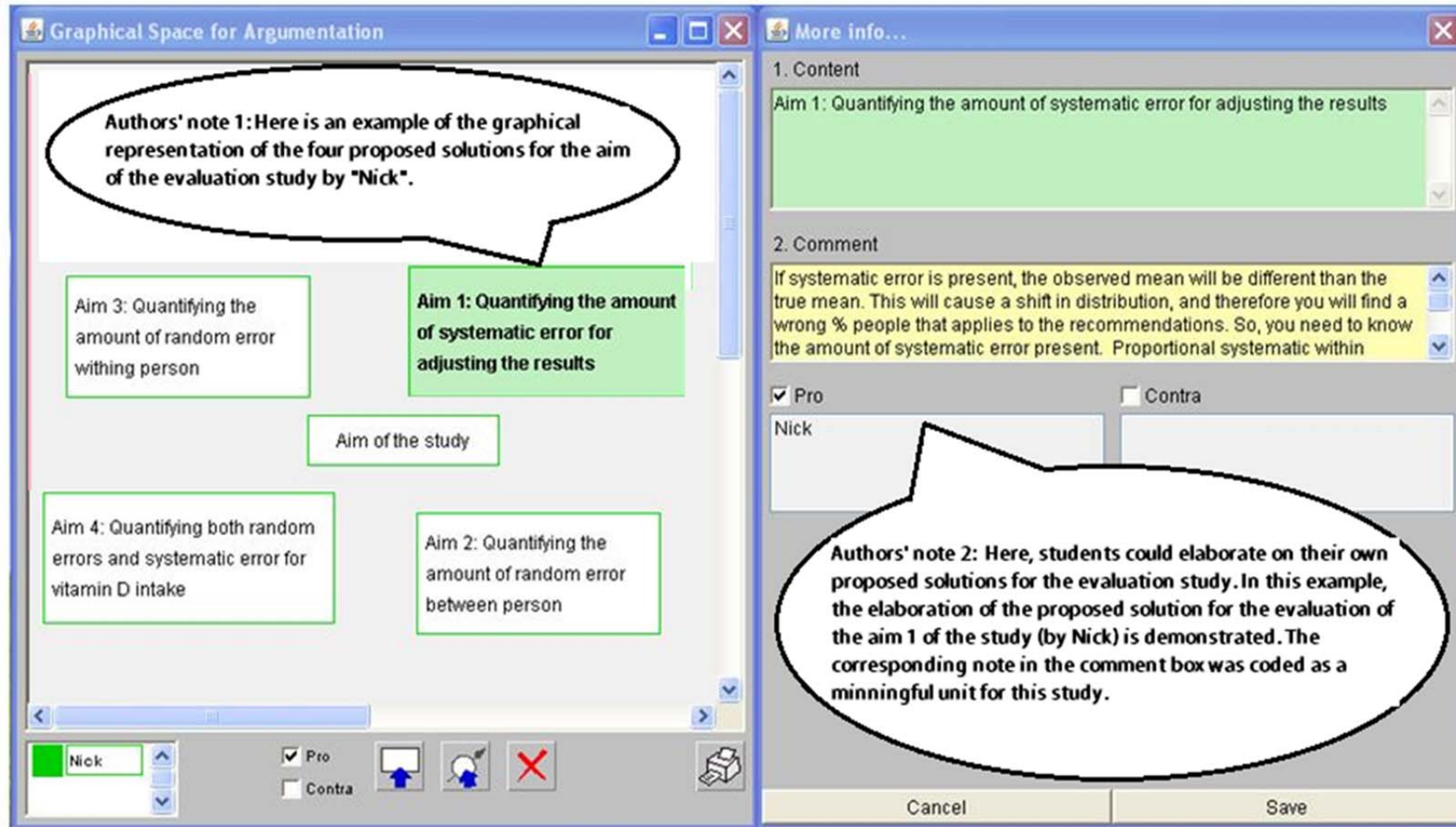
Figure 3.1: The interface of the DREWLITE graph module including input text fields for content and comments.
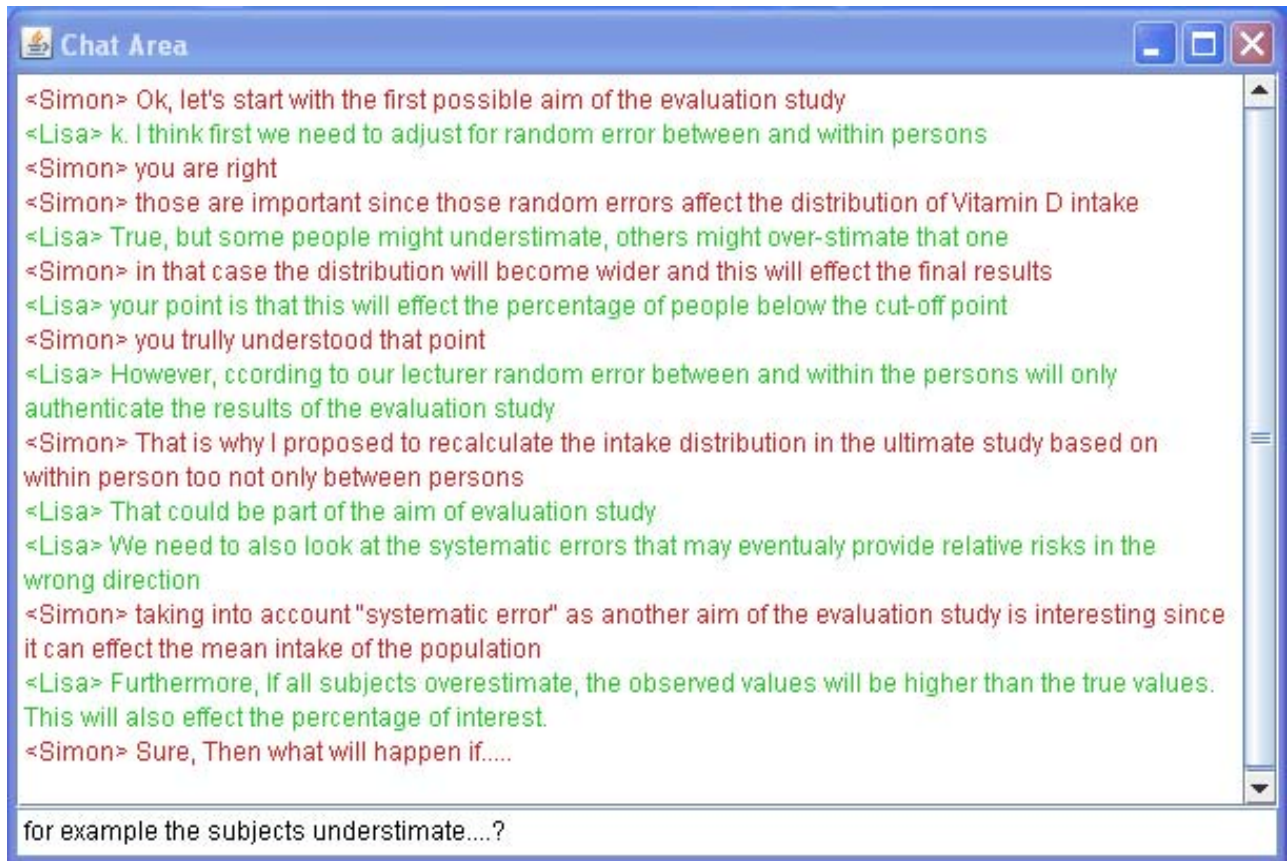
Figure 3.2: The interface of the DREWLITE chat module including a shared environment for students to chat, discuss, and argue about the topic.

The coding scheme designed by Veldhuis-Diermanse (2002) to analyse students' learning outcomes in terms of knowledge construction is based on the SOLO taxonomy (Biggs & Collis, 1982). SOLO taxonomy is a hierarchical representation of the structure of observed learning outcomes. This coding scheme provides a series of categories for ranking the complexity of students' contributions as a proxy of their level of knowledge construction. Veldhuis-Diermanse et al. (2006, pp. 48) mentioned that: "As students proceed in their learning process, the outcomes of their learning display comparable stages of increasing structural complexity". The original SOLO taxonomy consisted of five hierarchical levels (Biggs, 1999; Biggs & Collis, 1982; Jackson, 2000) from basic to advanced: E = prestructural (which reflects the lowest level of understanding or no understanding at all); D = unistructural; C = multistructural; B = relational; and A = extended abstract (which reflects the highest level of understanding). Veldhuis-Diermanse (2002) further operationalized this coding scheme by identifying and describing corresponding verbs for each of the levels (except for the lowest level E). In the current study, Veldhuis-Diermanse's coding scheme was used, but again with the addition of level E (see table 3.1).

This coding scheme was used to quantify the quality of student knowledge construction. Student contributions in the comment screens of the DREWLITE platform in the pre-test and the post-test were segmented into meaningful units and subsequently, each unit was labeled following the coding scheme described in table 3.1. Corresponding verbs were identified for each of the five quality levels to assess the learning outcomes. Student contributions were given points according to their level in the coding scheme: 1 point for category E contributions, 2 points for D, 3 for C, 4 for B, and 5 for A level contributions. Subsequently, the points for the contributions of each student were added together and this number was then divided by the number of meaningful units, which resulted in an individual mean score for the quality of knowledge construction in the pre-test and a mean quality score for the post-test.

As mentioned earlier, based on extensive analysis of scientific literature (see references in table 3.2), a new content analysis instrument was developed and used in this study to analyse the learning processes of the student pairs. The CSCL contributions of all pairs of students were used as data sources. To analyse their learning processes, the joint contributions made by each pair in their discussion and jointly written text (as recorded in the DRWELITE log-file) were segmented into meaningful units and each unit was labeled following the coding scheme described in table 3.2. The following learning process variables were scored for each meaningful unit (or topic): relevance, correctness, width and depth of discussion, as well as justification and reasoning. Relevance has to do with the degree to which each contribution of the particular pair of students is relevant content-related. Correctness pertains to the degree to which theories and information related to essential aspects of the evaluation study are discussed in an appropriate and accurate way. Width of discussion has to do with the degree to which the essential aspects of the evaluation study are broadly discussed. Depth of discussion has to do with the degree to which theories and information related to essential aspects of the evaluation study are elaborated in-depth. Justification and reasoning has to do with the degree to which a particular pair of students supports and justifies their arguments by using examples, proofs, reasonable evidence, and logical words related to essential aspects of the evaluation study. Moreover, the number of meaningful contributions (units) of each student pair was registered.

Table 3.1: Coding scheme to assess the quality of knowledge construction (based on Biggs & Collis, 1982; Veldhuis-Diermanse, 2002).

Level	Signifier	Description
E: Prestructural (no understanding at all)	-	Student makes irrelevant contributions which reflect outside (off-task) activities.
D: Unistructural (understanding as nominal)	*Identify*	Student recognizes or distinguishes something as being different. One point or item is given that is not related to other points in the discourse. Furthermore, this new point is not elaborated.
	Define	Student describes something clearly. The description is taken over from a text or someone else; it is not a self-made definition.
C: Multistructural (understanding as knowing about)	*List/enumerate/ number*	Items are listed in a particular or random order. Items are marked with a number, usually starting at one.
	Describe/organize	A self-made definition is given (e.g. a theory, idea, problem or solution) which explains distinguishing features of that thing. Ideas are organized, but descriptive in nature. No deeper explanatory relations are given, just a rough structure of information.
	Classify	Items are divided into groups or types so that those with similar characteristics are in the same group.
B: Relational (understanding as appreciating relationships)	*Explain*	Reasons are given for a choice made. An idea, theory, or line of thought is elaborated.
	Relate/combine	Two or more related things or facts are linked.
	Compare/ contrast/apply	Things are compared and differences or similarities between them are discovered. Acquired knowledge is used in the same or a different situation.
A: Extended abstract (higher level of abstraction; understanding as far transfer and as involving metacognitive knowledge)	*Reflect/conclude*	Arguments on relevance and truth are criticized. After considering relevant facts the student decides that something is true or false. A judgment is given after considering an argument or theory. (The conclusion has to be a point; it must rise above earlier statements, not just be a summary)
	Generalize/ theorize/ hypothesize	Concrete ideas are surpassed and the student formulates his or her own view or theory. The student predicts that something will be true because of various facts; this prediction has to be checked or examined.

For each meaningful contribution, a score was assigned for each of the process variables. Pairs of students were given one point for each level 1 assessment (e.g. irrelevant), two points for each level 2 assessment (e.g. partly relevant), and three points for each level 3 assessment (e.g. relevant). Points for the various learning process variables were assigned based on content information and guidelines from the teachers of the course. The teachers of the course helped coders to get in-depth insight into the content-related topics (on assessment in nutrition and health research). Subsequently, all points assigned to each pair were added together and this number was then divided by the number of meaningful units in order to calculate the mean quality score for each learning process variable. Thus, for each aspect of the learning process, pairs of students could get a mean quality score of between one and three. Scores of two inactive students were excluded from the analysis due to the limited number of their contributions, which means that for data analysis 42 students were included in the study.

In order to investigate the differences in learning processes between successful and less successful pairs of students in CSCL environments, the data collected for analysing learning processes and learning outcomes were combined. First, a mean quality score for knowledge gain was calculated for each individual student by measuring the difference in mean quality score for knowledge construction from pre-test to post-test ($M = t2 - t1$). Based on their mean quality scores for knowledge gain and using the median as the criterion, nine pairs of students could be classified as successful, nine pairs as less successful, and three pairs as mixed (combinations of one successful and one less successful student). These three mixed pairs of students were excluded from the analysis. Next, the quality of the learning processes of successful and less successful pairs of students in terms of relevance, correctness, width and depth of discussion, as well as justification and reasoning was compared.

Table 3.2: Coding scheme to analyse the quality of learning processes of student pairs in CSCL with process variables, levels and corresponding descriptions, and references.

Variable	Label	Description	Reference
Relevance	1) Irrelevant	Topic that does not contribute to completion of the task.	Buder & Bodemer, 2008; De Wever et al., 2007;
	2) Partly relevant	Topic that does not directly relate to completion of the task, but might contribute to understanding the task.	Newman et al., 1995; Van der Pol et al., 2008
	3) Relevant	Topic that needs to be brought up during discussion to allow for successful completion of the task.	
Correctness	1) Incorrect	Theories and studies are described incorrectly.	Buder & Bodemer, 2008; Barron & Sears, 2002;
	2) Partly correct	Due to the incompleteness of a statement, the discussion cannot be regarded as correct.	De Wever et al., 2007
	3) Correct	Theories and studies are described correctly.	
Width of discussion	1) Inadequate	Not enough topics are provided to complete the task.	Baker et al., 2007; Barron & Sears, 2002; Jeong & Hmelo-Silver, 2008; Munneke et al., 2007;
	2) Partly adequate	Not enough topics are provided to complete the task successfully.	Van Amelsvoort et al., 2007
	3) Adequate	Enough topics are provided to complete the task successfully.	
Depth of discussion	1) Superficial	Topic is not discussed or elaborated on or the topic is discussed in an insignificant way.	Baker et al., 2007; Jeong & Hmelo-Silver, 2008; Munneke et al., 2007; Van Amelsvoort et al.,
	2) Simple	Simple explanations or interpretations are given. The topic is discussed in a way that contributes partly to the advancement of the task completion.	2007; Victor, 1999
	3) Elaborated	Detailed and elaborated explanations or interpretations are given. The topic is discussed in a way that contributes significantly to completion of the task.	
Justification and reasoning	1) Illogical	Argument is not convincing or logical. Evidence and logic are weakly connected to argument.	Baker et al., 2007; Munneke, 2007; Van Amelsvoort et al., 2007
	2) Incomplete	Due to the incompleteness of a statement, the discussion cannot be regarded as correct.	
	3) Logical	Argument is convincing and logical. Evidence and logic are well-related to argument.	
Number of units		Number of meaningful units in discussion and text entered by the particular pair of students.	Clark et al., 2007a & 2007b; Jeong & Chi, 1997; Munneke et al., 2007

As discussed, analyses in this study were based on identifying and scoring meaningful units in the students' utterances. The students' utterances were segmented into meaningful units by distinguishing each solution that was mentioned or discussed. A solution was comprised of a discussion of the essential aspects of the evaluation study (purposes, the required type of information, the potential systematic and random errors, and the design of the evaluation study). Teachers of the course provided us with all possible solutions in terms of essential aspects of the evaluation study. Students' utterances could include one or more solutions (or meaningful solution units). Since the number of meaningful (solution) units could be determined unambiguously, no inter-rater reliability calculation was needed for the number of meaningful units. Next, for every meaningful unit, all relevant variables were scored. Thus, for every meaningful unit of a student pair, all categories of the process coding scheme were scored: every meaningful unit received a score on how relevant, correct, etc. it was. After that, for each student pair, a mean quality score was calculated for each learning process variable.

Although Veldhuis-Diermanse (2002) reported a satisfactory (0.72) inter-rater reliability for her coding scheme, the inter-rater reliability for the coding scheme was calculated in this study as well. Two coders analysed the students' contributions using the coding schemes described above. Cohen's kappa was employed as a reliability index of inter-rater agreement. Cohen's kappa was 0.78 (pre-test) and 0.81 (post-test) for the slightly revised coding scheme for learning outcomes, and 0.81 for the new coding scheme for learning process variables, which indicates acceptable levels of agreement. Moreover, intra-coder test-retest reliability was calculated for 20% of the contributions. This resulted in identical scores in 85% of the contributions for the coding scheme for learning outcomes and in 83% of the contributions for the coding scheme for learning process variables.

We used the individual learner as the unit of analysis to answer the research questions related to individual pre-test or post-test measures (student learning outcomes). We used the dyads as the unit of analysis to analyse characteristics of student learning processes during discourse. A one-way analysis of variance (ANOVA) tests were used to compare mean differences between successful and less successful students in the pre-test and post-test in terms of number of meaningful units and quality of knowledge construction. Furthermore, ANOVA tests for repeated measurement were used to compare the learning outcomes between successful and less successful pairs of students in terms of number of meaningful units and quality of knowledge construction. A one-way multivariate analysis of variance (MANOVA)

74

was conducted to determine the differences in learning processes between successful and less successful pairs of students in terms of various aspects of student learning processes (i.e. relevance, correctness, width and depth of discussion, as well as justification and reasoning). ANOVAs for each aspect of the student learning processes were then conducted as follow-up tests to the MANOVA.

Results

Before answering the research question, the characteristics of (pairs of) students' learning outcomes and processes will be discussed.

Characteristics of Students' Learning Outcomes

During the pre-test, 514 meaningful units were produced by the students (M = 12.23; SD = 3.58; Max = 21; Min = 7). During the post-test, the total number of meaningful units was 531 (M = 12.64; SD = 3.10; Max = 20; Min = 6). With respect to the quality of knowledge construction, the majority of students' contributions were assessed as level C (multistructural) or level B (relational): approximately 63% for the pre-test and 65% for the post-test. The percentages of contributions assessed as level E (prestructural) or level A (extended abstract) were considerably lower than other levels for both tests (see figure 3.3). Students' mean quality scores for knowledge construction were 3.01 (SD = .40) for the pre-test and 3.11 (SD = .34) for the post-test. As can be seen in figure 3.3, some differences can be found for the knowledge construction levels E (prestructual) and A (extended abstract) between pre-test and post-test: in the post-test, students constructed fewer (lowest) level E contributions and more (highest) level A contributions than in the pre-test. Figure 3.3 shows no differences between pre-test and post-test for levels B (relational), C (multistructural), and D (unistructural).
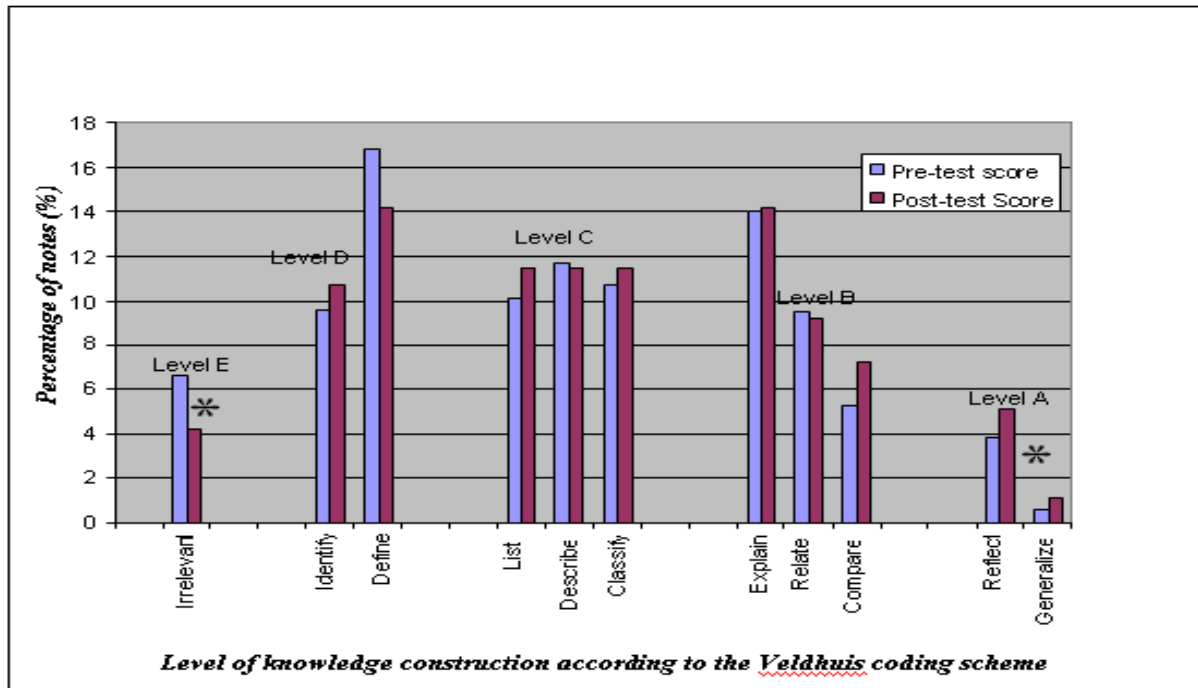
Figure 3.3: Students' meaningful units assessed for the quality of knowledge construction (*: mean differences between pre-test and post-test for levels A and E are significant at the .05 level).

Characteristics of Successful and Less Successful Students' Learning Outcomes

During the pre-test, 259 meaningful units were produced by successful students (M = 12.33; SD = 4.02; Max = 21; Min = 6) and 255 meaningful units by less successful students (M = 12.14; SD = 3.16; Max = 21; Min = 7). This difference was not statistically significant, $F(1, 40)$ = .03, p = .87. During the post-test, the total number of meaningful units was 263 (M = 12.52; SD = 3.35; Max = 21; Min = 6) for successful students, and 268 for less successful students (M = 12.76; SD = 2.91; Max = 20; Min = 7). This difference was not significant either, $F(1, 40)$ = .06, p = .81. The total number of meaningful units of all students increased significantly, $Wilks'$ λ = .98, $F(1, 40)$ = .44, p < .05, η^2 = .02, from pre-test to post-test, but this effect was only small. Less successful and successful students differed with respect to the number of meaningful units produced, $Wilks'$ λ = .10, $F(1, 40)$ = .68, p < .05, η^2 = .004, although this effect was again only small. Less successful students produced more meaningful units from pre-test to post-test compared with successful students.

Successful students' mean quality scores for knowledge construction were 3.03 (SD = .44) for the pre-test and 3.23 (SD = .34) for the post-test. Less successful students' mean scores for knowledge construction were 2.99 (SD = .35) for the pre-test and 3.00 (SD = .29) for the post-test. Less successful and successful students did not differ significantly with respect to their pre-test scores, $F(1, 40)$ = .11, p = .75: there appeared to be no significant differences with

respect to the prior knowledge of less successful ($M = 2.99$; $SD = .35$) and successful ($M = 3.03$; $SD = .44$) students. Less successful and successful students differed significantly with respect to their post-test scores, $F(1, 40) = 5.15$, $p < .05$, $\eta^2 = .12$, meaning that during the post-test the mean quality scores of knowledge construction was higher for successful ($M = 3.23$; $SD = .34$) than for less successful students ($M = 3.00$; $SD = .29$). The quality of knowledge construction of all students improved significantly, *Wilks' λ* = .87, $F(1, 40) = 6.18$, $p < .05$, $\eta^2 = .13$, from pre-test to post-test. All students tended to construct a higher quality of knowledge construction in the post-test than pre-test. Furthermore, less successful and successful students differed significantly with respect to their number of meaningful units, *Wilks' λ* = .89, $F(1, 40) = 5.03$, $p < .05$, $\eta^2 = .11$, although this effect was again only small. Successful students tended to construct a higher quality of knowledge construction from pre-test to post-test compared with less successful students.

Characteristics of Students' Learning Processes

Descriptive analyses were used to describe the learning processes of the student pairs (see table 3.3). In total, 264 meaningful discussion units were produced by the student pairs ($M = 12.57$; $SD = 2.06$; *Max* = 16, *Min* = 9). About 20 to 35 percent of the students' contributions could be characterized as irrelevant, incorrect, inadequate, superficial, or illogical.

Table 3.3: Characteristics of students' learning processes in CSCL.

Variable	Label	Frequency	Percentage
Relevance	*Irrelevant*	52	19.69
	Partly relevant	82	31.06
	Relevant	130	49.24
Correctness	*Incorrect*	69	26.13
	Partly correct	73	27.65
	Correct	122	46.21
Width of discussion	*Inadequate*	74	28.03
	Partly adequate	78	29.54
	Adequate	112	42.42
Depth of discussion	*Superficial*	87	32.95
	Simple	71	26.89
	Elaborated	106	40.15
Justification and reasoning	*Illogical*	92	34.84
	Incomplete	71	26.89
	Logical	101	38.25
Number of meaningful units	-	264	100

Relation between Learning Outcomes and Learning Processes in CSCL

Successful and less successful student pairs were compared in terms of the learning process variables mentioned earlier. There was a significant difference between learning processes of successful and less successful pairs of students in terms of quality of knowledge construction, *Wilks' λ* = .18, *F(*1, 16) = 8.35, *p* < .01*, η²* = .82. Successful pairs of students appeared to have higher scores on the following learning process variables than less successful students: relevance, *F(*1, 16) = 13.40, *p* < .01*, η²* = .46, width, *F(*1, 16) = 14.07, *p* < .01*, η²* = .47, depth of discussion, *F(*1, 16) = 9.90, *p* < .01*, η²* = .38, as well as justification and reasoning, *F(*1, 16) = 17.39, *p* < .01*, η²* = .52. In other words, successful pairs of students produced more relevant, more logical, and broader and deeper discussions and arguments than less successful pairs of students during the collaborative phase in the CSCL environment (see table 3.4). The difference between successful and less successful students with respect to the variable "correctness" was just below the significance level, *F(*1, 16) = 2.94, *p* = .11*, η²* = .15. The difference between the two groups of students in terms of number of meaningful units was not significant, *F(*1, 16) = .21, *p* = .66 (see table 3.4).

Table 3.4: Successful and less successful pairs of students compared in terms of learning process variables.

Variable	Label	Mean	Standard deviation
Relevance	*Successful*	2.39	.21
	Less successful	2.06	.25
	Total	2.23	.24
Correctness	*Successful*	2.30	.22
	Less successful	2.12	.20
	Total	2.21	.22
Width of discussion	*Successful*	2.34	.12
	Less successful	1.91	.32
	Total	2.12	.32
Depth of discussion	*Successful*	2.33	.29
	Less successful	1.96	.20
	Total	2.15	.31
Justification and reasoning	*Successful*	2.30	.24
	Less successful	1.87	.18
	Total	2.09	.30
Number of meaningful units	*Successful*	12.44	2.06
	Less successful	12.88	2.08
	Total	12.66	2.02

Conclusion and Discussion

The results of the present study showed a significant improvement in the quality of students' knowledge construction from pre-test to post-test. Several authors have indeed claimed that CSCL has an added value in terms of learning outcomes, especially in the quality of knowledge construction (Andriessen et al., 2003; Joiner & Jones, 2003; Kanselaar et al., 2000; Kirschner et al., 2003; Lipponen, 2002; Noroozi & Biemans et al., 2013; Noroozi & Busstra et al., 2012; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013). There could be several reasons for this. In CSCL, students can discuss their ideas and conceptions from different perspectives in order to re-construct and co-construct (new) knowledge while solving authentic and complex problems (Veldhuis-Diermanse et al., 2006; Weinberger & Fischer, 2006). Furthermore, through writing notes in CSCL environments, students can re-construct their thoughts while formulating and organizing ideas and opinions and they can also re-read posted notes by looking at the conversation history. Writing notes and re-reading and re-thinking those notes are regarded as important tools for learning and knowledge construction in CSCL (De Jong et al., 2002; Veerman, 2000).

The results of the present study also showed that students construct fewer irrelevant contributions (prestructural) and more contributions of the highest quality (extended abstract) during the post-test than the pre-test. It has been shown that CSCL can lead to higher-order thinking by giving students the opportunity to discover and generate arguments and therefore to further their understanding of the topic (Marttunen & Laurinen, 2001; Veerman, 2000; Veldhuis-Diermanse, 2002). The idea is that students in CSCL environments can discuss, elaborate, and integrate their thoughts and knowledge, which is likely to lead to developing a deeper understanding and higher-order skills (De Jong et al., 2002).

The research question of the present study, which aimed at analysing the nature and quality of these learning processes in-depth, concerned differences in learning process variables between less successful and successful pairs of students in CSCL. This study revealed that successful pairs constructed messages that were more relevant, wider and deeper, more convincing, and more logical than less successful pairs (i.e. systematic differences between successful and less successful students in the combination of learning process variables). In other words, individuals who engage in a "fruitful discussion" (i.e. more relevant, wider, and deeper) gain more knowledge than individuals whose discussion is less fruitful. This is in line with previous studies indicating that engaging in more relevant, sound, and on-task activities

79

(Buder & Bodemer, 2008; Barron & Sears, 2002; Joiner & Issroff, 2003) and making better elaborated (Victor, 1999) and justified contributions to discussions (Clark et al., 2007a & 2007b; Munneke et al., 2007; Van Amelsvoort et al., 2007) as well as making broader and deeper arguments (Baker et al., 2007; Jeong & Hmelo-Silver, 2008; Munneke, 2007; Van Amelsvoort et al., 2007) lead to better quality of knowledge construction processes than engaging in off-task activities and contributing less elaborated and justified and more narrow and superficial arguments and discussions in CSCL environments.

The current study led to a more comprehensive picture of learning in CSCL environments by taking into account several process variables in combination. This made it possible to examine what kinds of interaction appear to aid learning. Being able to determine crucial kinds of interaction opens the door for specific interventions aimed at improving the quality of these interactions. In order to improve students' learning outcomes in CSCL, one should pay explicit attention to the nature of their learning processes in these environments in terms of relevance, correctness, width and depth of discussion, as well as justification and reasoning. These aspects should be addressed in combination, which is a new implication of the present study (compared to previous studies).

The results of this study with respect to the characteristics of the learning processes of students in CSCL showed that about 20-35% of the students' contributions can be characterized as irrelevant, incorrect, inadequate, superficial, or illogical, and another 20-30% as only partly relevant, partly correct, partly adequate, simple, or incomplete, which are considerable percentages. In other words, there is considerable room for improvement through external support. Without external support in CSCL, one cannot expect that students will to a large extent broaden and deepen the space of debate with justified and reasonable arguments. Scripting could be a very crucial factor as an instructional support technique to scaffold learning in CSCL environments (Azevedo & Hadwin, 2005). Some of these scripts could be embedded in CSCL platforms to stimulate students to engage in more relevant, correct, broad, deep, and logical discussions. For example, by using the collaboration and argumentative scripts, students can ask clarifying questions and request their fellow-students to back up their statements and arguments with more reasonable evidence, examples, etc. Clarifying questions and criticizing could help groups of learners to elaborate, deepen, and broaden their arguments with regard to the topic of discussion. A study by Noroozi and Weinberger et al. (2012) provides an extensive overview on how, when, under what condition, and which types of scripts can be used to facilitate specific aspects of the learning process variables in CSCL.

In future empirical studies, the effects of different categories of scripts on the different aspects of learning processes in CSCL environments will be examined.

At this point, it is relevant to discuss some strengths and weaknesses of the present study. One of the strengths of this study is that the students' learning processes and outcomes in CSCL were assessed in an authentic educational setting (high ecological validity) in the domain of nutritional research education and not in an artificial setting. This provided the opportunity to shed light on the differences in the learning processes between successful and less successful students as they occur in authentic learning situations (direct practical relevance).

Another strength of this study is its use of two content analysis coding schemes to analyse the students' learning processes and outcomes in CSCL. Although content analysis is a very time-consuming process, it is one of the most frequently applied techniques for analysing written notes and transcripts of discourse corpora in CSCL environments. Learning outcomes were analysed by using a slightly revised version of an already available coding scheme developed by Veldhuis-Diermanse (2002), which had already been used in several other empirical studies. Its inter-rater reliability values had been reported as being satisfactory (De Laat & Lally, 2003; Veldhuis-Diermanse et al., 2006). In the present study, these values were even higher. Moreover, to analyse the students' learning processes, CSCL literature was reviewed and important aspects of learning processes were taken into account in developing a new coding scheme. This new scheme was used to construct a clear picture of learning processes and activities in CSCL. More than satisfactory inter-rater reliability and intra-coder test-retest reliability values for this coding scheme were obtained.

A limitation of this study is that student characteristics which could potentially influence learning processes and outcomes (age, cultural and educational background, experience with collaboration and group work, etc.) were not explicitly taken into account. Gress et al. (2010) listed individual differences between students (with respect to attitude toward collaborative learning, collaborative skills, computer efficiency, leadership abilities, learning skills and styles, metacognitive strategies, and social network from prior collaboration) that need to be taken into account when implementing CSCL. Having prior collaborative work experience before working in CSCL environments, for example, can influence the effectiveness of learning (Beers et al., 2007). Observations of students while working on the collaborative task in the present study showed that some students needed time to get used to working in CSCL environments even though instructions and hand-outs had been provided in advance.

Therefore, before implementing CSCL, it is crucial to provide students with guidelines and instructions as well as extensive opportunities to practice working with the computer-supported platform. Finally, it would be interesting to validate the findings of this study through other experimental studies in which students' backgrounds and other characteristics are taken into account in more controlled experimental conditions.

To summarize and conclude, this study revealed that the patterns of learning processes of successful and less successful students in the CSCL environment differ in terms of relevance, width and depth of discussion, as well as justification and reasoning. Previous studies have given the indication that there are differences among students in terms of learning process variables, but this study showed systematic differences of the combination of process variables. These learning process variables seem to be key to higher learning performance in CSCL environments (Koschmann, 1996; Mcdonald, 2003; Veerman, 2000).

Chapter

4

Scripting for Construction of a Transactive Memory System in a Multidisciplinary CSCL Environment*

Abstract

Establishing a transactive memory system (TMS) is essential for learning groups, especially when they are multidisciplinary and collaborate online. Environments for Computer-Supported Collaborative Learning (CSCL) could be designed to facilitate the TMS. This study investigates how various aspects of a TMS (specialization, coordination, credibility) can be facilitated using a transactive memory script that spans three interdependent processes (encoding, storage, retrieval) in a multidisciplinary CSCL environment. As part of a laboratory experiment, 60 university students were randomly assigned to multidisciplinary pairs based on their disciplinary backgrounds (i.e. water management or international development studies). These pairs were assigned at random to a scripted (experimental) or non-scripted (control) condition. They were asked to analyse, discuss, and solve an authentic problem case related to their domains (i.e. applying the concept of community-based social marketing in fostering sustainable agricultural water management). The results showed that the transactive memory script not only facilitates the construction of various aspects of a TMS, but also improves learners' group-to-individual and shared knowledge transfer as well as quality of problem solution plans. Specialization and coordination aspects of the TMS were shown to be mediators for the impacts of transactive memory script on joint but not individual solution plans. Explanations for these results, implications, limitations, and recommendations for further research are provided.

Introduction

For solving many of today's complex problems, professionals need to collaborate in multidisciplinary teams. Over the last decades, much attention has been given to learning processes and outcomes of multidisciplinary groups (e.g. Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Rummel & Spada, 2005) to prepare learners to construct solutions for, cope with, and adjust to today's complex issues (see Vennix, 1996). The main advantage of multidisciplinary learning is that learners from different disciplinary backgrounds benefit from one another's complimentary expertise and bring various perspectives and viewpoints to bear on a problem to create new ideas and products, which in turn raise new questions in such a way that would have been impossible through single disciplinary thinking (Boix-Mansilla, 2005; Spelt et al., 2009). However, group members with diverse backgrounds and viewpoints have little meta-knowledge about the domain expertise and knowledge of their learning partners (Wegner, 1987 & 1995). As a result, they may encounter difficulties during collaboration, such as coordinating joint problem-solving activities (Barron, 2000; Rummel & Spada, 2005), establishing common ground (Beers et al., 2005 & 2007), pooling and processing unshared information (Stasser & Titus, 1985; Rummel et al., 2009), and converging towards shared knowledge (Roschelle & Teasley, 1995; Weinberger et al., 2007a). These restrictions can especially be observed in newly formed groups (see Schreiber & Engelmann, 2010). The lack of knowledge about the collaborative partner(s) can negatively affect the exchange and distribution of unshared information and knowledge in the group (see Stasser et al., 2000). Encoding, storing, and retrieving knowledge in the group whilst building on and expanding knowledge about (learning) partners' expertise has been named the transactive memory system (TMS) (Wegner, 1987 & 1995). Since especially multidisciplinary learners in work and learning contexts suffer from having little knowledge about how expertise is distributed within a team (Rummel et al., 2009; Stasser et al., 1995), various techniques (e.g. individual and group training, formation of groups based on expertise, information and knowledge awareness tools, etc.) have been developed to facilitate the TMS in collaborative learning settings.

Recently, some research studies (e.g. Engelmann & Hesse, 2010; Schreiber & Engelmann, 2010) have shown that online support systems for collaboration in what has been named Computer-Supported Collaborative Learning (CSCL) can be designed to overcome barriers for establishing a TMS in collaborative learning contexts. Schreiber and Engelmann (2010),

for instance, found that using concept maps to visualize collaborators' knowledge structures (see also Engelmann et al., 2009; Fischer & Mandl, 2005) can initiate processes of a TMS, which is in turn beneficial for group performance in newly formed ad hoc learning groups. Therefore, the assumption that group awareness is a prerequisite for initiation of a TMS (Gross et al., 2005) was confirmed (Schreiber & Engelmann, 2010). This study, however, only revealed the effects of the concept maps on the directory update processes (initiation of a TMS) and not on the other processes of a TMS such as information allocation and retrieval coordination. The question of how CSCL should be designed to facilitate all processes of a TMS as a whole still needs to be clarified. In this paper, we present an innovative approach to facilitate various aspects of a TMS using a transactive memory script. Scripts have shown to be a promising approach to orchestrate various roles and activities of learners, to facilitate interaction and task coordination, and ultimately to foster learning (see Fischer et al., 2007; Noroozi & Weinberger et al., 2012; Weinberger, 2011). Hence, this study examined the extent to which a TMS could be facilitated by a transactive memory script in a multidisciplinary CSCL setting. In addition, the extent to which this specific script influenced learners' knowledge transfer as well as joint and individual problem solution plans was studied.

This article is structured as follows: First, relevant literature, various processes and aspects of a TMS, and computer-supported collaboration scripts to facilitate a TMS are described. Second, we describe research questions in relation to the theoretical framework. Third, a section is devoted to the applied method approach, describing the context, participants, learning materials, and implementation of the transactive memory script, explaining the procedure that was followed, as well as reporting on the measurements, instruments, and analysis process that were used. Fourth, the results in light of research questions are presented. Finally, the paper closes with a discussion of the results, implications, and suggestions for further research.

Transactive Memory System (TMS)

The TMS theory introduced by Wegner (1987) originally described how couples and families in close relationships coordinate their memory and tasks at home. TMS has also been studied in other contexts, mainly in organizational (e.g. Lewis et al., 2007; Liang et al., 1995; Littlepage et al., 1997; Hollingshead, 1998a, 1998b, 1998c, 1998d, & 2000) and also recently in educational settings (e.g. Engelmann & Hesse, 2010; Schreiber & Engelmann, 2010). The TMS theory is based on the interaction between individuals' internal and external memory

systems in the form of communication between group members (Wegner, 1987 & 1995). In collaborative learning, not only one's own knowledge and information as an internal source of knowledge comes to play but also knowledge of the learning partner(s) in the group as the external memory system. Internal memory is unshared information and knowledge located in an individual group member's mind, whilst external memory is knowledge represented outside the mind of a group member that can be shared through knowledge-relevant communication processes between the group members (Wegner, 1987 & 1995). In a TMS, group members need to look for external memories to identify the existence, location, and mechanisms for retrieval of knowledge held by other group members. The TMS can thus be described as a system which combines the knowledge stored in each individual's memory with meta-memory on knowledge structures of the learning partner(s) for developing a shared awareness of who knows what in the group (Moreland et al., 1996 & 1998; Wegner, 1987 & 1995). Specifically, a TMS refers to group members' views in terms of awareness of one another's knowledge, the accessibility of that knowledge, and the extent to which group members take responsibility for providing knowledge in their own area of expertise and for retrieval of information held by other group members in the group (Lewis, 2003; London et al., 2005; Wegner, 1995). These processes could result in forming a collaboratively shared system of encoding, storing, and retrieving information in the group as a whole for enhancing group performance (Wegner, 1995).

Various Processes of a TMS (Encoding, Storage, Retrieving)

Following Wegner's (1987 & 1995) ideas about the TMS, establishing and maintaining a TMS in a group involves three interdependent processes: encoding, storage, and retrieval. In collaborative settings, group members work best when they first discover and label information distributed in the group, then store that information with the appropriate individual(s) who has/have the specific expertise, and finally retrieve needed information from each individual when performing the task some time later (see Rulke & Rau, 2000).

In the encoding process, the initiation of a TMS or directory updating begins with the process of getting to know "who knows what" in the group (see Schreiber & Engelmann, 2010). During this process, group members gain an estimation of their learning partner(s)' areas of expertise, and categorize this information by ascribing each knowledge domain to the corresponding group member (Liang & Rau, 2000). In the storage process, group members store information with the appropriate individual(s), who has/have the specific expertise

regarding a particular topic of interest. During this process, group members allocate new information on a topic to the relevant expert(s) in the group on that topic. In the retrieving process, group members need to retrieve required information from the expert who has the stored information on a particular topic (Wegner, 1987 & 1995).

Various Aspects of a TMS (Specialization, Coordination, Trust)

Establishing and maintaining a TMS has mainly been studied along with three main aspects of a TMS in a group, namely specialization, coordination, and trust (see Lewis, 2003; Michinov & Michinov, 2009; Moreland et al., 1996 & 1998). Specialization represents the awareness and recognition of expertise distributed in the group. Credibility or trust represents the extent to which group members trust and rely on each other's specific expertise while collaborating on a learning task. Coordination represents the group members' ability to work together efficiently on a learning task with less confusion, fewer misunderstandings, and a greater sense of collaboration (Michinov & Michinov, 2009).

For the purpose of this study, it is important to describe the relation between various processes and aspects of a TMS in collaborative learning settings. Therefore, in the following section, essential interdependent processes for establishing and maintaining a TMS in a group (encoding, storage, retrieval) are explained in relation to the three main aspects of a TMS (specialization, coordination, trust).

Relations between Various Processes and Aspects of a TMS

Specialization is the product of the encoding process, which reflects the differentiation of one's own expertise from the knowledge repertoire of other group members (Michinov & Michinov, 2009; Wegner, 1995). This explication of expertise (encoding) allows the group to acquire different complementary knowledge and enlarge its total collective knowledge (Michinov & Michinov, 2009). Specialization in learning groups occurs when group members encode and evaluate one another's expertise and competence and label information as belonging to members whom the group trusts most as the source of specific expertise (Lewis, 2003; Moreland et al., 1996 & 1998). Encoding could be best achieved through proper interaction between group members as a first essential step towards specialization (Wegner, 1987 & 1995). This explication of expertise (encoding) helps learners initiate a productive discussion from the beginning to pool and process learning partners' unshared information and knowledge resources rather than engaging in discussions of information already shared

among group members (Moreland & Myaskovsky, 2000; Rummel & Spada, 2005; Rummel et al., 2009; Stasser et al., 1995), or discussions to establish common ground (Beers et al., 2005 & 2007). Speeding up the process of pooling unshared information as a way to heighten awareness of distributed knowledge resources in a group can be seen in the form of knowledge elicitation and/or knowledge externalization for the learning partners according to their areas of specialization. In externalization, learners explicate their knowledge with respect to the problem case, whereas elicitation aims at receiving information from the learning partner(s) in collaborative learning (Weinberger & Fischer, 2006). These transactions may further be followed by the exchange of specialized feedback. Content-related feedback can be based on the learning partner(s) specialized domains of expertise and be given in the form of further inquiry, clarification, and/or elaboration of the learning materials during discourse (Rummel & Spada, 2005; Rummel et al., 2009).

Specialization plays an important role during the storage process. Based on the estimation of knowledge awareness and recognition of expertise distributed in the group, learners can coordinate the distributed knowledge in the group. On the basis of this estimation of the specialized domains of expertise, learners assign responsibility to the expert in the group and store relevant information that fits their domains of expertise during the storage process (Wegner, 1987 & 1995). Coordination also plays a key role during the storage process since group members need to assign responsibility to the individual who has the most expertise in the group on a particular topic to ensure that no information is missed by the group as a whole (Lewis, 2003; Rulke & Rau, 2000). Coordination in a group could be best achieved in the storage process when learners share the task and collaboratively assign responsibilities based on the labeled information in the encoding process (Lewis, 2003). Trust is also important during the storage process since learning partners should make sure that the information that is required for solving the learning task is stored by one of the credible group members.

Coordination comes to play during the retrieval process since group members need to turn to the relevant expert(s) for the retrieval of information based on the group members' expertise (Wegner, 1995). Retrieval coordination is best achieved when group members provide relevant information on the topic and analyse parts of the problem case based on assigned tasks and roles in relation to their specialized domains of expertise. Finally, they can combine their analyses followed by discussions and elaborations on the basis of their own and the learning partner's specialized expertise (Lewis, 2003; Rulke & Rau, 2000; Wegner, 1987). Trust also plays an important role during the retrieval process since learners need to make

sure that the stored information of the learning partners is credible when combining and retrieving knowledge and information for accomplishing the joint learning task. In problem-solving settings, learners may sometimes use their meta-knowledge for coordinating subtasks and the division of labour such that their individual contributions can later be assembled into a group product (Dillenbourg, 1999). This form of combining knowledge involves little transactivity and may therefore represent a division of labour in what can be called "cooperation" in contrast to "collaboration" (Dillenbourg, 1999, p. 8). In cooperation, learning partners typically split the task, and individually take responsibility for part of the task based on their expertise and then assemble the partial results into the final output (Dillenbourg, 1999). As a result, learners may avoid engaging in critical and transactive discussions and immediately accept their partner(s)' contributions without further discussion. In contrast, learners may use their meta-knowledge in a collaborative rather than cooperative manner by elaborating on the material, integrating, and synthesizing one another's perspectives and ideas in order to jointly make sense of the learning task (Fischer et al., 2002; Nastasi & Clements, 1992; Schoor & Bannert, 2011). This productive interaction followed by persuasive discussions would help learners revise, modify, and adjust their initial contributions on the basis of their partner(s)' contributions. In this form of combining knowledge, learning partners use their meta-knowledge not only for coordinating subtasks, but also for creating novel information by integrating their individual expertise in a collaborative manner. In other words, learning partners integrate information from a TMS to work together in what can be called "collaboration" rather than "cooperation" (Dillenbourg, 1999, p. 8). This integrative form of combining knowledge involves more transactivity since information coming from different locations in the transactive system is tied together by a common label leading to elaboration of the material and knowledge of the partner(s) for making sense of the joint solution and discovering new knowledge (Dillenbourg, 1999).

The third aspect of TMS, trust is the result of the other two aspects, namely specialization and coordination (Lewis, 2003). The level of trust in a group can be enhanced if learners make sure that their learning partner(s)' knowledge is credible (Lewis, 2003). When members of a learning group are not fully aware of other members' expertise, they may exhibit a lack of trust, for example by ignoring or disregarding information submitted by their learning partners (Zheng, 2012). Making portfolios of one's own and the learning partner(s)' expertise in the encoding process, coupled with interaction between group members, sharing one's own knowledge and externalizing others' knowledge during the storage and retrieval processes

allows group members to judge and evaluate the trustworthiness, accuracy, and credibility of their learning partner(s)' knowledge (Moreland et al., 1996 & 1998; Rulke & Rau, 2000). Mutual trust and credibility could be achieved by appropriate communication and interaction between group members for sharing task responsibilities based on relevant experience of other individuals in the group while collaborating on a learning task. Learning partners need to trust and rely on each other when they divide the learning task and accept responsibilities for parts of the tasks for which they have the most expertise.

Despite the positive role played by mutual trust in the construction of a TMS among group members, over-reliance on trust without the effective utilization of members' expertise has been argued to be counter-productive (Zheng, 2012). This often happens when learners exhibit a high level of mutual trust without accurately understanding individual members' expertise in the group. When learning partners build mutual trust based on the proper awareness of each other's expertise, they are willing to not only externalize their specialized knowledge but also confront each other without worrying about negative consequences (Zheng, 2012). Building such a mutual trust can help learning partners to elaborate on the learning materials and challenge one another's opinions based on individual members' expertise in a psychologically safe environment (Edmondson, 1999).

Techniques to Facilitate a TMS in Collaborative Learning

Different approaches have been used to facilitate various aspects of a TMS in both organizational and educational settings. These techniques include individual and group training (e.g. Liang et al., 1995; Prichard & Ashleigh, 2007; Moreland et al., 1996 & 1998), formation of groups based on complementary expertise (e.g. Hollingshead, 2000 & 2001), and computer-supported settings (e.g. Engelmann & Hesse, 2010; Schreiber & Engelmann, 2010). This paper focuses on the use of computer support systems to facilitate construction of a TMS in a multidisciplinary setting. These platforms, known collectively as Computer-Supported Collaborative Learning (CSCL), allow for the embedding of various representational structures to facilitate knowledge construction and sharing. These structures can be represented graphically (e.g. in the form of digital concept maps or awareness tools) or textually (e.g. with text prompts in some computer-supported collaboration scripts) to guide learners' interactions and to co-construct shared knowledge (e.g. Kirschner et al., 2003; Noroozi & Biemans et al., 2011; Noroozi & Busstra et al., 2012; Weinberger et al., 2005a).

In CSCL, learning partners are seen as additional learning resources when they contribute unshared prior knowledge to the discussion, which may eventually be shared after collaboration (Noroozi & Weinberger et al., 2013; Weinberger et al., 2010). Interacting with one another and being involved in various activities (e.g. social, epistemic, and argumentative activities), learners could both individually and collectively (co)construct knowledge in CSCL while elaborating learning materials in problem-solving activities (e.g. Weinberger et al., 2005a). Furthermore, this co-construction of knowledge about the issue at stake in CSCL environments can also be applied to solve complex and ill-defined problems (e.g. Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Janssen et al., 2010). One of the most prominent instructional approaches in CSCL is the use of scripts that can facilitate both knowledge construction and transfer as well as problem-solving activities.

Computer-Supported Collaboration Scripts to Facilitate a TMS

Despite vast research on various techniques to facilitate a TMS in collaborative settings, the effects of computer-supported collaboration scripts on various aspects of a TMS especially in multidisciplinary settings are still unclear. This is striking since scripts can be textually implemented into the CSCL platform in a variety of forms such as cues, prompts, input text boxes, etc. (e.g. Weinberger et al., 2005a) to foster both collaborative and individual learning (e.g. Fischer et al., 2002; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Weinberger et al, 2005a & 2007b). Scripts are specific instructions that stipulate the type and sequence of collaborative learning activities in order to help group members collaborate and accomplish tasks (see Dillenbourg, 2002; Noroozi & Weinberger et al., 2012; Tchounikine, 2008). Epistemic scripts structure and sequence discourse activities with respect to the content and task strategies (Weinberger et al., 2005a). Such a script can be used to facilitate the specialization aspect of the TMS by providing guidelines for learners to appropriately engage in task-oriented activities on the basis of their prior knowledge and specialized domains of expertise. For example, the results of two empirical studies (Schellens et al., 2007; Weinberger et al., 2005a) showed that epistemic scripts facilitate collaborative learning. Specifically, in a study by Schellens et al. (2007), content-oriented (epistemic) scripts facilitated epistemic activities and induced meta-cognitive activities. A social script specifies and sequences learners' discourse activities with respect to the transactive social modes and interaction strategies (Weinberger & Fischer, 2006). Such a script can be used to facilitate the specialization aspect of the TMS by providing guidelines for learners to adopt adequate interaction and social strategies such as elicitation, externalization, and transactivity

(responding critically to partners' contributions). Collaboration scripts provide explicit guidelines for small groups of learners to clarify when and by whom certain activities need to be executed (Weinberger & Fischer, 2006; Weinberger et al., 2005a). Such a script can be used to facilitate the coordination aspect of a TMS by assigning responsibilities for the division of labour and roles as well as time management (e.g. what to do, when, by whom, how, etc.). In studies by Strijbos et al. (2004b & 2007), the use of collaboration scripts in the form of assigning functional roles stimulated coordination, which was related to the number of task-content-focused statements. The communication-oriented (collaboration) scripts facilitated interaction between participants and induced cognitive processes (Schellens et al., 2007). CSCL scripts could be designed in such a way as to regulate learners' interaction and coordination strategies. For example, Rummel and colleagues asked multidisciplinary groups of learners to work on a complex learning task followed by detailed and step-by-step script guidelines prescribing specific phases for their interaction (Rummel & Spada, 2005; Rummel et al., 2009). Here, dyads of advanced medical and psychology students were composed to jointly diagnose patients and to develop a therapy plan making use of their complementary expertise. The results showed that collaboration scripts facilitate coordination and problem-solving activities, and hence learners benefit from one another's expertise as a source for clarifications and deepening of knowledge. Other research studies have also shown various benefits of different scripts on task coordination and performance in CSCL (e.g. Fischer & Mandl, 2005; Noroozi & Weinberger et al., 2013; Weinberger et al., 2005). The role of these scripts, however, has not been reported as such in relation to the interdependent processes of the TMS in multidisciplinary CSCL settings.

Research Questions

The effects of computer-supported collaboration scripts on the construction of a TMS are still under-investigated in multidisciplinary collaborative learning contexts. The picture is even more unclear with respect to whether and how facilitation of a TMS by CSCL scripts influences learners' knowledge transfer as well as joint and individual problem solutions in a multidisciplinary CSCL setting. Therefore, the current study was designed to test the effects of a transactive memory script that spans three interdependent processes (encoding, storage, retrieval) on various aspects of a TMS (specialization, coordination, trust) in a problem-based multidisciplinary CSCL setting. In addition, the extent to which this specific script influenced learners' knowledge transfer as well as joint and individual problem solution plans was studied. The following research questions were formulated to address these issues:

1. To what extent does a transactive memory script facilitate various aspects of a TMS (specialization, coordination, trust) in a multidisciplinary CSCL setting?

This research question was designed to investigate the impact of a transactive memory script on the construction of a TMS in newly formed CSCL dyads. Specifically, we tested whether a TMS could be constructed without longer-lasting interaction and communication in multidisciplinary dyads of learners in a CSCL setting. To date, positive effects of meta-knowledge awareness of the learning partner on construction of a TMS have been reported in terms of directory updating processes through group training (e.g. Moreland & Myaskovsky, 2000) and graphical knowledge maps in CSCL (Schreiber & Engelmann, 2010). The underlying question for this study was whether a transactive memory script, established through a set of prompts in CSCL, would lead to a prompt construction of a TMS in ad hoc groups of experts to solve a complex problem. Since all essential processes for establishing a TMS in a group (encoding, storage, retrieval) were targeted by specific prompts, it was expected that the transactive memory script would be effective in facilitating construction of a TMS in newly formed dyads of learners in a multidisciplinary CSCL setting. Therefore, we expected that our transactive memory script would facilitate aspects of a TMS, namely specialization, coordination, and trust.

2. What are the effects of a transactive memory script on learners' knowledge transfer measures and quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?

This research question was designed to investigate the impact of transactive memory script on knowledge transfer measures and quality of joint and individual problem solution plans in a multidisciplinary CSCL setting. In line with previous findings of a positive impact of a TMS on group performance (e.g. Hollingshead, 1998a, 1998b, & 1998d; Liang et al., 1995; Moreland et al., 1996; Stasser et al., 1995), it was expected that the transactive memory script would improve the quality of joint problem solution plans. Furthermore, since a comparable case-based assignment was used to assess the quality of individual problem solution plans right after the collaborative learning phase, it was expected that the transactive memory script would also improve the quality of individual problem solution plans as well as knowledge transfer in newly formed dyads in a multidisciplinary CSCL setting.

3. What are the mediating effects of the TMS on the impacts of the transactive memory script on the quality of learners' joint and individual problem solution plans in a multidisciplinary CSCL setting?

This research question was designed to investigate whether the specific aspects of a TMS mediate the impacts of a transactive memory script on the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting. The mediating effect of the TMS has been shown previously (e.g. Liang et al., 1995), but has not yet been tested for the transactive memory script in newly formed dyads in a multidisciplinary CSCL setting. If the first and second assumptions of this study are confirmed, we can also expect that the specific aspects of a TMS could explain the underlying impacts of a transactive memory script on the quality of joint and individual problem solution plans in newly formed dyads in a multidisciplinary CSCL setting.

Method

Context and Participants

The study took place at Wageningen University in the Netherlands focused on the life sciences, especially food and health, sustainability, and the healthy living environment. Students at this university are stimulated to combine natural and social sciences: from plant sciences to economics and from food technology to sociology. The participants were 60 university students from two disciplinary backgrounds, namely international land and water management as well as international development studies. These two complementary domains of expertise were required for accomplishing the learning task of this study. The mean age of the participants was 24.93 ($SD = 3.40$) years. The majority of participants (63%) were female; only 37% were male. This almost mirrors the proportion of female and male students in this university. The numbers of Dutch and foreign students were about equal.

The participants, who were compensated €50 for their contribution to this study, were divided into multidisciplinary pairs based on their disciplinary backgrounds. In other words, participants were randomly paired, with one learner having a water management disciplinary background and the other learner having an international development disciplinary background. The participants in each pair did not know each other beforehand. Next, each pair was randomly assigned to either the treatment condition (scripted) or the control group (unscripted) in a one factorial design. After dividing pairs of learners into these two

conditions, each of which included 15 pairs, the experimental group was given a transactive memory script and the control group was not given a transactive memory script.

Learning Materials

The subject to be learned was the concept of Community-Based Social Marketing (CBSM) and its application in Sustainable Agricultural Water Management (SAWM). The participants' task was to apply the concept of CBSM in fostering sustainable behaviour among farmers in terms of SAWM. Specifically, in a collaborative learning phase, learners were asked to analyse and discuss the problem case and design an effective plan for fostering sustainable behaviour as a solution. They were asked to take into account the farmers' various perspectives on the need – or lack thereof – of implementing SAWM. The learning task was authentic and complex and allowed learners to construct different arguments based on the concepts of CBSM and SAWM. CBSM is based on research in the social sciences demonstrating that behaviour change is most effectively achieved through initiatives delivered at the community level which focus on removing barriers to an activity while simultaneously enhancing the activity's benefits. Learners with an international development studies background were expected to have knowledge on CBSM. They thus were required to have passed at least two courses in which the concept of CBSM or related topics had been studied ($M = 3.78$, $SD = 1.64$). SAWM can be defined as the manipulation of water within the borders of an individual farm, a farming plot or field. SAWM seeks to optimize soil-water-plant relationships to achieve a yield of desired products. SAWM may therefore begin at the farm gate and end at the disposal point of the drainage water to a public watercourse, open drain or sink. Learners with an international land and water management studies background were expected to have knowledge on SAWM. They thus were required to have passed at least two courses in which the concept of SAWM or related topics had been studied ($M = 3.50$, $SD = 1.23$). In order to avoid any possible overlapping between students in the subjects (SAWM and CBSM), they were asked to write down passed relevant courses that belong to the domain expertise of the learning partner. No overlapping was found.

According to Kitaygorodskaya and Helo (2006), both knowledge heterogeneity and homogeneity are required for team performance to be efficient in collaborative learning (see Cannon-Bowers & Salas, 1997). Knowledge heterogeneity is required for team members to benefit from and take advantage of one another's complementary expertise for jointly accomplishing learning tasks that would have been nearly impossible individually

(Kitaygorodskaya & Helo, 2006). Knowledge homogeneity or overlapping knowledge is still to some degree required for team members in order to be able to understand each other (Kitaygorodskaya & Helo, 2006) and also to establish adequate coordination (Mohammed & Dumville, 2001). Therefore, all learners were provided with a three-page description of the CBSM and SAWM and also demographic characteristics of the farmers and geographical characteristics of the location. The description of the problem case and theoretical background was embedded in the web-based learning environment during collaboration, so that the learners could study them while composing new messages on the discussion boards.

Implementation of the Transactive Memory Script in the CSCL Platform

The two learning partners in each dyad were distributed over two laboratory rooms. An asynchronous text-based discussion board called SharePoint was customized for the purpose of our study. Immediate (chat-like) answers were not possible in the learning environment. The style of the interaction rather resembled e-mail communication for the exchange of text messages. During the collaborative phase, the learners' task in both conditions was to analyse, discuss, and solve the problem case in pairs on the basis of the theoretical background (conceptual space) and to arrive at a joint solution. The goals were for the students to share as much knowledge as possible during collaboration and to discuss and elaborate on the theoretical concepts in each partner's specific domain to collectively design sound solution plans for the problem case. In other words, students were expected to combine their complementary domain-specific knowledge, and then to discuss and elaborate on this information such that it could be applied for designing solution plans for the problem cases.

Each message consisted of a subject line, date, time, and the message body. While the SharePoint platform set author, date, time, and subject line automatically, the learners had to enter the body of the message. The platform allowed for textual implementation of scripts. The CSCL environment for learners in the experimental condition was the same as in the control condition except for the transactive memory script, which structured the discussion phase in the platform. The conditions were distinguished and implemented as follows:

The control condition

The learning partners received no further support beyond being asked to analyse, discuss, and solve the problem case on the basis of the conceptual space and to type their arguments into a blank text box.

97

The experimental condition

The platform in this condition was the same as in the control condition except for the transactive memory script. Building on interdependent processes of the TMS, namely encoding, storage, retrieval (see Wegner, 1987), we developed a script that spanned three phases: building awareness (encoding), storage, retrieval. For each phase, specific types of prompts were embedded in the CSCL platform; however, all replies by learning partners were standard messages without a prompt (see figure 4.1 for an example). The number of prompts was different for each phase. Each learner received three prompts for the building awareness phase, two prompts for the storage phase, two prompts for the individual retrieval phase, and two prompts for the collaborative retrieval phase. Learners received each set of prompts separately for each specific phase at the same time. In other words, respective sets of prompts were given to learners at four intervals (building awareness, storage, individual and collaborative retrieval phases). For example, a set of prompts for the building awareness phase was given to each learner of a dyad at the same time and she/he was asked to answer these three pre-structured messages and submit the responses into the CSCL platform (see figure 4.1). For all four intervals, learning partners were able to see one another's prompts and their respective responses after the learning partner submitted his/her responses into the CSCL platform. The same approach was followed for all four intervals. The CSCL platform offered the particular set of prompts and learners were responsible for selecting these prompts and then replying to them accordingly. These prompts are described below.

In the phase of building awareness, learners were given 10 minutes to introduce themselves, compose a portfolio of their expertise, and indicate what aspects of their expertise applied to the given case. They were prompted to present their specific expertise, and not general knowledge, in the portfolio message (see figure 4.1). Therefore, the content of the initial messages was pre-structured with prompts (e.g. "Briefly sketch the knowledge areas you have mastered in your studies so far..."; "Indicate what aspects of your expertise apply to this case..."; "Indicate what other knowledge might be relevant to this case..."). The prompts in the phase of building awareness were intended to facilitate the encoding process and specialization aspect of the TMS by creating knowledge awareness and recognition of expertise distributed in the dyad. These prompts, in line with epistemic and social scripts, help learning partners appropriately engage in discourse activities for knowledge elicitation and externalization on the basis of their awareness of one another's specialized expertise (see Schellens et al., 2007; Noroozi & Weinberger et al., 2012; Weinberger et al., 2005a).
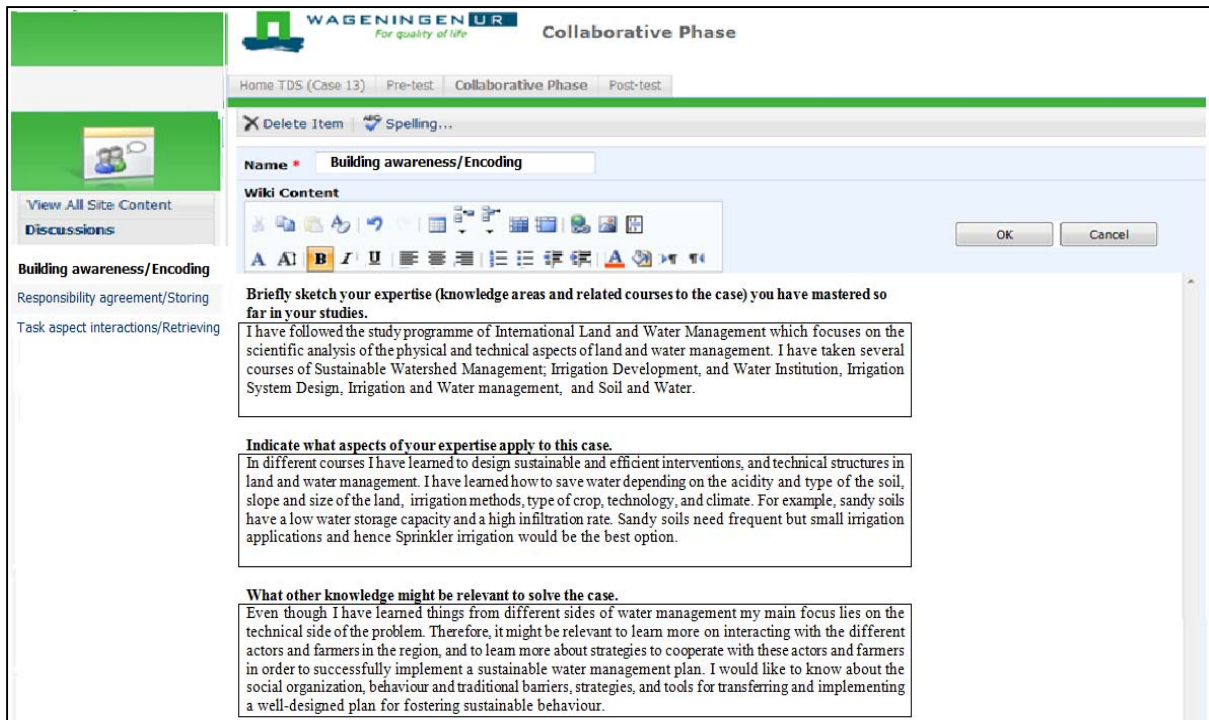
Figure 4.1: Screenshot of the transactive memory script for building awareness (encoding) phase.

In the storage phase, the group members were given 15 minutes to read the portfolios and discuss the case, with the goal of distributing responsibility for various aspects of the learning task in the group. Respective prompts aimed at helping the students to identify what expertise should be applied to what aspect of the task and to take responsibility for those aspects that matched their own expertise. The content of the initial messages in this phase were pre-structured with prompts, such as: "The following aspects of the task should be analysed by..."; "I will take responsibility for the following aspects of the learning task...". The group members were asked to compose at least one task distribution and one acceptance of responsibility message. The prompts in the storage phase were intended to facilitate the coordination aspect of a TMS through the assignment of responsibilities for labeling and storing information and acceptance of those responsibilities. These prompts, in line with collaboration scripts, help learning partners clarify what, when, and by whom certain activities need to be executed to accomplish the learning task (Weinberger et al., 2005a).

In the individual part of the retrieval phase, the group members were given 15 minutes to analyse and solve previously assigned parts of the task based on their specific expertise. Again, the content of the initial messages was pre-structured with prompts (e.g. "The task aspects related to expertise XY are addressed as follows…"). In the collaborative part of the retrieval phase, learners were given 40 minutes and guided to combine their solutions on the

basis of their specialized domains of expertise. They received prompts to construct a joint solution, to consider both areas of expertise in a balanced way and to indicate agreement on the solution based on argumentation. The content of their initial messages was pre-structured with prompts such as: "The two aspects of the task interact in the following way..."; "To adjust and combine our solutions, I suggest that...". These prompts were intended to facilitate the coordination aspect of a TMS by guiding learners to regulate the processes of retrieving and including knowledge in the group. These prompts, in line with collaboration scripts, stipulate the type and sequence of learning activities to help group members collaborate and accomplish tasks (Noroozi & Teasley et al., in press; Weinberger et al., 2005a). As discussed above, the trust aspect of a TMS as the outcome of the other two aspects was expected to be indirectly facilitated through the transactive memory script (Lewis, 2003).

Procedure

In a pilot study with eight learners we first ensured adequate levels of task difficulty, comprehensibility of the learning materials, applicability of the tests and the technical functioning of the script, and the learning environment. Overall, the experimental session took about 3.5 hours and consisted of four main phases with a 10-minute break between phases two and three. During the (1) introduction and pre-test phase, which took 35 minutes, individual learners received introductory explanations for 5 minutes. They were then asked to complete several questionnaires (30 minutes) on demographic variables, computer literacy, prior experience with and attitude towards collaboration. The data from these tests were used to check for randomization (see section Control Measures). During the (2) individual learning phase, learners first received an introductory explanation of how to analyse the case (5 minutes). They were then given 5 minutes to read the problem case and 10 minutes to study a three-page summary of the theoretical text regarding SAWM and CBSM. Learners were allowed to make notes and keep the text and their notes during the experiment. Prior to collaboration, learners were asked to individually analyse the problem case and design an effective plan (20 minutes) for fostering sustainable behaviour on the basis of their own domain of expertise. Specifically, learners with an international development background were asked to design an effective plan for fostering sustainable behaviour among Nahavand farmers taking into account the concept of CBSM, whereas learners with an international land and water management background were asked to design an effective plan for fostering SAWM. The data from this test served two purposes: to assess learners' prior knowledge regarding SAWM or CBSM, and to help us check for the randomization of learners in terms

of prior knowledge over two conditions. After a 10-minute break, the (3) collaborative learning phase (90 minutes) began. First, learners were oriented to the CSCL platform and acquainted with the procedure of the collaboration phase (10 minutes). Subsequently, learners were asked to discuss and argue their analyses and design plans in pairs (80 minutes). Specifically, they were asked to analyse and discuss the problem case and jointly design an effective plan for fostering SAWM based on the concept of CBSM. This joint solution served as the criteria for assessing the quality of joint problem solution plans. During the (4) post-test and debriefing phase (45 minutes), learners were asked to work on a comparable case-based assignment individually (20 minutes) based on what they had learnt in the collaboration phase. Specifically, they were asked to analyse and design an effective plan for fostering sustainable behaviour among Nahavand wheat farmers in terms of irrigation methods that could be applied for fostering SAWM as a CBSM advisor. This individual task was used for assessing the quality of individual problem solution plans. As a post-test, learners were asked to fill out several questionnaires to assess various aspects of a TMS and their satisfaction with the learning experiences and its outcomes (20 minutes). Finally, the participants got a short debriefing for about 5 minutes (see table 4.1 for the procedure of the study).

Table 4.1: Overview of the procedure of the experimental study.

Phase	Description	Duration
(1)	*Introduction and pre-test phase*	*35 min*
	Introductory explanations	5 min
	Assessment of personal data (questionnaires)	10 min
	Assessment of collaboration and computer experiences, prior experience with and attitude towards collaboration, etc. (questionnaires)	20 min
(2)	*Individual learning phase*	*40 min*
	Introductory remarks	5 min
	Individual study phase of the theoretical text (conceptual space and problem case)	15 min
	Measurement of prior knowledge (individual analysis)	20 min
(3)	*Collaborative learning phase*	*90 min*
	Introduction to the CSCL platform	5 min
	Explanation of the procedure	5 min
	Collaborative learning phase (online discussion)	80 min
(4)	*Post-tests and debriefing*	*45 min*
	Individual analysis of the problem case	20 min
	Assessment of the TMS, satisfaction with the learning effects and experiences	20 min
	Debriefing	5 min
Total time		*3.5 hrs.*

Measurements, Instruments, and Data Sources

Measurement of the TMS

Studies conducted to date on the TMS differ in terms of measurement approaches. Most authors favour a multi-method approach to measure the TMS (Moreland et al., 2010). For the purpose of our study, we employed two different approaches to measure the TMS. Data concerning the TMS measures were collected by means of a questionnaire and by analysing the discourse activities during the collaborative learning phase.

Measurement of the TMS by questionnaire

We adapted a questionnaire from Lewis (2003) to assess the learners' TMS (see table 4.2). This questionnaire consisted of three sections corresponding to three aspects of the TMS (specialization, coordination, and trust) with 15 items in total on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". The reliability and validity of these scales have been reported as adequate in various contexts (e.g. London et al., 2005; Michinov, 2007; Michinov & Michinov, 2009). In this study, the reliability coefficient was satisfactory for all three aspects of the TMS (*Cronbach* α = .75, .78, and .74 respectively).

Table 4.2: The transactive memory system scale items adapted from Lewis (2003).

Variable	Item
Specialization	Each team member has specialized knowledge of some aspect of the case.
	I have different knowledge about an aspect of the case than my partner has.
	Different team members were responsible for expertise in different areas.
	My partner's specialized knowledge was needed to complete the task.
	I now know what expertise my partner has and the specific areas it relates to.
Trust	I was comfortable accepting procedural suggestions from my partner.
	I trusted that my partner's further knowledge about the case was credible.
	I was confident relying on the information that my partner brought to the discussion.
	When my partner contributed information, I wanted to double-check it for myself. (reversed)
	I did not have much faith in my partner's expertise. (reversed)
Coordination	Our team worked together in a well-coordinated fashion.
	Our team had very few misunderstandings about what to do.
	Our team needed to backtrack and start over a lot. (reversed)
	We accomplished the task smoothly and efficiently.
	There was much confusion about how we would accomplish the task. (reversed)

Measurement of the TMS using discourse

Prior research studies (e.g. Austin, 2003; Schreiber, & Engelmann, 2010; Rau, 2005) have mostly used survey, questionnaire, and/or interview methods to measure different aspects of the TMS. In this study, we adapted a coding scheme developed by Rummel and Spada (2005) and Rummel et al. (2009) based on the purpose of our study and used the interaction patterns of the dyads of learners during discourse activities to measure the three aspects of the TMS, namely specialization, coordination, and trust.

Specialization was operationalized in terms of the number of messages that were allocated for (1) elicitation, (2) externalization, and (3) giving feedback. When learners asked for or invited a reaction from their learning partners, we coded the message as elicitation (e.g. "What are the possible technical problems in the area in terms of implementing a sprinkler irrigation method?"). Typically, this was done by asking questions, however, learners often forgot the question marks or made proposals rather than asking directly (e.g. "We should also talk about the external barriers for behaviour change."). When learners outlined their knowledge and explained new content to the learning partners without reference to earlier messages, for instance when they composed the first analysis in the discussion board or typically also the first messages in a discussion thread, we coded the message as externalization (e.g. "I would encourage farmers to use a drip irrigation method since there is steeply sloped land in the area and this could prevent runoff."). Sometimes, learners might have juxtaposed externalizations by replying to earlier externalizations, with an externalization. When learners outlined their knowledge and gave feedback to the learning partner in response to earlier messages and the questions raised, for instance when they provided clarifications, and elaborations for their already externalized information during discussion, we coded the message as giving feedback. We then computed all messages that were allocated for elicitation, externalization, and giving feedback and used the total as an indicator for the specialization aspect of the TMS.

Coordination was operationalized in terms of the number of messages that were allocated for (1) time management, (2) task division (in terms of labour and roles), and (3) technical coordination. When learners checked for the timeline, arranged a timetable or referred to the time (e.g. "Time is running out quickly; How much time is left?"; "Write down your answer faster."; "Only 20 minutes left to come up with our joint solution."), we coded the message as time management. When learners referred to assigning task responsibility, acceptance of responsibility regarding who should do what, we coded the message as task division (e.g.

"Shall I write about the type of irrigation and you write about the external barriers in technology adoption?"; "I am going to write about the technical infrastructure for an irrigation system."; "Can you take responsibility for the social aspects of the learning task?"). When learners asked or explained anything regarding the functionality of the platform (e.g. "Are we supposed to put our individual analysis in the text editor?"; "I cannot find the Italic font in the shared text editor! Can you help me with that?"), we coded the message as technical coordination. We then computed all messages that were allocated for time management, task division, and technical coordination and used the total as an indicator for the coordination aspect of the TMS.

There were other types of messages during the collaborative learning phase (e.g. task enjoyment, task motivation, off-task messages) that could not be allocated to specialization or coordination indicators in this experiment (e.g. "I really enjoy using the platform, do you?"; "I am very happy with my learning progress."; "It was a great idea to participate in this experiment."). Since these types of messages during the collaborative phase were not dependent on the TMS (i.e. not typical indicators of the TMS) and also since they were not targeted by the transactive memory script, we excluded them from analysis.

Trust or credibility was operationalized in terms of the extent to which each learner in the dyad trusted the knowledge of his/her learning partner. Trust or credibility could be established between learners when they agreed to incorporate theoretical concepts that were discussed during discourse into their joint problem solution plan. As a data source, the contributions of the two learners in a dyad to the discourse and to the joint problem solution plan were used. As an indication of the level of trust of learner A in learner B, the number of theoretical concepts (present in the joint solution plan) originally introduced by learner B was divided by the total number of concepts brought in by learner B in the discourse. In addition, as an indication of the level of trust of learner B in learner A, the number of theoretical concepts originally introduced by learner A was divided by the total number of elements brought in by learner A in the discourse. To calculate a total trust score for each dyad, the individual trust scores for learners A and B were added and divided by 2.

Two trained coders coded three discourse corpora in each condition to evaluate reliability index of inter-rater agreement. The inter-rater agreement computed on the basis of this overlapping coding of the processes of the TMS was sufficiently high (*Cohen's* κ = .88). Moreover, intra-coder test-retest reliability was calculated for 10% of the discourse corpora.

This resulted in identical scores in 93% of the contributions. Since the number of messages for each aspect of the TMS were not independent and could be influenced by the total number of messages that were exchanged between learning partners, the scores for each aspect of the TMS were transformed into proportions. In other words, a pair's score on specialization and coordination aspects of the TMS was divided by the total number of messages that they produced during discourse. In such an approach, we could measure to what extent each pair of learners allocated their discourse activities to each specific aspect of the TMS.

Measuring knowledge transfer

We operationalized knowledge transfer as an interaction between domain-specific knowledge of the individual learner and learning partner in terms of individual-to-group, group-to-individual, and shared knowledge transfer measures (see Noroozi & Teasley et al., in press). Knowledge transfer measures were analysed based on an expert solution. This expert solution included all the possible theoretical concepts of SAWM and CBSM and their relations to one another and to the problem cases. The next step involved characterizing the content of all individual representations, both before (pre-test) and after collaboration (post-test), and the group representation. Learners received credits for adequately applying theoretical concepts and for relating them appropriately to one another and to case information in their solution plans. Both inter-rater agreement between two coders (*Cohen's κ = .88*) and intra-coder test-retest reliability for each coder for 10% of the data (90% of identical scores) were sufficiently high. The descriptions of various forms of knowledge transfer are as follows:

Individual-to-group knowledge transfer

The impact that each individual learner may have on the group solution plan was estimated by the total number of his/her own individual representations that s/he managed to incorporate in the group solution plan (see Noroozi & Teasley et al., in press). The indicator of individual-to-group knowledge transfer for each participant was then the sum score of all relevant and correct applications of one's own theoretical concepts that were incorporated in the dyad's joint solution plan (see figure 4.2).

Group-to-individual knowledge transfer

Building on Noroozi and Teasley et al. (in press), the impact that each dyad may have on the individual learner was estimated by the total number of relevant and correct applications of a

learning partner's theoretical concepts that were transferred from the shared group cognition (present in joint solution plan) to the individual cognitions (individual post-test measures). The indicator of group-to-individual knowledge transfer for each participant was then the sum score of all relevant and correct applications of the learning partner's theoretical concepts from the joint solution plan that were transferred to one's own individual solution plan in the post-test (see figure 4.2).

Shared knowledge transfer

We used individual learners' solution plans after the collaborative learning phase to measure shared knowledge transfer between individual members of the dyads, that is knowledge convergence (see Noroozi & Teasley et al., in press). Knowledge convergence refers to knowledge that learning partners share after collaborative learning (i.e. Jeong & Chi, 2007; Weinberger et al., 2007a). The indicator of shared knowledge transfer for each dyad was the sum score of all relevant and correct applications of theoretical concepts, which both partners in a dyad appropriately shared in their individual representations in the post-test case analysis (see also Fischer & Mandl, 2005). For example, as can be seen in figure 4.2, Tom and Jane shared eight relevant and correct applications of theoretical concepts. Five of these concepts belong to Tom's domain of expertise and three of them belong to Jane's domain of expertise.

Measuring quality of collaborative and individual problem solution plans

The measure of group performance was operationalized as the quality of the joint solution plan produced by the dyad during discourse. The measure of individual performance was operationalized as the quality of the individual solution plan produced by each learner after collaboration in the post-test written analysis. In our quantitative analyses of knowledge transfer measurements, we focused on the applications of the theoretical concepts, relations between them and to the case information (see Noroozi & Teasley et al., in press).

The strategy adopted for measuring the quality of collaborative and individual problem solution plans was to focus on the extent to which pairs and individual learners were able to support their theoretical assumptions in relation to the case with justifiable arguments, discussions, and sound interpretations that contributed to the advancement of the solution plan. Both group and individual solution plans were independently rated by two coders on a four-point scale ranging from "inadequate solution plan" to "high-quality solution plan" (see table 4.3). Both inter-rater agreement between two coders (*Cohen's κ = .91*) and intra-coder

test-retest reliability for each coder for 10% of the data (95% of identical scores) were sufficiently high. We then assigned 0 points for inadequate problem solution plans, 1 point for low quality, 2 points for rather low quality, 3 points for rather high quality, and 4 points for high-quality problem solution plans. Based on these points, we calculated the mean quality score for the joint (group values) and individual (aggregated individual values) problem solution plans in both scripted and unscripted conditions.

Table 4.3: Coding scheme for assessing quality of collaborative and individual problem solution plans.

Code	Description
Inadequate solution plan quality	Solution plan is weakly supported, if at all. The solution plan only contains everyday concepts and case information. None or hardly any aspect of the theoretical concepts is discovered.
Low quality solution plan	The solution plan is partly supported by a mix of theoretical concepts in relation to the problem case with little, if any, discussion and justification of the assumptions made.
Rather low quality solution plan	The solution plan is adequately supported by a mix of theoretical concepts in relation to the problem case. Assumptions made are not, however, adequately elaborated on, justified, or discussed.
Rather high quality solution plan	The solution plan is adequately supported by a mix of theoretical concepts in relation to the problem case. Assumptions made are partly elaborated on, discussed, or justified.
High quality solution plan	The solution plan is adequately supported by a mix of theoretical concepts in relation to the problem case. Assumptions made are adequately elaborated on, discussed, or justified. Almost all or all of the relation between theoretical concepts and problem case are discovered, discussed, and justified.
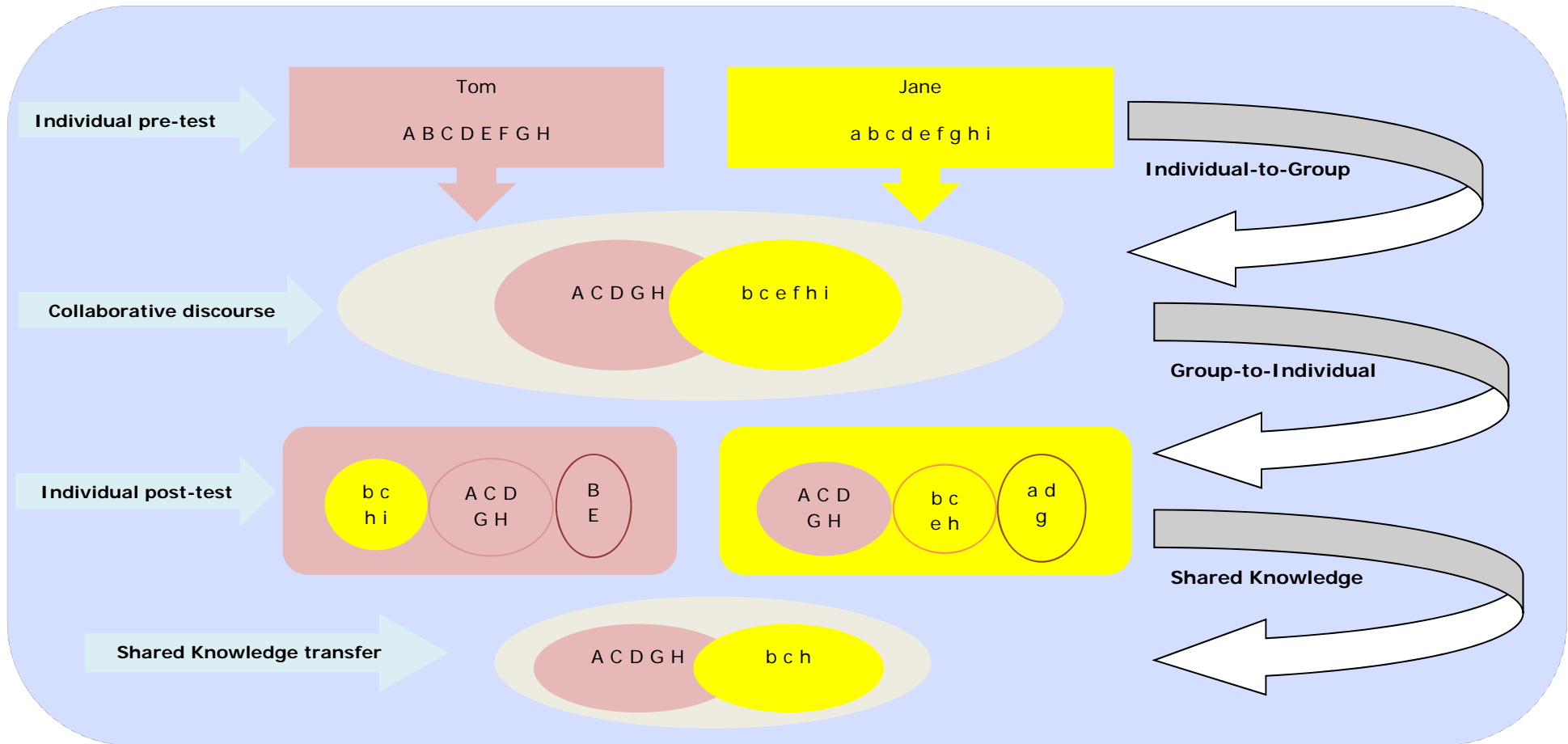
Figure 4.2: A graphical representation for measuring domain-specific knowledge transfer. (Capital letters represent relevant and correct application of the theoretical concepts from Tom's domain of expertise. Lower case letters represent relevant and correct application of the theoretical concepts from Jane's domain of expertise.).

Tom scores 5 and 4 on individual-to-group and group-to-individual knowledge transfer respectively. Jane scores 6 and 5 on individual-to-group and group-to-individual knowledge transfer respectively. Tom and Jane score 8 on shared knowledge transfer.

Capital letters "B" and "E" and also lower case letters "a", "d", and "g" were not transferred from individual to group representations. They were, however, transferred from the learners' own individual pre-tests to their individual post-tests.

Control Measures

Learners' prerequisites, such as computer literacy and prior experience with and attitude towards collaboration are seen as relevant and important in CSCL settings (see Noroozi & Biemans et al., 2011; Noroozi & Weinberger et al., 2012). We therefore controlled for uneven distribution of these measures over the two conditions.

Measurement of computer literacy

The learners were measured on computer literacy using a questionnaire with 10 items on a five-point Likert scale ranging from "almost never true" to "almost always true". The questionnaire was designed to ascertain the extent to which learners were skillful in terms of (a) software applications (MS Word, Excel, other programmes), and (b) using the Internet for communication via e-mail, Chat, Blackboard, SharePoint, Web 2.0 tools, and other social media. Furthermore, we asked learners to rate themselves in terms of general computer skills on a scale of one to five. The reliability coefficient was sufficiently high (*Cronbach α = .88*).

Measurement of prior experience with and attitude towards collaboration

These variables were measured using a questionnaire with 25 items on a five-point Likert scale ranging from "almost never true" to "almost always true". Nine items of this questionnaire asked learners to ascertain the extent to which they had prior experience with collaboration. For example, they were asked to specify their collaboration experience by choosing from a list of alternatives (school, workplace, etc.) and also to rate themselves on general prior experience with collaboration. Sixteen items of this questionnaire were aimed to ascertain learners' attitudes towards collaboration. For example, they were asked to rate themselves on statements such as "collaboration fosters learning", "collaboration improves my weaknesses", "learning should involve social negotiation", "one learns more while performing tasks in a collaborative manner than individually", etc. The reliability coefficient was sufficient for both prior experience with (*Cronbach α = .81*) and attitudes towards collaboration (*Cronbach α = .85*).

Unit of Analysis and Statistical Tests

We used the individual learner as the unit of analysis to measure the control variables in the individual pre-test. We used the dyads as the unit of analysis (group values) only to measure

the quality of joint problem solution plans and shared knowledge transfer, which were based on the collaborative solution of the learning task. Although the rest of the dependent variables were measured at the individual level, these measurements were not independent observations due to the collaboration that preceded it (Kapur, 2008; Kirschner et al., 2011; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013; Raudenbush & Bryk, 2002). Therefore, we used aggregated individual values to analyse various aspects of the TMS, individual-to-group and group-to-individual knowledge transfer as well as individual problem solution plans. For all the analyses, the coders were unaware of participant characteristics.

In the statistical tests on mean differences, the alpha level was set to 5%. To test equal distribution of the control variables in both conditions the alpha level was set to 20%. The scores of two inactive pairs of learners (one pair in each condition) were excluded from the analyses due to the incompleteness of their contributions. For personal reasons, one learner in each these two pairs decided not to continue with the experiment after the 10-minute break between phases two and three. Therefore, for data analyses, 56 learners (14 pairs in each of the two conditions) were included in the study.

A one-way multivariate analysis of variance (MANOVA) was conducted to determine the effects of a transactive memory script on construction of a TMS in terms of specialization, coordination, and trust. ANOVAs for each of these aspects of the TMS were then conducted as follow-up tests to the MANOVA. A Pearson correlation coefficient was computed to assess the relationship between different components of TMS as assessed by questionnaire and interaction data analysis. Furthermore, MANOVA was conducted to compare mean differences between learners in the two conditions in terms of knowledge transfer measures. ANOVAs for each of these knowledge transfer measures (individual-to-group, group-to-individual, and shared knowledge transfer) were then conducted as follow-up tests to the MANOVA. MANOVA was again conducted to compare mean differences between learners in the two conditions in terms of quality of problem solution plans. ANOVAs for each of these problem solution plans (group and individual problem solution plans) were then conducted as follow-up tests to the MANOVA.

There are various approaches for mediation analysis, such as causal steps, mediation by calculating difference and product of coefficients (MacKinnon, 2008; MacKinnon et al., 2002 & 2007). Based on an extensive review study by Fritz and MacKinnon (2007), the causal-steps test developed by Baron and Kenny (1986) is by far the most commonly used test of

mediation in the social sciences. Therefore, regression analyses for casual steps were used to determine whether the TMS mediates the impacts of transactive memory script on quality of joint and individual problem solution plans. Following Barron and Kenny (1986), four regression equations were used to assess mediation. In the first equation, separate linear regression analyses were used to assess the impacts of the transactive memory script (predictor) on quality of joint and individual problem solution plans (outcomes). In the second equation, separate linear regression analyses were used to assess the impacts of the transactive memory script (predictor) on each of the mediators, namely process aspects of the TMS (specialization, coordination, trust), during the discourse. The next analysis examined the impacts of the specific aspects of the TMS (mediators) on quality of both joint and individual problem solution plans (outcomes). All of the above equations had to be significant to proceed with the following analysis. The final analysis examined whether the specific aspects of the TMS (mediators) mediated the impacts of transactive memory script (predictor) on quality of problem solution plans (outcomes). If the impact of the transactive memory script (predictor) on the quality of problem solution plans (outcomes) was reduced or no longer significant, then it could be concluded that the association between the predictor and the outcomes is mediated by specific aspects of the TMS (mediators). A strong mediation can be established if the association between the transactive memory script (predictor) and the quality of problem solution plans (outcomes) is reduced to zero.

There are, however, potential shortcomings with Barron and Kenny's (1986) approach including the low power of casual steps to detect true mediation (Type II error; MacKinnon et al., 2002 & 2007). For example, some researchers argue there is no need for an initial overall effect when the mediator acts like a suppressor variable; and hence a reduced or non-significant association between the predictor and the outcomes after controlling for the mediator is not necessarily a sign of a strong mediation (see Kenny et al., 1998; MacKinnon et al., 2007). That is why Fritz et al. (2012) strongly urged researchers to use other approaches in conjunction with the casual steps to test the significance of indirect effect. Structural equation modelling (SEM) is more suitable for complicated models with large sample size studies, whereas bootstrapping (Preacher & Hayes, 2004; Shrout & Bolger, 2002) and Sobel test (Sobel, 1982) approaches can be used for common sample size studies (see Fritz & MacKinnon, 2007). Due to the possibility for the large Type I error in the bootstrapping approach (see Fritz & MacKinnon, 2007; MacKinnon et al., 2004), we used Sobel's (1982) approach for calculating indirect effect tests using the standard error for the product of

regression coefficients. Regression analyses were performed separately for joint and individual problem solution plans. The coefficient of transactive memory script was the experimental variation between the control and the experimental condition.

Results

Learning Prerequisites and Control Measures

The learners with an international development studies background in the two conditions showed no differences with respect to prior knowledge, $F(1, 26) = .22$, $p > .2$ ($M = 11.32$, $SD = 2.73$, $Max = 16$, $Min = 7$), and number of passed courses ($M = 3.79$, $SD = 1.64$, $Max = 7$, $Min = 2$) on CBSM and related topics, $F(1, 26) = .46$, $p > .2$. The same was true for the learners with an international land and water management studies background regarding prior knowledge, $F(1, 26) = .16$, $p > .2$ ($M = 7.89$, $SD = 2.30$, $Max = 13$, $Min = 4$), and number of passed courses ($M = 3.50$, $SD = 1.23$, $Max = 6$, $Min = 2$) on SAWM and related topics, $F(1, 26) = .09$, $p > .2$. These results show that there were no substantial differences between learners' prior knowledge and background requirements in the two conditions.

Furthermore, learners in the two conditions showed no differences regarding the mean scores of computer literacy, $F(1, 54) = .27$, $p > .2$, and prior experience with collaboration, $F(1, 54) = .16$, $p > .2$. The same was true for the learners' attitudes towards collaboration, $F(1, 54) = .24$, $p > .2$. These results showed that there were no substantial differences between learners' individual prerequisites in the two conditions.

The Effects of a Transactive Memory Script on Construction of a TMS

Based on measurement of the TMS by questionnaire, the average score for a TMS as a whole was higher for scripted than unscripted learners, *Wilks' λ* $= .37$, $F (1, 26) = 13.41$, $p < .01$, $\eta^2 = .63$. Specifically, the difference between specialization means was significant, $F(1, 26) = 29.11$, $p < .01$, $\eta^2 = .53$, with scripted learners ($M = 4.63$, $SD = .27$) scoring higher than unscripted learners ($M = 3.81$, $SD = .50$). Coordination means also differed significantly, $F(1, 26) = 9.24$, $p < .01$, $\eta^2 = .26$, with scripted learners ($M = 4.35$, $SD = .47$) scoring higher than unscripted learners ($M = 3.75$, $SD = .57$). Similarly, the difference in trust means was significant, $F(1, 26) = 18.80$, $p < .01$, $\eta^2 = .42$, with scripted learners ($M = 4.64$, $SD = .40$) scoring higher than unscripted learners ($M = 3.95$, $SD = .44$).

Based on measurement of the TMS using discourse, the average score for the TMS as a whole was higher for scripted than unscripted learners, *Wilks' λ* = .11, *F* (1, 26) = 67.03, *p* < .01, η^2 = .89. Specifically, the mean scores for specialization, *F*(1, 26) = 176.93, *p* < .01, η^2 = .87, and coordination, *F*(1, 26) = 131.38, *p* < .01, η^2 = .83, were different between scripted and unscripted learners. In the scripted condition (*M* = .89, *SD* = .07), about 37% more specialization messages were exchanged in comparison to the unscripted condition (*M* = .49, *SD* = .09). Instead, in the unscripted condition (*M* = .38, *SD* = .09), about 31% more coordination messages were exchanged in comparison to the scripted condition (*M* = .07, *SD* = .05). Credibility means did not differ significantly, *F*(1, 26) = .45, *p* = .51, with scripted learners (*M* = .66, *SD* = .05) scoring the same as unscripted learners (*M* = .64, *SD* = .07).

Concerning the correlation between the two TMS measures, we found a positive correlation between the specialization aspect of the TMS in the two measures, *r* = .67(28), *p* < .01. There was a negative correlation between the coordination aspect of the TMS in the two measures, *r* = -.47(28), *p* < .05. This negative correlation indicates that learning dyads that allocated more messages for coordination activities during the collaborative learning phase scored lower with respect to satisfaction with their coordination in the questionnaire and vice versa. There was no significant correlation between the mutual trust aspect of the TMS in the two measures, *r* = -.01(28), *p* = .95.

Concerning the inter-correlation between various aspects of the TMS, based on discourse data, we found a substantial negative correlation between specialization and coordination, *r* = -.92(28), *p* < .01. This negative correlation indicates that learning dyads that allocated more messages for coordination activities scored lower for specialization during the collaborative learning phase and vice versa. The mutual trust was correlated with neither specialization, *r* = .19(28), *p* = .32, nor coordination, *r* = -.017(28), *p* = .93, aspects of the TMS. Concerning the inter-correlation between various aspects of the TMS based on questionnaire data, we found positive correlations between all aspects of the TMS namely between specialization and coordination, *r* = .54(28), *p* < .01, specialization and trust, *r* = .53(28), *p* < .01, as well as coordination and trust, *r* = .74(28), *p* < .01.

The Effects of a Transactive Memory Script on Learners' Knowledge Transfer Measures

The average score for knowledge transfer measures as a whole was higher for scripted than unscripted learners, *Wilks' λ* = .56, *F* (1, 26) = 6.24, *p* < .01, η^2 = .44. The difference between

113

individual-to-group knowledge transfer means was not significant, $F(1, 26) = 1.08$, $p = .31$, with scripted learners ($M = 16.64$, $SD = 3.77$) scoring about the same as unscripted learners ($M = 15.14$, $SD = 3.86$). In contrast, the difference in group-to-individual knowledge transfer means was significant, $F(1, 26) = 16.95$, $p < .01$, $\eta^2 = .40$, with scripted learners ($M = 6.14$, $SD = 1.70$) scoring higher than unscripted learners ($M = 3.93$, $SD = 1.07$). Shared knowledge transfer means differed significantly, $F(1, 26) = 19.01$, $p < .01$, $\eta^2 = .42$, with scripted learners ($M = 11.79$, $SD = 3.12$) scoring higher than unscripted learners ($M = 7.50$, $SD = 1.95$).

The Effects of a Transactive Memory Script on Learners' Quality of Joint and Individual Problem Solution Plans

The average scores for quality of problem solution plans as a whole was higher for scripted than unscripted learners, *Wilks' λ* = .72, $F (1, 26) = 6.24$, $p < 4.81$, $\eta^2 = .28$. Specifically, the difference between joint problem solution plan mean scores was significant, $F(1, 26) = 9.09$, $p < .01$, $\eta^2 = .26$, with scripted learners ($M = 2.99$, $SD = .78$, *Max* = 4, *Min* = 2) scoring higher than unscripted learners ($M = 2.21$, $SD = .58$, *Max* = 3, *Min* = 1). Similarly, the difference in individual problem solution plan mean scores was significant, $F(1, 26) = 4.62$, $p < .05$, $\eta^2 = .15$, with scripted learners ($M = 2.93$, $SD = .76$, *Max* = 4, *Min* = 2) scoring higher than unscripted learners ($M = 2.43$, $SD = .43$, *Max* = 3, *Min* = 1).

The Mediating Impacts of the TMS on the Effects of a Transactive Memory Script on Quality of Learners' Joint and Individual Problem Solution Plans

First, the independent factor, transactive memory script, had a significant impact on the joint, $b = .79$, $t(26) = 3.02$, $p < .01$, and individual, $b = .50$, $t(26) = 2.15$, $p < .05$, problem solution plans. Transactive memory script explained a significant proportion of variance of joint, $R^2 = .26$, $F(1, 26) = 9.09$, $p < .01$, and individual, $R^2 = .15$, $F(1, 26) = 4.62$, $p < .05$, problem solution plans (see figure 4.3).

Second, the independent factor, transactive memory script, was a significant predictor of the mediator variables specialization, $b = .40$, $t(26) = 13.30$, $p < .01$, and coordination, $b = -.31$, $t(26) = -11.46$, $p < .01$. Transactive memory script explained a significant proportion of variance of specialization, $R^2 = .87$, $F(1, 26) = 176.83$, $p < .01$, and coordination, $R^2 = .83$, $F(1, 26) = 131.38$, $p < .01$. This was not significant for the mediator variable trust, $b = .02$, $t(26) = .67$, $p = .51$, and therefore trust was dropped from subsequent regression models (see figure 4.3).

Third, concerning the impact of the specific aspects of the TMS on dependent variables, the specialization, $b = 1.97$, $t(26) = 3.29$, $p < .01$, and coordination, $b = -2.16$, $t(26) = -2.71$, $p < .05$, predicted the quality of joint problem solution plans. Specialization, $R^2 = .29$, $F(1, 26) = 10.80$, $p < .01$, and coordination, $R^2 = .22$, $F(1, 26) = 7.32$, $p < .05$, explained a significant proportion of variance of quality of joint problem solution plans. The regression analyses did not reach statistical significance with regard to the impact of specialization, $b = .89$, $t(26) = 1.55$, $p = .13$, and coordination, $b = -1.26$, $t(26) = -1.76$, $p = .09$, on the quality of individual problem solution plans, and therefore this was dropped from subsequent regression models (see figure 4.3).

According to the results so far, the specific aspects of the TMS can be a mediator for the impacts of the transactive memory script on only a joint product, and this applies only to specialization and coordination. The reason is that in all three regression analyses, the predictor predicts the criterion, which are criteria that need to be met to prove mediation (Barron & Kenny, 1986).

For specialization, when the independent factor was included simultaneously in the regression model, the impact of the transactive memory script on the quality of joint problem solution plan was no longer significant, $b = .04$, $t(26) = .05$, $p = .95$. This indicates a strong mediation effect of the specialization aspect of the TMS between the independent variable (transactive memory script) and dependent variable (quality of joint problem solution plan). A Sobel test confirmed that the impact of the transactive memory script on quality of joint problem solution plan was mediated by the specialization aspect of the TMS during discourse, $SEb = .60$; $b = 1.97$; $tSobel = 3.18$; $p < .01$.

There was a mediation effect for the coordination aspect of the TMS, but it was smaller than for specialization. When the independent factor was included simultaneously in the regression model, the impact of the transactive memory script on the quality of joint problem solution plan was no longer significant, $b = .75$, $t(26) = 1.15$, $p = .26$. A Sobel test confirmed that the impact of the transactive memory script on quality of joint problem solution plan was mediated by the coordination aspect of the TMS during discourse, $SEb = .80$; $b = -2.16$; $tSobel = 2.63$; $p < .01$.
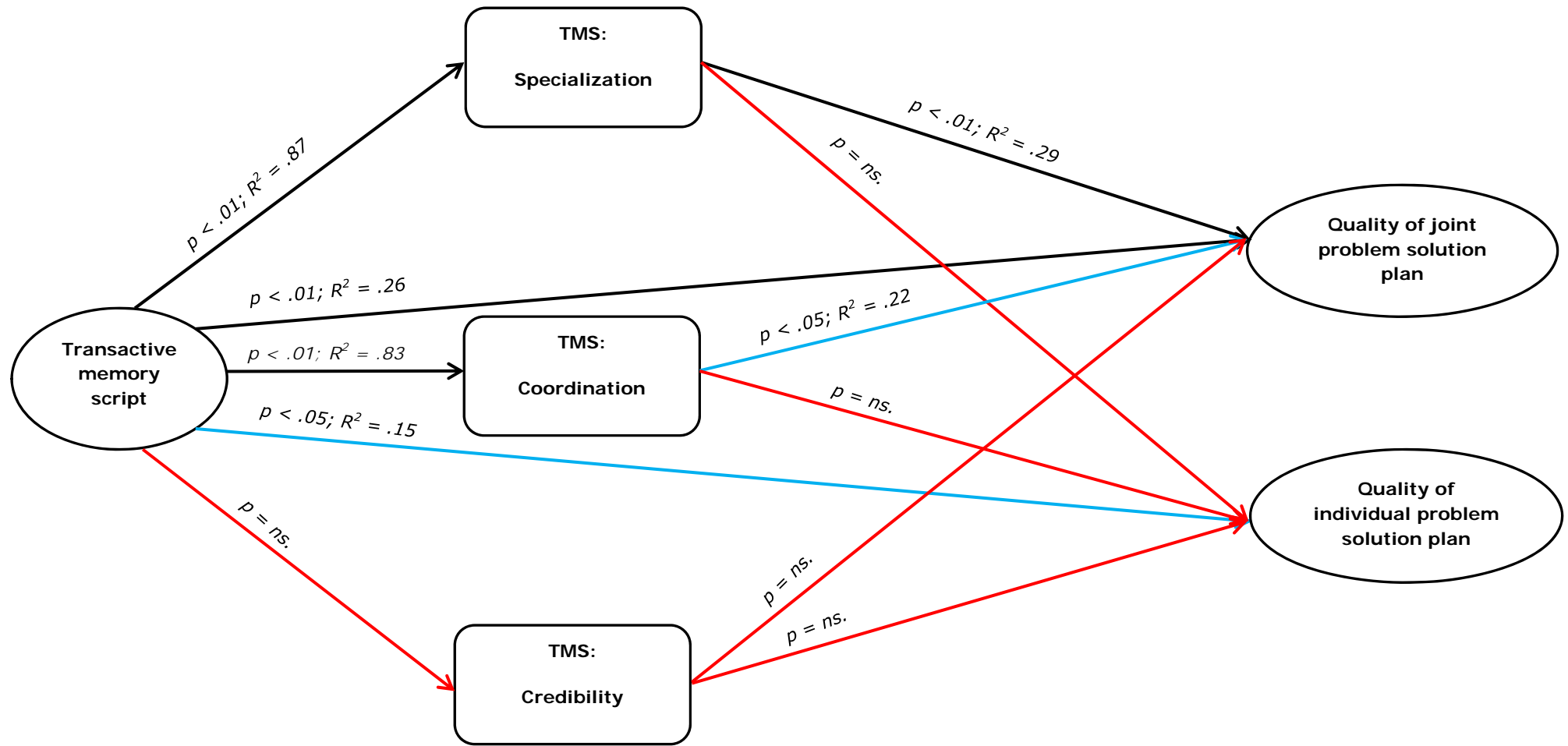
Figure 4.3: A graphical representation for the results of the regression equation models. Black arrows indicate significance at the .01 level. Blue arrows indicate significance at .05 level. Red arrows indicate no significance.

Discussion

Implementation of a transactive memory script in the form of prompts appeared to facilitate the TMS in a multidisciplinary CSCL setting. Following step-by-step guidelines and instructions embedded in the platform for each process of the TMS (encoding, storage, retrieval) helped learners to quickly become aware of their learning partners' expertise, to coordinate the collaborative learning activities by assigning and sharing task responsibilities, and finally to retrieve needed information from individuals who had the most expertise with the appropriate specialization in the group during the collaborative phase (Rulke & Rau, 2000; Wegner, 1987). Specifically, making portfolios of their own expertise by sketching domain expertise areas helped learners to make an appropriate estimation of their learning partners' knowledge, resulting in differentiation of their own memory and expertise from the knowledge repertoire of the learning partner (Michinov & Michinov, 2009). The specialization of the knowledge along with recognition and awareness of expertise distributed in the group during the encoding process played an important role in coordinating problem-solving activities. Subsequently, assigning responsibility based on awareness of this specialized knowledge, and that individual's acceptance of the responsibility, helped coordinate the process of problem-solving by directing learners' focus to parts of the task that they had the most expertise for. These task coordination activities helped group members to work effectively with a great sense of collaboration during the collaborative phase. That is why we found a substantial correlation between specialization and coordination aspects of the TMS in this study. Finally, prompts for combining individual solutions helped learners to consider both complementary areas of expertise in a balanced way, to retrieve required information and knowledge from the sources of expertise who had the stored information, and to arrive at a joint solution for the problem case with an appropriate specialization of knowledge and expertise distributed in the group (Rulke & Rau, 2000; Wegner, 1987). Appropriate coordination of the learning activities by assigning and acceptance of responsibilities could in turn impact the specialization aspect of the TMS in a group. The reason is that group members provide relevant information on the topic and analyse parts of the problem case based on assigned tasks and roles in relation to their specialized domains of expertise. As a result of this assignment of tasks and roles, group members effectively pool unshared information from their learning partners based on a heightened awareness of distributed knowledge resources in the group (Rummel & Spada, 2005; Rummel et al., 2009).

According to the learners' responses to our questionnaire (Lewis, 2003), credibility or trust is indirectly influenced when the other two aspects are facilitated by a script. For example, when learners read and analysed one another's portfolios, they understood that the complementary expertise for solving the problem case was located within the domain expertise of their learning partner. Having meta-knowledge about the domain expertise of their learning partner created a level of trust among individuals in the learning dyads (Rulke & Rau, 2000; Wegner, 1987). In other words, when learners became aware of the credibility of their learning partner's expertise that could be applied in solving the problem case, they could be sure that no information would be missed by the group if they trusted the source of expertise. This credibility can create a psychologically safe environment for learners to work on the learning task as a team, with a high level of trust resulting in greater awareness and precision of individual members' expertise as well as coordination of the learning activities (Zheng, 2012). Learning groups with a high level of trust have more opportunities to increase the entire team's knowledge stock based on awareness of the individual members' expertise (Henry et al., 1996), which can also result in better coordination with fewer social conflicts among members than learning groups with a low level of trust (McEvily et al., 2003).

Implementation of a transactive memory script did not facilitate individual-to-group knowledge transfer. A plausible reason for the lack of difference between scripted and unscripted learners in transferring individual representations into the group product could involve the nature of the learning task and multidisciplinary context of the study. Due to the multidisciplinary nature of the learning task, learners in both conditions needed the complementary expertise of their learning partners in order to jointly make sense of the learning task and design a joint problem solution plan. As a result, it could be that learners in both conditions were inclined to immediately accept rather than oppose the contributions of their learning partners while working on the joint problem solution plan. In both conditions, learners might have seen themselves as less competent than their learning partners regarding the latter's specialized expertise. This could also happen when learners want to manage the interaction and continue the discussion in terms of other aspects of the learning task and not because they are convinced (Clark & Brennan, 1991; Weinberger & Fischer, 2006).

Implementation of a transactive memory script did facilitate group-to-individual and shared knowledge transfer. This is because the formation of a collaboratively shared system for encoding, storage, and retrieving knowledge fosters the integrative usage of information from a well-constructed TMS in the group. Creating such a TMS is effective when learners use

their meta-knowledge awareness not only for coordinating subtasks and the division of labour/roles, but also for converging knowledge and transactions of unshared information (i.e. elicitation, externalization, and giving specialized feedback) in a collaborative manner rather than just cooperating.

As discussed earlier, scripted learners were able to extract more unshared information through elicitation, externalization, and giving specialized feedback than unscripted learners. These transactions amounted to a successful exchange of unshared information among members of a group in a collaborative problem-solving setting (King, 1999; Weinberger et al., 2005a & 2007b). For example, elicitation of information (e.g. asking questions to receive information from learning partners) could lead to externalization of information (e.g. giving explanations by learning partners), which may in turn be followed by further feedback, inquiry, clarification, and/or elaboration of the learning materials (Weinberger et al., 2005a & 2007b). In the scripted condition, these transactions of unshared information were followed by elaboration on and integration of one another's perspectives and ideas on the basis of the reasoning of peers. Therefore, scripted learners were able to engage in deep cognitive processing for learning and discovering complementary knowledge of the learning partner in a collaborative manner (Dillenbourg, 1999) that could also be applied for designing similar problem solution plans in the subsequent learning task. For this reason, scripted learners were able to converge their complementary knowledge and transfer the theoretical concepts from group representation into their individual post-test representations. In contrast, unscripted learners may have used their complementary knowledge only for coordinating subtasks and the division of labour/roles and not for integrative usage of information in a collaborative rather than cooperative manner (Dillenbourg, 1999). Specifically, they just divided the learning task and individually took responsibility for part of the task based on their own expertise, and then assembled the partial results into the final output without further discussions. Unscripted learners did not elaborate on the learning materials, integrate, and synthesize one another's perspectives and ideas in order to jointly make sense of the learning task. Instead, they took advantage of the knowledge of their learning partners only in a cooperative manner for accomplishing the learning task, rather than collaborating to learn about each other's domain expertise. Due to the lack of integrative usage of information for transactions of unshared information, clarification, and/or elaboration of the learning materials, unscripted learners were not able to transfer the domain expertise contributions of their learning partners to their individual representations in the post-test.

Implementation of a transactive memory script improved the quality of both collaborative and individual problem solution plans. This finding corroborates other research results which showed a positive impact of a TMS on performance in collaborative problem-solving settings (e.g. Hollingshead, 1998a, 1998b, & 1998d; Liang et al., 1995; Littlepage et al., 1997; Moreland et al., 1996; Stasser et al., 1995). In collaborative problem-solving, groups whose members are aware of one another's knowledge and expertise develop a shared understanding of who knows what in the group (Wegner, 1987) and thus perform better than groups whose members do not possess such knowledge (e.g. Moreland et al., 1998; Moreland & Argote, 2003). The significance of shared knowledge for collaborative learning activities especially among heterogonous groups of learners has been widely acknowledged in the scientific literature (see Hollingshead, 2000; Liang et al., 1995) since learners typically influence one another when learning together (e.g. De Lisi & Golbeck, 1999). Furthermore, having meta-knowledge about the domain expertise of learning partner(s) fosters the distribution of the task and coordination of distributed knowledge (Wegner, 1987), which in turn results in successful transactions among learning partners in collaborative learning settings (e.g. Moreland & Myaskovsky, 2000; Rummel & Spada, 2005; Stasser et al., 1995). These transactions (e.g. externalization of one's own knowledge and elicitation of a learning partner's knowledge) have been regarded as important for improving learning performance (Fischer et al., 2002; King, 1999; Rosenshine et al., 1996; Rummel et al., 2009).

Contrary to most research studies on the TMS, which mostly report on learning in relation to group performance (e.g. Hollingshead, 1998a, 1998b, & 1998d; Prichard & Ashleigh, 2007; Michinov & Michinov, 2009; Moreland et al., 1996), this study presents separate data on the quality of individual problem solution plans. Similar to a study by Prichard et al. (2006), the findings of the current study support the positive effects of a TMS on individual performance. However, as assumed by Prichard et al. (2006), group members may employ strategies that enhance their group product, which is not necessarily the same as individual performance (Prichard et al., 2006). This implies that success in group performance does not always mirror individual performance. For example, more active or knowledgeable members in the group may complete the task on behalf of the group; as a result, less active or knowledgeable members (so-called free riders) may fail to enhance their individual performance (Prichard et al., 2006). This can be observed in the findings of a study by Hollingshead (1998c), in which a group-to-individual transfer was not reported (i.e. group training on task practice improved group but not individual performance). As found in a study by Lewis and colleagues (2005),

the TMS transfers across tasks; hence groups with a strong TMS develop it further on subsequent learning tasks. Such a transfer was shown to happen when group members maintain the same division of cognitive labour and roles across tasks (Lewis et al., 2005). In the current study, this division of labour and roles was taken away in the subsequent individual learning task. Since the individual post-test was conducted immediately after the collaborative learning phase with an identical problem case, the difference in the quality of individual problem solution plan between scripted and unscripted learners still remained significant for the subsequent learning task. This difference was, however, less than the difference between scripted and unscripted learners for the group product. This individual difference may not have been achieved if the individual post-test had been conducted some time later with a rather different learning task. That is why in the current study, the impact of the transactive memory script was higher for collaborative than individual problem solution plans. The difference in the mean scores of the individual problem solution plan was significant at the 5% level ($\eta^2 = .26$), whereas this difference was significant at the 1% ($\eta^2 = .15$) for the joint problem solution plans between scripted and unscripted learners. The reason is that construction of a TMS in the group, with the increasing the degree of specialization, might take away the responsibility of individuals for learning new information that falls in another group member's area of specialization (see Lewis et al., 2005). This domain-specific dependence may thus hinder performance for comparable learning tasks that need complementary expertise and have to be solved individually without the presence of the domain expertise of the learning partner.

Various aspects of the TMS had an impact on the group product, namely quality of collaborative problem solution plans. This is in line with other research findings showing the impacts of the TMS on group performance (e.g. Liang et al., 1995; Moreland et al., 1998; Moreland & Myaskovsky, 2000; Schreiber & Engelmann, 2010). Furthermore, since the TMS has been shown to mediate the impact of group training on group performance in previous studies (e.g. Liang et al., 1995), it was expected that it should also mediate the impact of a transactive memory script on group performance. This assumption was confirmed and the specialization and coordination aspects of the TMS significantly conveyed the influence of the transactive memory script on the quality of joint but not individual problem solution plans. This result indicates that the transactive memory script improved the quality of joint problem solution plans primarily by fostering the specialization and coordination aspects of the TMS among group members. We discussed earlier how the construction of a TMS in the group

121

fosters meta-knowledge awareness and coordination of distributed knowledge. We also discussed how specialization impacts coordination and vice versa. When learners make an appropriate estimation of the learning partner(s)' knowledge in relation to the problem case, they are able to effectively distribute the task based on specialized expertise, coordinate the distributed knowledge by assigning and acceptance of task/role responsibilities. When learners coordinate the learning activities, they can effectively pool and process one another's unshared information (elicitation and externalization), give feedback, ask clarifying questions, and elaborate on one another's ideas in relation to the problem case. Thus specialization and coordination help learners elaborate on the learning materials, integrate and synthesize one another's perspectives and ideas in order to jointly make sense of the learning task (Fischer et al., 2002; Nastasi & Clements, 1992; Schoor & Bannert, 2011). They make integrative usage of meta-knowledge in a collaborative manner rather than just cooperating (Dillenbourg, 1999), resulting in higher quality of joint problem solution plans. However, the TMS did not convey the influence of the transactive memory script on the quality of individual problem solution plans. As discussed earlier, in the individual learning task, the division of labour and roles was taken away; and in such a situation the construction of a TMS would not be as effective as in a situation in which the group members maintain the same division of cognitive labour and roles across tasks (Lewis et al., 2005).

Implications, Limitations, and Suggestions for Future Research

Based on this study, the general conclusion can be drawn that not only concept maps (see Engelmann & Hesse, 2010; Schreiber & Engelmann, 2010) in a CSCL environment but also implementation of a transactive memory script in the form of prompts can positively foster the construction of a TMS in a multidisciplinary collaborative problem-solving setting. Furthermore, facilitation of a TMS not only improves learners' group-to-individual and shared knowledge transfer but also fosters the quality of their joint product. At this point, it is relevant to discuss some strengths, weaknesses, and implications of the present study.

This study was conducted in a control-based laboratory setting with its own advantages and disadvantages. The control-based experiment provided us with the opportunity to take individual learners' characteristics into account. These measurements guaranteed that the observed differences between learners in the two conditions were indeed due to our intervention and not due to the biased or false distribution of learners over the two conditions in terms of learners' characteristics.

As the learners in this study were chosen from university with two complementary backgrounds, and as the learning task was authentic for multidisciplinary contexts, we assume that comparable results would be achieved in curricular educational settings with a high ecological validity. This is not certain, however, and it could potentially have consequences for the ways in which students perform in a real multidisciplinary course in an authentic setting. Furthermore, although we used both quantitative and qualitative data analysis, the sample size of the current study was rather small with 56 learners who were formed into 28 dyads. Therefore, we advise that further research be conducted in real educational settings with more students to test the extent to which the results can be generalized.

This study used a mixed approach to analyse the TMS, since such an approach for measuring the TMS has been recommended in the scientific literature (e.g. Moreland et al., 2010). We employed a validated questionnaire instrument (Lewis, 2003) and adapted it to fit the purpose of this study. The inter-rater reliability and values of this instrument have been reported as being satisfactory (e.g. London et al., 2005; Michinov, 2007), and these values were even higher in the present study. Based on the literature, we also developed a content analysis scheme and looked at the interaction data during collaborative discourse to measure the construction of various aspects of the TMS. Although we found strong correlations between the coordination and specialization indicators, there was no correlation between the mutual trust aspect of the TMS in the two measures. Based on the results of the questionnaire (Lewis, 2003), the transactive memory script facilitated all three aspects of the TMS (specialization, coordination, and trust). The same results were also achieved on the basis of the collaborative discourse analysis, except for the trust aspect of the TMS. The reason is that the trust aspect of the TMS was not explicitly targeted by the transactive memory script introduced in this study. Based on Lewis (2003), we assumed that credibility or trust would be facilitated as the result of the other two aspects of the TMS, namely specialization and coordination. However, this was not confirmed based on the content analysis coding scheme as opposed to the questionnaire instrument developed by Lewis (2003). This slight difference could be an effect of social desirability bias inherent in self-reporting responses, such as those elicited by a questionnaire (Huber & Power 1985). Although, the confidentiality of the responses was assured to eliminate such a potential bias, this might not have completely excluded the possibility of learners coming up with answers that would be seen as desirable. To mitigate this effect in measuring the TMS, we therefore also analysed the discourse activities during the collaborative phase.

In this study we operationalized trust or credibility as the extent to which learners incorporated one another's theoretical concepts that were discussed during discourse into their joint problem solution plan. Apart from the mutual trust or credibility between the learning dyads there could be some other factors that may potentially influence the inclusion of a proportion of concepts from a person's contributions into the joint solution. These factors include the quality, the extent, and the total number of concepts a person contributed, as well as the independent of that person's dominance or rhetoric skills, argumentation competence, persuasiveness, and negotiation skills. Further analysis needs to determine the extent to which each of these factors separately and in combination influence the transition of learning partners' theoretical concepts that are discussed during discourse into their joint problem solution plan. We therefore advise that follow-up studies be aimed at this question.

We used a content analysis coding scheme to analyse the quality of joint and individual problem solution plans. Although high inter-rater reliability and intra-coder test-retest reliability values for this coding scheme were obtained, we advise using regular course exams to measure learners' achievement in real educational settings. Further analysis needs to determine the extent to which the results of course exams (mid-term and final exam) are consistent with the results obtained in this study. If they are not consistent, and the psychometric properties of the exams pass the minimum quality thresholds, calibration of the coding scheme (like the one we used) could be necessary.

In this study, we only administrated short-term individual measurement to account for individual performance. Individual performance was measured immediately after the collaborative phase with a comparable problem case. This may have resulted in a misleading boost in the short-term individual performance measures without fostering deeper processing that encourages long-term retention (see Noroozi & Biemans et al., 2012; Noroozi & Busstra et al., 2012). The long-term impacts of a transactive memory script on the TMS aspects and also on individual performance are unclear. Therefore we suggest that follow-up research be aimed at measuring the impacts of a transactive memory script on long-term retention.

In this study, we operationalized the theory of the TMS in a multidisciplinary problem-solving setting that lasted a relatively short period of time. This is an important issue since TMS is typically described based on relatively long-term collaboration within groups; and TMS is seen as something that continually develops and increases over the history of a group. We chose the shorter setting in order to investigate whether media-specific affordances in

124

online collaboration, such as a CSCL script, could be designed in such a way as to facilitate the construction of the TMS without longer-lasting interaction and communication. This idea was in line with the research study of Schreiber and Engelmann (2010), who found that using CSCL concept maps to visualize collaborators' knowledge structures (see also Engelmann et al., 2009) can lead to the construction of TMS in newly formed groups, without longer-lasting interaction and communication. Now that we know that the CSCL script can be designed for facilitation of the TMS in multidisciplinary settings in a rather short time period, we advise that follow-up studies test the impacts of such a script on construction of the TMS over a relatively long period of time. This could have consequences not only for the design principles of the CSCL scripts in relation to various aspects of the TMS, but also for the knowledge transfer from individuals-to-group and group-to-individuals in a long-term study.

The collaboration in this study was realized in the form of dyads. Scientific literature suggests that the nature of collaborative learning differs depending on group size, since active participation can be much higher and common ground can be established much faster and easier in dyads than triads or larger groups (see Noroozi & Weinberger et al., 2012). Communication difficulties therefore increase with group size (Steiner, 1972). This is especially important with respect to the various aspects of the TMS (knowledge specialization, coordination of the learning task, and mutual trust), since it may take longer for learners to efficiently establish their TMS for improving their performance in larger than in smaller groups. This is why in the study by Michinov and Michinov (2009), dyads and triads differed in the way the specialization aspect of the TMS influenced enhancement of learning performance. It would be insightful to test and accordingly adjust the effects of a transactive memory script on various aspects of the TMS in different-sized groups in order to maximize the likelihood of successful learning.

Acknowledgments

Chapter

5

Facilitating Argumentative Knowledge Construction through a Transactive Discussion Script in CSCL*

Abstract

Learning to argue is prerequisite to solving complex problems in groups, especially when they are multidisciplinary and collaborate online. Environments for Computer-Supported Collaborative Learning (CSCL) can be designed to facilitate argumentative knowledge construction. This study investigates how argumentative knowledge construction in multidisciplinary CSCL groups can be facilitated with a transactive discussion script. The script prompts learners to paraphrase, criticize, ask meaningful questions, construct counter-arguments, and propose argument syntheses. As part of a laboratory experiment, 60 university students were randomly assigned to multidisciplinary dyads based on their disciplinary backgrounds (i.e. water management or international development studies). These dyads were randomly assigned to a scripted (experimental) or non-scripted (control) condition. They were asked to analyse, discuss, and solve an authentic problem case related to both of their domains (i.e. applying the concept of community-based social marketing in fostering sustainable agricultural water management). The results showed that the transactive discussion script facilitates argumentative knowledge construction during discourse. Furthermore, learners assigned to the scripted condition acquired significantly more domain-specific and domain-general knowledge on argumentation than learners assigned to the unscripted condition. We discuss how these results advance research on multidisciplinary learning, CSCL scripts, and argumentative knowledge construction.

Introduction

Argumentation is an essential aspect of scientific thinking; and the ability to reason is an important skill for engaging in various workplace and community contexts. Argumentation is not restricted to one discipline and has been the subject of study in a range of disciplines including linguistics, philosophy, psychology, and communication (Noroozi & Weinberger et al., 2012; Van Eemeren et al., 1987 & 1996). Argumentation is also an essential objective in education; and that is why educational argumentation, its methods, and analysis approaches have received much attention from scholars in the field (see Coffin & O'Halloran, 2008). Over the last couple of years, research on educational argumentation has been influenced by developments in technology-enhanced environments focusing on the role of new teaching-learning tools and strategies on effectiveness, development, and quality of argumentation processes and outcomes (see Coffin & O'Halloran, 2008).

For example, Computer-Supported Collaborative Learning (CSCL) settings in which learners argue in teams have been designed to facilitate representing, constructing, and sharing of arguments with the aim of learning. Various forms of collaboration scripts have been designed to facilitate particular process categories of argumentative knowledge construction, such as the construction of single arguments by supporting learners to warrant and qualify their claims as well as the construction of specific argumentation sequences (e.g. argument, counter-argument, integration) (see Stegmann et al., 2007). In spite of their positive effects on the discourse activities they were directed at and also on the acquisition of knowledge on argumentation, these scripts have not all facilitated the acquisition of domain-specific knowledge (see Baker & Lund, 1997; Jermann & Dillenbourg, 2003; Kollar et al., 2007; Stegmann et al., 2007). Stegmann and colleagues (2012) show that argumentative scripts demand that learners allocate a considerable part of their time and cognitive capacity to constructing formally adequate arguments, at the cost of operating on contributions of learning partners and jointly elaborating diverse aspects and multiple perspectives on what is to be learned. This is striking, since evidence shows that cognitive elaboration of the learning materials is positively related to knowledge acquisition (see Stegmann et al., 2011; Stein & Bransford, 1979). Facilitating argumentative knowledge construction may, therefore, not only be a question of supporting process categories of argumentative discourse activities, but also of facilitating elaboration of the learning materials for enhanced domain-specific knowledge acquisition. This study thus investigates how scripts can facilitate argumentative discourse

129

activities and knowledge on argumentation as well as domain-specific knowledge acquisition in a multidisciplinary CSCL setting.

Argumentative Knowledge Construction

Arguing, critical thinking, and logical reasoning are essential objectives in education. Learners of all ages need to learn to clearly explain their informed opinions and give reasons for the way in which they carry out tasks and solve problems. Ravenscroft and McAlister (2008) as well as Ravenscroft et al. (2007) argue for the need and importance of effective argumentation for managing today's knowledge society and engaging in reasoned debate for conceptual learning, especially with the recent explosion in the use of online communities. Ravenscroft and McAlister (2008) argue that we need to argue effectively to be able to participate in communities of inquiry, reflect, reason, share, improve our understanding of topics, and hence develop critical thinking ideas for constructing knowledge.

Argumentative knowledge construction concerns the joint construction and the individual acquisition of knowledge through reasoning processes and collective exploration of the dialogical space of the solutions during collaborative argumentation (Andriessen et al., 2003; Stegmann et al., 2007 & 2012). Engaging learners in collaborative argumentation is an educational approach for preparing learners to manage today's complex issues and actively participate in knowledge societies (see Andriessen, 2006; Jeong & Frazier, 2008; Noroozi & Weinberger et al., 2012; Van Amelsvoort et al., 2007). Collaborative argumentation can be described as engaging learners in a group in dialogical argumentation, critical thinking, elaboration, and reasoning so that they can build up a shared understanding of the issue at stake instead of merely convincing or changing their own and each other's beliefs (see Baker, 2009). This type of collaborative argumentation is different from a "debate-type, win-lose situation", as in law (see Pinkwart et al. 2006 & 2007) in which argumentation is perceived as a means to compete and/or convince others (see Andriessen, 2006; Asterhan & Schwarz, 2009), i.e. argumentation serving persuasion or eristic argumentation ("fighting").

We define collaborative argumentation as the learning partners' collective contributions of reasons and evidence from different viewpoints with the goal of learning (see Baker, 2009; Ravenscroft & McAlister, 2008). In argumentative knowledge construction, learners are supposed to build arguments and support a position, to consider and weigh arguments and counter-arguments, to test, enlighten, and clarify their uncertainties, to elaborate on the

learning materials, and thus acquire knowledge and achieve understanding about complex ill-structured problems during collaborative argumentation (Aleixandre-Jimenez, 2007; Cho & Jonassen, 2002). Lately, research on argumentative knowledge construction has differentiated the specific processes of argumentative discourse activities into three dimensions, namely an epistemic dimension that describes arguments as steps towards solving the learning task, a formal-argumentative dimension that represents the structural elements of single arguments and argumentation sequences, and a dimension of social modes of co-construction that describes how learners interact with their partners (see Weinberger & Fischer, 2006). This study focuses on the formal-argumentative dimension of CSCL, whereby individual learners in an online environment construct single arguments (Kollar et al., 2007; Stegmann et al., 2007 & 2012) and exchange them in argumentation sequences (Baker, 2003, Leitão, 2000) to resolve different standpoints on the issue at stake and to find well-elaborated solutions for complex problems (Stegmann et al., 2007 & 2012; Walton & Krabbe, 1995).

Construction of single arguments

Toulmin (1958) proposed a highly influential model of the "grammar" of argument to analyse single arguments of everyday use by analogy with the syntax of the structure of a well-formed sentence. This model considers six argument components: claim, datum, warrant, backing, rebuttal, and qualifier. The claim is an expression of the position that is advanced in the argument. Datum is the factual information that is expressed to support the acceptance of the claim such as observations. Warrant is a rule of inference that justifies the transition from the datum to the claim and reveals the relevance of the data for the claim such as definitions, theories, and rules. Backing is factual information such as reasonable evidence, statistics, or expert ideas, that provides a rationale for a warrant. Qualifiers and their interrelated rebuttals have to do with qualifying the relationship between claim and warrant that limit the validity of a claim. Explicitly, qualifier has to do with expressing a potential limitation and rebuttal has to do with further explanation when the claim is not valid (Kollar et al., 2007; Stegmann et al., 2007; Noroozi & Weinberger et al., 2012; Weinberger & Fischer, 2006). These interconnected parts hardly appear together in any argument put forward in everyday language for the sake of communication efficiency (Grice, 1979). Furthermore, one can hardly find explicit and valid inferences according to the standards of formal logic argumentation (Leitão, 2003). For example, it is difficult to distinguish warrant (which is mostly implicit) from backing (Jonassen & Kim, 2010). There is also ambiguity with regard to the components of an argument or what counts as a claim, warrant, or data (see Erduran et

131

al., 2004; Simon, 2008). To apply Toulmin's analytical scheme for prescriptive purposes in relation to knowledge acquisition, the model has been simplified and cut down in various studies to the components claim, grounds, and qualifications (see Baker, 2003; Kollar et al., 2007; Leitão, 2000; Simon, 2008; Stegmann et al., 2007). The elements datum, warrant, and backing from Toulmin's model all fall within the term grounds. Simon (2008) as well as Erduran et al. (2004) proposed to use contextual clues (so, because, since, etc.) for resolving any ambiguities in deciding what counts as a claim or grounds. Hence, whereas in everyday situations arguments are generally not fully explicit and do not comprise all of Toulmin's elements, in CSCL scenarios learners are supposed to build complete arguments, which comprise a claim supported by grounds and limited by qualifications (Stegmann et al., 2012).

Despite the influential role of Toulmin's model in the field of argumentation theory, the application of this model is considered to be more useful in analysing completed declarative arguments than in the dynamic process of argumentation. When considering argumentation as a collaborative discourse phenomenon, Toulmin's model is not considered as dialogic and as a result it does not have the power to capture the interdependency of moves among collaborators (Andrews, 1995). Toulmin's model only considers the proponent's side and ignores the role of an opponent in the process of argumentation (Andriessen, 2006). Therefore, the development of multiple perspectives, the pro and the contra, on the topic, which is the fundamental nature of argumentative discourse (Schwarz et al., 2000), is underestimated in Toulmin's model (Voss et al., 1983). For these reasons, we further analyse argumentative knowledge construction based on sequential collaborative argumentation.

Construction of argumentation sequences

When considering argumentation as a collaborative discourse phenomenon, the role of an opponent and the development of multiple perspectives in the process of argumentation need to be taken into account as well (see Andriessen, 2006; Jonassen & Kim, 2010; Leitão, 2003; Schwarz et al., 2000; Van Eemeren et al., 1987 & 1996; Voss et al., 1983). For this reason, the dialectical form of argument known as dialogical or multi-voiced argument has been proposed. Dialectical argument refers to the situation in which proponents' alternative and diverse opinions are expressed through discourses and clarified, contested, and refined through critical dialogue (Ravenscroft, 2011).

A variety of dialectical models of argumentation have been introduced in the learning sciences. For example, formal-dialectics (Barth & Krabbe, 1982) views argumentation as a dialogue between a proponent and an opponent around a certain topic. Pragma-dialectics (Van Eemeren et al., 1987 & 1996) emphasizes that argumentation as interaction between two parties serves to resolve differences of opinion by critically testing the acceptability of the standpoints at issue. Dialogue theory (Walton, 2000) differentiates between various necessary steps of a dialogue (i.e. persuasion, inquiry, negotiation, information-seeking, deliberation, and eristic) that a proponent and an opponent may follow for reasoning together. The common feature of these dialectical models is that they give just as much weight to counter-arguments as to the original argument. The ideal form of dialectical argumentation known as sequential-dialogue (Leitão, 2000) emphasizes the dynamic macro-level of argumentative dialogue including arguments, counter-arguments, and integrations. Argument is a statement put forward in favour of a specific proposition. Counter-argument is an argument opposing a preceding argument or favouring an opposite proposition. Integration is a statement that aims to balance, integrate, and advance a preceding argument and counter-argument (Stegmann et al., 2007; Weinberger & Fischer, 2006). Leitão's (2000) model is designed in such a way to promote the construction of valid knowledge in a collaborative discourse.

Technological Innovations for Argumentation

Over the last two decades, a variety of technological innovations for collaborative argumentation have been introduced to support the sharing, constructing and representing of arguments with the aim of learning. Dialogue games, knowledge representational tools, and computer-supported collaboration scripts are amongst the most prominent instructional approaches that have been used for educational argumentation. Loll (2012), McLaren et al. (2010), Scheuer et al. (2010), as well as Noroozi and Weinberger et al. (2012) provide extensive overviews of technological environments for various instructional approaches, intelligence techniques, and their functionalities that support computer-supported argumentation. Coffin and O'Halloran (2008) have recently categorized two significant trends of educational argumentation: dialogic dimension of argumentation, and combined argumentation, problem-solving, and collaborative learning.

The dialogic dimension of argumentation can be linked to the socio-constructivist and socio-cognitive theory (Coffin & O'Halloran, 2008). From this perspective, argumentation can be considered as part of a dialogic process between learners with peers or experts. This dialogic

process followed by reasoned debate has been argued to be central to the process by which higher-order mental thinking, critical reasoning, and reflection is developed (McAlister et al., 2004). Application of the dialogic dimension of argumentation has been recently well-researched in the context of digital dialogue games. Examples of digital dialogue games include an intelligent computer-based argumentation modeling system named "Computer-based Lab for Language Games in Education" (CoLLeGE) (e.g. Ravenscroft & Pilkington, 2000), as well as computer-mediated argumentation tools such as AcademicTalk (e.g. McAlister et al., 2004) and InterLoc (e.g. Ravenscroft & McAlister 2006). Ravenscroft (2007 & 2011) provide an overview of these digital dialogue games, which are designed to promote students' reasoning, conceptual change, and argumentative dialogue processes and practices.

The second trend of educational argumentation has linked collaborative argumentation and dialogue with small group problem-solving activities (Coffin & O'Halloran, 2008). From this perspective, argumentation can be seen as a dialogic process for considering multiple perspectives and resolving differences of opinions through critical discussion and dialogue to convince opponents (Jonassen & Kim, 2010) or compromise on multiple claims (Driver et al., 2000) on the issue at stake in complex problem-solving settings. Examples of the second trend of educational argumentation include the use of knowledge representation tools that have been developed to support dialogical and rhetorical argumentation processes through graphical (e.g. schemes, tables, visualizations) and textual representations (see Noroozi & Weinberger et al., 2012 for a review). The focus of this study is on the use of the textual form of knowledge representation called "computer-supported collaboration script" to support collaborative argumentation and argumentative knowledge construction.

Computer-Supported Collaboration Scripts

Over the last 15 years, various forms of computer-supported collaboration scripts have been designed as stand-alone instructional tools or scaffolds to guide learners to engage in specific activities in CSCL. Collaboration scripts provide detailed and explicit guidelines for small groups of learners to clarify what, when, and by whom certain activities need to be executed (Weinberger et al., 2007b). Scripts come in different forms (explicit or implicit; graphically embedded in a CSCL tool, or included in a teacher's oral presentation, or hand-out materials) (Kollar et al., 2006) and can sequence and specify both individual and collaborative learning activities to facilitate various learning processes and outcomes, including argumentative knowledge construction (see Weinberger & Fischer, 2006). To prevent split attention of the

learners, CSCL scripts have often been realized through prompts (Baker & Lund, 1997). Prompts can (as in this study) take the form of sentence starters (McAlister et al., 2004; Nussbaum et al., 2004; Ravenscroft, 2007) or question stems (Ge & Land, 2004) and provide learners with guidelines, hints, and suggestions that facilitate the enacting of scripts (Ge & Land, 2004; Noroozi & Weinberger et al., 2012).

Effects of CSCL scripts on argumentative knowledge construction

There is empirical evidence accumulating that various forms of collaboration scripts have positively facilitate the specific activities they were aimed for. A set of argumentative sentence starters facilitated the construction of counter-arguments (Nussbaum et al., 2004) and sound arguments (Yiong-Hwee & Churchill, 2007) during online discussion. A set of specific message labels known as conversational language facilitated the construction of high levels of critical discourse (more argument, evidence, critique, explanation) during the interaction (Jeong, 2006b). Argumentative scripts, such as the ArgueGraph script facilitated argumentative discourse (Jermann & Dillenbourg, 2003; Stegmann et al., 2007). Epistemic scripts facilitated the content quality of discourse (i.e. how adequately learners solved a task) (Schellens et al., 2007; Weinberger et al., 2005a, 2005b, & 2007b). Communication-oriented scripts facilitated interaction and social modes of co-construction (Rummel & Spada, 2005; Schellens et al., 2007; Weinberger et al., 2007b).

Despite the fact that CSCL scripts have been regarded as successful in terms of facilitating specific aspects of discourse activities, not all of them have resulted in positive learning outcomes in terms of facilitation of domain-specific knowledge construction (see Baker & Lund, 1997; Kollar et al., 2007; Stegmann et al., 2007; Weinberger et al., 2007b). For example, despite the positive effects of epistemic scripts on the reduction of cognitive effort (Weinberger et al., 2005a, 2005b, & 2007b) and of the task-coordination scripts on the reduction of coordination overload (Baker & Lund, 1997) in discourse activities, domain-specific knowledge acquisition was not facilitated in these studies and was even lower among supported learners than unsupported learners due to the hindering of learners' cognitive engagement. Some scripts can supplement learning activities rather than stimulate learners to engage in specific learning activities themselves (Reiser, 2004; Weinberger 2011). Furthermore, CSCL scripts were shown to create unintended side effects with respect to different aspects of argumentative knowledge construction (Weinberger et al., 2005a, 2005b, & 2007b). In studies by Ertl et al. (2005 & 2006a), collaboration scripts and content-specific

schemes were beneficial to collaborative case solutions, however they reduced the level of strategic negotiation and the level of learners' content-specific negotiation (presenting information or explaining concepts).

A study by Stegmann et al. (2007) investigated the effects of scripts for construction of single arguments and argumentation sequences on the formal quality of single arguments and argumentation sequences. The former approach improved the formal quality of single arguments (see also Stegmann et al., 2012) and the latter improved the formal quality of argumentation sequences during discourse activities. The acquisition of knowledge on argumentation was also improved without impacting on the acquisition of domain-specific knowledge (Stegmann et al., 2007 & 2012). Scripted learners mostly devoted their cognitive capacity to argumentation and hence little cognitive effort and time were allocated to elaboration of the materials and additional resources for enhanced domain-specific knowledge acquisition (Baker & Lund, 1997; Stegmann et al., 2007; Weinberger et al., 2007b).

It seems that alternative instructional information in how to design CSCL scripts is needed if learners are to construct sound arguments and engage in argumentation sequences in such a way as to also benefit from argumentative activities as an approach for enhanced domain-specific knowledge acquisition. In this paper, we present an innovative approach to balance argumentative discourse activities and cognitive elaboration of the learning materials using a transactive discussion script. The design of this script builds on the coding scheme from Berkowitz and Gibbs (1983) that provides an extensive categorization of transactive contributions which have been regarded as important tools for learning (see Teasley, 1997). Transactivity is a term derived from Berkowitz and Gibbs (1983) and introduced to collaborative learning by Teasley (1997) meaning "reasoning operating on the reasoning of the other". Transactivity indicates to what extent learners build on, relate to, and refer to what their learning partners have said before. When learners coordinate their interactions by operating on the reasoning of their peers, they are more likely to elaborate on the learning materials, to take advantage of the knowledge of their partners, and to arrive at a shared understanding (see Teasley, 1997; Weinberger, 2011; Weinberger & Fischer, 2006).

Based on CSCL literature, we have modified Berkowitz and Gibbs' (1983) scheme to develop a transactive discussion script to facilitate argument reception as well as argument construction with the goal of achieving transactive argumentation for enhanced domain-specific knowledge acquisition. In designing a transactive discussion script, we implemented

four types of question prompts (i.e. for argumentation analysis, feedback analysis, extension of the argument, and construction of argumentation sequences) in the online learning platform to facilitate argumentative knowledge construction. Specifically, we designed a transactive discussion script using question prompts for construction of sound single argument (analysis of the learning partner's arguments), construction of argumentation sequences (building argument-counterarguments-integration sequences), feedback analysis (clarification aspects of the case), and extension of the argument (further explanation and development of the arguments). Both argumentative discourse activities and also domain-specific knowledge acquisition can be facilitated if learners sufficiently elaborate on the learning materials in a transactive manner when making analyses of the argument(s) put forward by their partners and constructing arguments that relate to already externalized arguments.

Research Questions

To date, it is unclear how CSCL scripts can be designed to facilitate argumentative discourse activities in such a way as to also promote cognitive elaboration of the learning materials for enhanced domain-specific knowledge acquisition. Furthermore, there has been little empirical research on the assumption that both construction and reception of sound arguments and argumentation sequences have a positive effect on argumentative discourse activities and domain-specific knowledge acquisition. The following research questions were formulated to address these issues:

1. To what extent can a transactive discussion script affect argumentative discourse activities in a multidisciplinary CSCL setting?

We expect that the question prompts for argumentation analysis (making analyses of the partners' arguments and paraphrasing them into pre-structured boxes) will improve construction of sound single arguments during online discussion. We also expect that the question prompts for building counter-argument followed by feedback analysis will improve construction of argumentation sequences during online discussion. This is different from prior script approaches (Stegmann et al., 2007 & 2012), since these question prompts point learners towards analysing the partners' arguments rather than emphasizing construction of their own arguments. By changing learners' expectations in this way, we expect to improve formal quality of argumentation sequences during online discussion.

2. To what extent are acquisition and application of knowledge on argumentation affected by a transactive discussion script in a multidisciplinary CSCL setting?

We expect that the support from the transactive discussion script will facilitate the acquisition and application of knowledge on argumentation (construction of single arguments and argumentation sequences), as the necessary information about both aspects is represented in the transactive discussion script. Our assumption is that not only the script prompting learners to construct arguments and argumentation sequences, but also the analysis of learning partners' arguments followed by argumentation sequences facilitate the acquisition and application of knowledge on argumentation.

3. To what extent is individual domain-specific knowledge acquisition affected by a transactive discussion script in a multidisciplinary CSCL setting?

We expect that the support from the transactive discussion script will facilitate the acquisition of domain-specific knowledge, as the script supports elaboration of the learning materials and external memories (knowledge of the learning partners) through question prompts for feedback analysis (clarification aspects of the case) and extension of the argument (further explanation and development of the arguments).

4. To what extent is collaborative knowledge construction affected by a transactive discussion script in a multidisciplinary CSCL setting?

With this research question, we aim to investigate the effect of the transactive discussion script on dyad knowledge construction during the collaborative discourse phase in a multidisciplinary CSCL setting. We expect that the support from the script should facilitate collaborative knowledge construction as learners are guided to promptly benefit from one another's complementary expertise and to jointly elaborate on the learning materials through representation of the transactive discussion script.

Method

Context and Participants

The study took place at Wageningen University in the Netherlands, which focuses primarily on the life sciences, especially food and health, sustainability, and the healthy living environment. Students at this university are stimulated to combine natural and social sciences:

from plant sciences to economics and from food technology to sociology. The participants were 60 students from two different disciplinary backgrounds, namely international land and water management and international development studies. These two complementary domains of expertise were required for accomplishing the learning task of this study. The mean age of the participants was 24.98 (SD = 3.59) years. The numbers of female (56%) and male (44%) students were about equal. The same was true for the numbers of Dutch and foreign students.

The participants, who were compensated €50 for their contribution to this study, were divided into multidisciplinary pairs based on their disciplinary backgrounds. In other words, participants were randomly paired, with one learner having a water management disciplinary background and the other learner having an international development disciplinary background. The participants in each pair did not know each other beforehand. Next, each pair was randomly assigned to either the treatment condition (scripted) or the control group (unscripted) in a one factorial design. Scripted learners refer to learners who worked under the scripted condition, and unscripted learners refer to learners who worked under the unscripted condition. After dividing pairs of learners into these two conditions, each of which included 15 pairs, the experimental group was given a transactive discussion script and the control group was not. The experimental condition differed from the control group only with respect to the presence of the transactive discussion script that was implemented in the platform using the interface of the online environment.

Learning Materials

The subject to be learned was the concept of Community-Based Social Marketing (CBSM) and its application in Sustainable Agricultural Water Management (SAWM). The participants' task was to apply the concept of CBSM in fostering sustainable behaviour among farmers in terms of SAWM. Specifically, learners were asked to analyse and discuss the problem case and design an effective plan for fostering sustainable behaviour as a solution. They were asked to take into account the farmers' various perspectives on the need – or lack thereof – of implementing SAWM. The learning task was authentic and complex and allowed learners to construct different arguments based on the concepts of CBSM and SAWM (see Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013 for a full description of the theoretical concepts of the CBSM and SAWM as well as the learning task). Learners with an international development studies background were expected to be knowledgeable about CBSM. They were required to have passed at least two courses in which

the concept of CBSM or related topics had been studied ($M = 3.96$; $SD = 1.57$). Learners with an international land and water management studies background were expected to be knowledgeable about SAWM. They were required to have passed at least two courses in which the concept of SAWM or related topics had been studied ($M = 3.29$; $SD = 1.08$). In order for learners to understand each other and to be efficient in a collaborative multidisciplinary setting, all learners were provided with a three-page description of CBSM and SAWM and also demographic characteristics of the farmers and geographical characteristics of the location. The description of the problem case and theoretical background were embedded in the web-based environment during collaboration, so that the learners could study them while composing new messages on the discussion boards.

Learning Environment

The two learning partners in each dyad were distributed over two laboratory rooms. An asynchronous text-based discussion board called SharePoint was customized for the purpose of our study for the collaboration phase. Based on an extensive overview by Noroozi and Weinberger et al. (2012), it can be concluded that CSCL environments for educational argumentation demand a user-friendly platform that take into account the level of technology affordances, users' experiences, learning goals, etc. Being highly configurable, SharePoint platform was suitable for the goals of the current study and allowed for textual implementation of the transactive discussion script. Furthermore, students were familiar with the SharePoint environment and its functionalities since this platform is used extensively by teachers and students at Wageningen University for various purposes (social computing, sharing documents, collaborating, creating blogs, sites, wikis, etc.). Since this user-friendly platform was already embedded in the current educational system of the University (adaptability to user's experiences), it was not necessary to spend such a long time explaining to students how to work with the platform. Immediate (chat-like) answers were not possible in the learning environment. The style of the interaction rather resembled e-mail communication for the exchange of text messages. This means that learners needed to click on the "OK" or "REPLY" buttons to make their contributions available for the learning partners (see figures 5.1, 5.2, and 5.3). During the collaborative phase, the learners' task in both conditions was to analyse, discuss, and solve the problem case in pairs on the basis of the theoretical background (conceptual space) and to arrive at a joint solution. The goals were to (1) learn to argue in their specific domains, (2) learn from each other, and (3) share as much knowledge as possible during collaboration. Each message consisted of a subject line, date, time, and the

message body. While the SharePoint platform set author, date, time, and subject line automatically, the learners had to enter the body of the message. The platform allowed for textual implementation of computer-supported collaboration scripts. The CSCL environment for scripted learners was the same as in the control group except for the transactive discussion script, which structured the discussion phase in the platform. The conditions were distinguished and implemented as follows:

The control group

The learning partners received no further support beyond being asked to analyse, discuss, and solve the problem case on the basis of the conceptual space and theoretical background of the SAWM and CBSM and to type their arguments into the standard blank text box that the SharePoint platform provides.

The experimental group

The platform in this condition was the same as in the control group except for the transactive script, which structured the replied messages in text windows (see figures 5.1, 5.2, and 5.3 for examples of the transactive discussion script). Every group member was first asked to individually analyse the problem case and then to enter their conclusions into a blank text box. The learning partners were then asked to discuss the case on the basis of the individual analyses while receiving additional guidance that applied to every reply they sent off. Building on a modified coding scheme from Berkowitz and Gibbs (1983), four types of question prompts were automatically embedded into the reply messages in text windows, each of which was expected to facilitate various process and outcome categories of argumentative knowledge construction. On the basis of four types of question prompts for facilitation of transactive argumentative discourse, each participant was asked to paraphrase, criticize, ask clarifying/extension questions, give counter-arguments, and propose an integration of arguments into each message that had been posted by the learning partner until they reached consensus and could indicate agreement on the solutions. Learners could either start a new topic by posting a new message or reply to messages that had been posted previously. The structure of the four question prompts was as follows.

1) Argumentation analysis and paraphrasing, for the construction of a single argument in accordance with a simplified version of Toulmin's (1958) model (claim, ground, and qualification). In some studies (Stegmann et al., 2007 & 2012; Kollar et al., 2007), learners

were provided with a set of input text boxes for construction of sound explicit arguments (e.g. claim, grounds, and qualifications) within the interface of the discussion board. Scripted learners in our study were first asked to analyse the case and write their own argument(s) in the discussion board. They were then required to make analyses of the argument(s) being put forward by their partners and paraphrase them in pre-structured boxes. Therefore, the subjects of the reply messages were pre-structured with question prompts (e.g. "You claim..."; "Building on the reason..."; "The noted limitation of your claim is..."). Learners were encouraged to construct sound explicit arguments based on their partners' contributions rather than their own arguments. Figure 5.1 shows an example of the transactive discussion script initiated by prompts for argumentation analysis and paraphrasing.
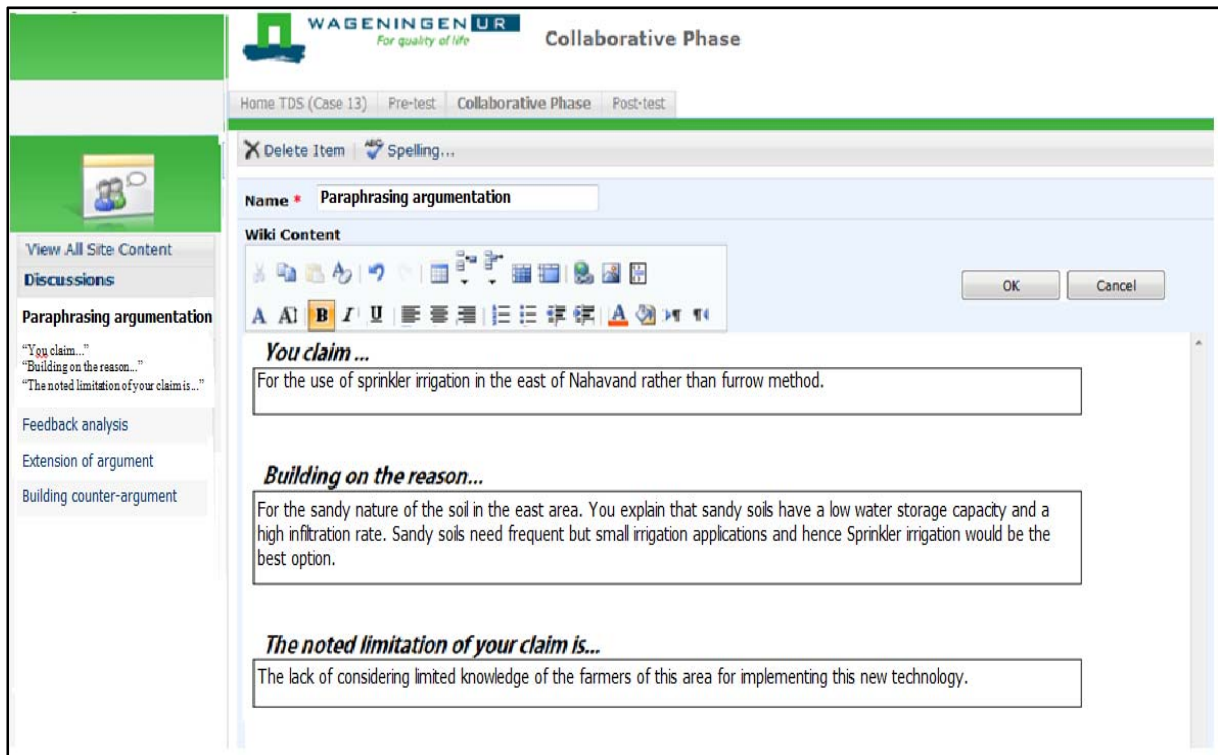
Figure 5.1: Screenshot of the transactive discussion script initiated by prompts for argumentation analysis and paraphrasing.

2) Feedback analysis, focused on clarifying aspects of the problem case based on individual analysis by the learning partners. The subjects of the reply messages were pre-structured with question prompts for feedback analysis (e.g. "I (do not) understand or agree with the following aspects of your position..., Could you please elaborate on that..."; "... is not yet clear to me, What do you mean by that?" etc.). Figure 5.2 shows an example of the transactive discussion script initiated by a prompt for feedback analysis.

Figure 5.2: Screenshot of the transactive discussion script initiated by a prompt for feedback analysis.

3) Extension of the argument, focused on further explanation and development of the arguments. The subjects of the reply messages were pre-structured with question prompts for extension of the argument (e.g. "Here's a further thought or an elaboration of your position …" etc.).

4) Building counter-arguments and interactive arguments for different areas of expertise in accordance with Leitão's (2000) model of argumentation sequence (argument–counterargument–integrative argument…). For scripted learners, the subjects of the reply messages were pre-structured with question prompts for construction of argumentation sequences (e.g. "Here's a different claim and reason from my area of expertise..."). We expect that question prompts for construction of argumentation sequences should improve formal quality of argumentation sequences during online discussion. Figure 5.3 shows an example of the transactive discussion script initiated by a prompt for building counter-arguments and interactive arguments.

Figure 5.3: Screenshot of the transactive discussion script initiated by a prompt for building counter-arguments and interactive arguments.

Procedure

In a pilot study with eight learners we first ensured adequate levels of task difficulty, comprehensibility of the learning materials, applicability of the tests and the technical functioning of the script and the learning environment. Overall, the experimental session took about 3.5 hours and consisted of four main phases with a 10-minute break between phases two and three. During the (1) introduction and pre-test phase, which took 35 minutes, individual learners received introductory explanations for 5 minutes. They were then asked to complete several questionnaires (15 minutes) on demographic variables, computer literacy, prior experience with and attitude towards collaboration. Next, the learners' knowledge on argumentation was tested (15 minutes). These tests measured the learners' prior knowledge on both formal quality of single arguments and argumentation sequences. The data from these tests were used to check whether randomization was successful (see section Control Measures). During the (2) individual learning phase, learners first received an introductory explanation of how to analyse the case (5 minutes). They were then given 5 minutes to read the problem case and 10 minutes to study a three-page summary of the theoretical text regarding SAWM and CBSM and also demographic characteristics of the farmers and the location of the case study. Learners were allowed to make notes and keep the text and their

notes during the experiment. Prior to collaboration, learners were asked to individually analyse the problem case and design an effective plan (20 minutes) for fostering sustainable behaviour on the basis of their own domain of expertise. Specifically, learners with an international development studies background were asked to design an effective plan for fostering sustainable behaviour among Nahavand farmers taking into account the concept of CBSM, whereas learners with an international land and water management studies background were asked to design an effective plan for fostering SAWM among Nahavand farmers. The data from this test served two purposes: to assess learners' prior knowledge regarding SAWM or CBSM, and to help us make sure that the randomization of learners in terms of prior knowledge over two experimental conditions was successful. The data were also used to help assess learners' prior knowledge on construction of single arguments. After a 10-minute break, the (3) collaborative learning phase (90 minutes) began. First, learners were oriented to the CSCL platform and acquainted with the procedure of the collaboration phase (10 minutes). Subsequently, learners were asked to discuss their analyses and design plans in pairs (80 minutes). Specifically, they were asked to analyse and discuss the problem case and jointly design an effective plan for fostering SAWM based on the concept of CBSM. This joint solution served as the criteria for assessing collaborative knowledge construction and formal quality of single arguments and argumentation sequences. During the (4) post-test and debriefing phase (45 minutes), learners were first asked to work on a comparable case-based assignment individually (20 minutes) based on what they had learnt in the collaboration phase. Specifically, they were asked to analyse and design an effective plan for fostering sustainable behaviour among Nahavand wheat farmers in terms of irrigation methods that could be applied for fostering SAWM as a CBSM advisor. This individual task was used for assessing domain-specific knowledge acquisition. The data were also used to help assess learners' application of formal quality of single arguments. Furthermore, as a post-test, learners were asked to fill out several questionnaires to assess learners' acquisition of knowledge on the formal quality of single arguments and argumentation sequences as well as their satisfaction with the learning experiences and its outcomes (20 minutes). Finally, the participants got a short debriefing for about 5 minutes (see table 5.1).

Table 5.1: Overview of the procedure of the experimental study.

Phase	Description	Duration
(1)	*Introduction and pre-test phase*	*35 min*
	Introductory explanations	5 min
	Assessment of personal data (questionnaires)	10 min
	Pre-test of knowledge on argumentation	20 min
(2)	*Individual learning phase*	*40 min*
	Introductory remarks	5 min
	Individual study phase of the theoretical text (conceptual space and problem case)	15 min
	Pre-test of domain-specific prior knowledge (individual analysis)	20 min
(3)	*Collaborative learning phase*	*90 min*
	Introduction to the CSCL platform	5 min
	Explanation of the procedure	5 min
	Collaborative learning phase (online discussion)	80 min
(4)	*Post-tests and debriefing*	*45 min*
	Individual analysis of the problem case	20 min
	Post-test of knowledge on argumentation	15 min
	Assessment of satisfaction with the learning effects	5 min
	Debriefing	5 min
Total time		*3.5 hrs.*

Measurements, Instruments, and Data Sources

Two coders were employed for coding of the content analysis in this study. These coders had previous experience coding comparable online discussions in the context of other projects, especially for content analysis schemes. However, for the purposes of the current project and to assure reliability of the coding process, they received extensive extra training on applying various coding schemes as well as on the project's conceptual framework, coding rubrics, frequent misconceptions, and rules and instructions for the coding process. The coders were then given the opportunity to practice with sample data and the data from the pilot study. Discrepancies were resolved through discussion. Any problems they encountered in coding ambiguous texts during this practice round were discussed between themselves and also with the project researchers until agreement was reached on how to resolve them. The ambiguities were mostly about whether a claim was supported or just a bare claim. This was the case only when the learners did not explicitly connect reasons to the corresponding claims with

conjunctions such as "because", "since", "due to the fact that" etc. Furthermore, the coders were unaware of subjects' characteristics. In order to avoid any type of bias, the data from both conditions were divided between the two coders so that each coder was responsible for the codings of the half of the data in each condition.

Assessing argumentation during discourse

The learners' online contributions during the collaborative learning phase were analysed by means of a coding scheme developed by Weinberger and Fischer (2006). First, trained coders segmented the discourse corpora based on propositional units (i.e. the criterion for segmentation was to separate units that included concepts from SAWM and CBSM that could be evaluated as true or false). With respect to the segmentation of the discourse corpora, the coders achieved an agreement of 88% during the training. The discrepancies were then resolved through discussion. Second, the segmented discussions were analysed for the formal quality of single arguments and argumentation sequences.

Assessing formal quality of single arguments

We used share of segments that were coded as claims with grounds and/or qualifications to measure the formal quality of single arguments in online discussion. Following Weinberger and Fischer (2006), the trained coders distinguished between (1) bare claims, (2) supported claims, (3) limited claims, (4) supported and limited claims, and (5) non-argumentative moves. Bare claims are statements that advance a position that is neither explicitly supported by grounds, nor explicitly limited by qualifications. Supported claims are claims without limitation of their validity, but with the provision of grounds that warrant the claim. These grounds can be data such as given information from case description, or warrants such as theoretical concepts, explanations, definitions or empirical data from research on SAWM and CBSM. Indicators for grounds are conjunctions such as "because", "since", "due to the fact that", etc. Learners, however, do not always explicitly connect reasons to the corresponding claims. Limited claims are restricted in their claimed validity by qualifications but without provision of grounds. Supported and limited claims are both accompanied by grounds and restricted by qualifications. Non-argumentative moves refer to questions, such as "Did we cover all relevant aspects?", coordinating moves, such as "Could you check this sentence?", and meta-statements on argumentation, such as "We are doing quite well, aren't we?".

Two coders coded five online discussions both in the scripted and unscripted conditions to evaluate reliability index of inter-rater agreement. The inter-rater agreement computed on the basis of these overlapping coding was sufficiently high (*Cohen's κ = .91*). Moreover, intra-coder test-retest reliability was calculated for 10% of the contributions. This resulted in identical scores in 90% of the contributions. We counted the sum of claims that were either supported, limited, or both as an indicator of formal quality of single arguments. In addition, we analysed the proportion of non-argumentative messages, supported (with grounds) claims, limited claims (with qualifications), and both supported and limited claims (see also Kollar et al., 2007; Stegmann et al., 2007 & 2012).

Assessing formal quality of argumentation sequences

We used sequence analyses of learners' online discussions to measure the formal quality of argumentation sequences. Following Leitão (2000), the trained coders distinguished between arguments, counter-arguments, integrations, and non-argumentative moves (see also Kollar et al., 2007; Leitão, 2000; Stegmann et al., 2007; Weinberger & Fischer, 2006; Weinberger et al., 2007b). An argument is a statement put forward in favour of a specific proposition that comprises claims that have not been discussed before. Counter-argument is an argument opposing a preceding argument or favouring an opposite proposition: If a claim opposes or attacks a preceding claim, the later claim is coded as a counter-argument. An integration is a statement that aims to balance, integrate, and advance a preceding argument and counter-argument. Integrations thus resolve the conflict or tension between arguments and counter-arguments on a higher level. However, learners are not limited to writing counter-arguments and integrations that address the arguments of their learning partners; they may also construct counter-arguments or integrations for their own arguments. In order to analyse the sequences on the level of the messages exchanged, trained coders used propositional segments to classify each message as an argument, counter-argument, or integration. Subsequently, the number of transitions between the message types (argument, counter-argument, or integration) was computed for each dyad.

Two coders coded five online discussions both in the scripted and unscripted conditions to evaluate the reliability index of inter-rater agreement. The inter-rater agreement computed on the basis of this overlapping coding was sufficiently high (*Cohen's κ = .83*). Moreover, intra-coder test-retest reliability was calculated for 10% of the contributions. This resulted in identical scores in 90% of the contributions. We counted the number of transitions from

argument to counter-argument, counter-argument to integration, and integration to counter-argument as an indicator of quality of argumentation sequences for each dyad. In addition, we analysed the proportion of non-argumentative messages, arguments, counter-arguments, and integrations. The reliability coefficient was sufficiently high (*Cronbach* α = .72).

Measuring individual acquisition of knowledge on argumentation

The argumentation test measures were analysed as indicators of acquisition of knowledge on argumentation. The acquisition of knowledge on argumentation was operationalized with respect to the quality of single arguments and the quality of argumentation sequences.

Measuring individual acquisition of knowledge on formal quality of single arguments

A pre-test, post-test design was used to measure individual learners' acquisition of knowledge on formal quality of single arguments. Learners were provided with argumentative texts about "private and public education" in the pre-test and "multi-cultural and mono-cultural group work in school" in the post-test, in which they were required to identify "complete" and "incomplete" explicit arguments. They were asked to back up their choices with explanations and arguments. The "complete" argumentative texts contained all of the components of the simplified Toulmin model (claim, ground, and qualifier), whereas the "incomplete" argumentative texts lacked at least one of those components. For each learner, three points were assigned for the correct identification of complete and incomplete argumentative text and three points for a reasonable explanation of the choice they had made. As a maximum, both in the pre-test and post-test, six points could be obtained on these measures by each individual learner. The reliability coefficient was sufficient both for the pre-test (*Cronbach* α = .78) and post-test (*Cronbach* α = .82). The gain of knowledge from pre-test to post-test was calculated and served as an indicator for the acquisition of knowledge on single arguments.

Measuring individual acquisition of knowledge on formal quality of argumentation sequences

A pre-test, post-test design was used to measure individual learners' acquisition of knowledge on formal quality of argumentation sequences. Learners were provided with argumentative texts about "private and public education" in the pre-test and "multi-cultural and mono-cultural group work in school" in the post-test in which they were required to identify "good" and "poor" argumentative moves (e.g. too short, non-sequential and/or non-supported arguments). They were asked to back up their choices with explanations and arguments. The

"good" argumentative texts contained all of the components of the Leitão model (argument, counter-argument, and integration), whereas the "poor" argumentative texts lacked at least one of those components. For each learner, three points were assigned for the correct identification of good and poor argumentative text and three points for a reasonable explanation of the choice they had made. As a maximum, both in the pre-test and post-test, six points could be obtained on these measures by each learner. The reliability coefficient of the measures was sufficiently high both for the pre-test (*Cronbach* α = .79) and post-test (*Cronbach* α = .88). The gain of knowledge from pre-test to post-test was calculated and served as an indicator for the acquisition of knowledge on argumentation sequences.

Measuring individual application of knowledge on argumentation

The application of knowledge on argumentation was operationalized with respect to the formal quality of single arguments. The written analyses of the individual learners prior to and after collaboration were differentiated and segmented in terms of components of single arguments (the same segmentation rules as for the discourse data were applied). We then counted the number of arguments (claims) that were either supported (with grounds) or limited (with qualifications), or both, in the individual analyses of each learner both in the pre-test and post-test. The reliability coefficient was sufficiently high both for the pre-test (*Cronbach* α = .84) and post-test (*Cronbach* α = .89). The gain in the number of supported, limited, or both arguments that the individual learners were able to construct before and after collaboration was calculated and served as an indicator for the individual knowledge acquisition on formal quality of single arguments.

Measuring individual acquisition of domain-specific knowledge

We used individual solution plans after the collaborative learning phase (post-test) to measure individual acquisition of domain-specific knowledge and compared them to an expert solution. This expert solution included all the possible theoretical concepts and their relations to one another and to the problem case (see Noroozi & Biemans et al., 2013; Noroozi & Teasley et al., in press). In this expert solution, multiple perspectives were applied to the problem case. First, individual learners' solution plans were segmented into propositional units and coded with respect to adequate applications of theoretical concepts to the problem case. The median of the agreement between the coders concerning the categorization of the segments was sufficiently high (*Cohen's* κ = .88). Learners received credits for adequately

applying theoretical concepts to case information. An equally valid indicator of domain-specific knowledge was adequate application of correct and relevant theoretical concepts in relation to one another and to the problem case. The indicator of domain-specific knowledge application for each participant was then the sum score of all relevant and correct applications of the theoretical concepts (i.e. relations between them and relations to the case information) which could be identified in the learners' individual written analyses after the collaborative phase. Both inter-rater agreement between the two coders (*Cohen's κ = .91*) and intra-coder test-retest reliability for each coder for 10% of the data (90% of identical scores) were high.

Measuring collaborative knowledge construction

As data sources to assess collaborative knowledge construction, we used learners' joint solution plans developed during discourse. The same analysis approach was used for assessing collaborative knowledge construction. The indicator of collaborative knowledge construction for each pair was then the sum score of all relevant and correct applications of the theoretical concepts, relations between them and to the case information, which could be identified within the joint analyses of the pairs of learners during the collaborative learning phase (*Cohen's κ = .93*).

Control Measures

Learners' prerequisites, such as computer literacy and prior experience with and attitude towards collaboration, have been discussed as being relevant and important in CSCL settings (see Noroozi & Biemans et al., 2011 & 2012; Noroozi & Busstra et al., 2012; Noroozi & Weinberger et al., 2012). We therefore controlled for uneven distribution of these measures over the two conditions.

Measurement of computer literacy

The learners were measured on computer literacy using a questionnaire with 10 items on a five-point Likert scale ranging from "almost never true" to "almost always true". The questionnaire was designed to ascertain the extent to which learners were skillful in terms of (a) software applications (MS Word, Excel, other programmes), (b) using the Internet for communication via e-mail, chatting, Blackboard, SharePoint, Web 2.0 tools, and other social media. Furthermore, we asked learners to rate themselves in terms of general computer skills on a scale of one to five. The reliability coefficient was sufficiently high (*Cronbach α = .87*).

Measurement of prior experience with and attitude towards collaboration

The learners were measured on these variables using a questionnaire with 25 items on a five-point Likert scale ranging from "almost never true" to "almost always true". Nine items of this questionnaire asked learners to ascertain the extent to which they had prior experience with collaboration. For example, they were asked to specify their collaboration experience by choosing from a list of alternatives (school, workplace, etc.) and also to rate themselves on general prior experience with collaboration. Sixteen items of this questionnaire were aimed to ascertain learners' attitudes towards collaboration. For example, they were asked to rate themselves on statements such as "collaboration fosters learning", "collaboration improves my weaknesses", "learning should involve social negotiation", "one learns more while performing tasks in a collaborative manner than individually", etc. The reliability coefficient was sufficient for both prior experience with (*Cronbach* α = .83) and attitudes towards collaboration (*Cronbach* α = .88).

Unit of Analysis and Statistical Tests

We used the dyads (group values) as the unit of analysis for research questions 1 and 4, which are directed to the discourse corpora. In contrast, the individual as the unit of analysis (aggregated individual values) was used to determine the individual transfer from argumentative knowledge construction according to research questions 2 and 3. We used ANOVA analysis (see Cohen, 1988) to compare formal quality of single arguments and argumentation sequences during discourse corpora. MANOVA was used to examine the effects of the transactive discussion script across several similar sets of dependent variables. MANOVA analysis has been used extensively across the literature to examine dependent variables simultaneously in such a way that it also controls for Type 1 error (the probability of rejecting the null hypothesis when it is true) in the model (Tabachnick & Fidell, 2007). In this study, MANOVA was used to analyse the proportion of various types of claims by degree of formal structure of single arguments (non-argumentative, bare, supported, limited, and supported/limited) during discourse activities. The same analysis was used for the proportion of various types of argumentation sequences (non-argumentative, argument, counter-argument, and integration) during discourse. For these tests, the scores were transformed into proportions. In other words, a pair's score on each category of the formal quality of single arguments and argumentation sequences was divided by the maximum number of messages during discourse. ANOVAs for each type of single argument and argumentation sequence

were then conducted as follow-up tests to the MANOVA. We used ANOVA for repeated measurement to compare individual acquisition of knowledge on argumentation (acquisition of formal quality of single arguments and argumentation sequences) between learners in the two conditions. The same analysis was used to compare individual application of knowledge on argumentation between scripted and unscripted learners. Finally, ANOVA was used to compare individual domain-specific knowledge application (post-test) and collaborative knowledge construction (during discourse) between scripted and unscripted learners. In the statistical tests on mean differences, the alpha level was set to 5%. To test equal distribution of the control variables in both conditions the alpha level was set to 20%. The scores of two inactive pairs of learners (one pair in each condition) were excluded from the analyses due to the limited number of their contributions. Therefore, for data analyses, 56 learners (14 pairs in each of the two conditions) were included in the study.

Results

Learning Prerequisites and Control Measures

The learners with an international development background in the two conditions showed no differences with respect to prior knowledge, $F(1, 26) = .35$, $p > .2$ ($M = 10.78$, $SD = 2.53$, $Max = 16$, $Min = 7$), and number of passed courses ($M = 3.96$, $SD = 1.57$, $Max = 7$, $Min = 2$) on CBSM and related topics, $F(1, 26) = .01$, $p > .2$. The same was true for the learners with an international land and water management background regarding prior knowledge, $F(1, 26) = .07$, $p > .2$ ($M = 7.86$, $SD = 2.74$, $Max = 13$, $Min = 2$), and number of passed courses ($M = 3.28$, $SD = 1.08$, $Max = 5$, $Min = 2$) on SAWM and related topics, $F(1, 26) = .48$, $p > .2$.

Furthermore, learners in the two conditions showed no differences regarding the mean scores of computer literacy, $F(1, 54) = .32$, $p > .2$, and prior experience with collaboration, $F(1, 54) = .18$, $p > .2$. The same was true for their attitudes towards collaboration, $F(1, 54) = .26$, $p > .2$. These results show that the randomization in terms of learners' individual prerequisites, prior knowledge and background requirements in the two conditions was successful.

Results for Research Question 1

In this section we will first present our findings on formal quality of single arguments during discourse. Then, we will describe the results for the formal quality of argumentation sequences.

Construction of single arguments during discourse

Learners in the two conditions showed significant difference with respect to formal quality of single arguments during discourse, $F(1, 26) = 17.33$, $p < .01$, $\eta^2 = .40$. The average scores for quality of single arguments were higher for scripted ($M = 18.14$, $SD = 5.26$, $Max = 30$, $Min = 10$) than unscripted learners ($M = 10.93$, $SD = 3.79$, $Max = 18$, $Min = 4$). Specifically, scripted learners were able to construct more supported and/or limited claims than unscripted learners.

Overall, learners in the two conditions showed significant differences with respect to share of arguments by degree of formal structure of single arguments, $Wilks'\ \lambda = .30$, $F(1, 26) = 13.10$, $p < .01$, $\eta^2 = .69$. Specifically, scripted learners formulated nearly 32% fewer bare claims than unscripted learners, $F(1, 26) = 44.81$, $p < .01$, $\eta^2 = .63$. Instead, in the scripted condition, about 15% more supported claims were formulated in comparison to the unscripted condition, $F(1, 26) = 15.19$, $p < .01$, $\eta^2 = .37$. The difference between scripted and unscripted learners in terms of share of supported and limited claims was just below the significance level, $F(1, 26) = 3.96$, $p = .06$, $\eta^2 = .13$, favouring scripted learners with only 4% more supported and limited claims than unscripted learners. There was no difference in the share of non-argumentative moves, $F(1, 26) = 2.87$, $p = .10$, between scripted and unscripted learners. Neither scripted nor unscripted learners produced limited claims during discourse (see table 5.2).

Table 5.2: Share of arguments in discourse by degree of formal structure of single arguments.

Item	Label	Mean (%)	SD	F	Sig	Eta Squared
No argumentative moves	*Scripted*	.73	1.95	2.87	.102	.10
	Unscripted	3.10	4.85			
	Total	1.92	3.82			
Bare claims	*Scripted*	20.76	12.29	44.81*	.000	.63
	Unscripted	52.05	12.44			
	Total	36.41	20.02			
Supported claims	*Scripted*	58.03	9.56	15.19*	.001	.37
	Unscripted	43.62	10.01			
	Total	50.82	12.09			
Limited claims	*Scripted*	-	-	-	-	-
	Unscripted	-	-			
	Total	-	-			
Supported and limited claims	*Scripted*	6.26	4.09	3.96	.057	.13
	Unscripted	2.47	5.83			
	Total	4.37	5.31			

* Significant at the .01 level

Construction of argumentation sequences during discourse

Learners in the two conditions showed significant difference with respect to formal quality of argumentation sequences, $F(1, 26) = 7.25$, $p < .05$, $\eta^2 = .22$. The average scores for the number of transitions from argument to counter-argument, counter-argument to integration, and integration to counter-argument were higher for scripted ($M = 16.29$, $SD = 4.87$, $Max = 27$, $Min = 10$) than unscripted learners ($M = 11.86$, $SD = 3.76$, $Max = 20$, $Min = 7$).

Overall, learners in the two conditions showed significant differences with respect to share of arguments by degree of formal structure of argumentation sequences, *Wilks' λ* $= .27$, $F (1, 26) = 15.56$, $p < .01$, $\eta^2 = .73$. Specifically, scripted learners constructed nearly 20% fewer arguments than unscripted learners, $F(1, 26) = 27.77$, $p < .01$, $\eta^2 = .52$. Instead, in the scripted condition, about 8% more integrations were formulated in comparison to the unscripted condition, $F(1, 26) = 10.84$, $p < .05$, $\eta^2 = .29$. There were no significant differences in the share of non-argumentative moves, $F(1, 26) = 1.98$, $p = .17$, or counter-arguments, $F(1, 26) = .04$, $p = .84$, between scripted and unscripted learners (see table 5.3).

Table 5.3: Share of arguments in discourse by degree of formal structure of argumentation sequences.

Item	Label	Mean (%)	SD	F	Sig	Eta Squared
No argumentative moves	*Scripted*	.73	1.95	1.98	.17	.07
	Unscripted	2.70	4.86			
	Total	1.72	3.77			
Arguments	*Scripted*	25.28	5.60	27.77*	.000	.52
	Unscripted	46.12	13.70			
	Total	35.70	14.76			
Counter-arguments	*Scripted*	35.60	6.32	.04	.842	.00
	Unscripted	36.18	9.12			
	Total	35.89	7.70			
Integration	*Scripted*	22.35	6.76	10.84*	.003	.29
	Unscripted	14.63	5.58			
	Total	18.49	7.24			

* Significant at the .01 level

Results for Research Question 2

In this section we will first present our findings on domain-general knowledge acquisition in terms of formal quality of single arguments and argumentation sequences. Then, we will describe the results for the individual application of knowledge on argumentation.

Acquisition of knowledge on formal quality of single arguments

On the basis of pre-test and post-test mean scores, knowledge on the formal quality of single arguments improved significantly for all learners, *Wilks' λ* = .36, $F(1, 26)$ = 45.56, $p < .01$, η^2 = .64, from pre-test to post-test (M_{T1} = 4.11; M_{T2} = 4.98; SD_{T1} = .64; SD_{T2} = .65). Furthermore, scripted and unscripted learners differed significantly with respect to their acquisition of knowledge on formal quality of single arguments, *Wilks' λ* = .69, $F(1, 26)$ = 11.86, $p < .01$, η^2 = .31. The gain of knowledge for scripted learners (M_{T1} = 4.11; M_{T2} = 5.43; SD_{T1} = .76; SD_{T2} = .47) was higher compared with unscripted learners (M_{T1} = 4.11; M_{T2} = 4.53; SD_{T1} = .52; SD_{T2} = .46) in terms of formal quality of single arguments (see table 5.4).

Acquisition of knowledge on formal quality of argumentation sequences

On the basis of pre-test and post-test mean scores, knowledge on the formal quality of argumentation sequences improved significantly for all learners, *Wilks' λ* = .34, $F(1, 26)$ = 49.46, $p < .01$, η^2 = .65, from pre-test to post-test (M_{T1} = 3.43; M_{T2} = 4.48; SD_{T1} = .77; SD_{T2} = .89). Furthermore, scripted and unscripted learners differed significantly with respect to their acquisition of knowledge on formal quality of argumentation sequences, *Wilks' λ* = .66, $F(1, 26)$ = 13.65, $p < .01$, η^2 = .34. Scripted learners acquired significantly more knowledge on formal quality of argumentation sequences (M_{T1} = 3.39; M_{T2} = 5.00; SD_{T1} = .84; SD_{T2} = .94) than unscripted learners (M_{T1} = 3.46; M_{T2} = 3.96; SD_{T1} = .71; SD_{T2} = .41) (see table 5.4).

Application of knowledge on formal quality of single arguments

On the basis of written analyses, all learners were able to apply their knowledge on the formal quality of single arguments, *Wilks' λ* = .43, $F(1, 26)$ = 33.92, $p < .01$, η^2 = .56, from prior to after collaboration (M_{T1} = 7.90; M_{T2} = 11.82; SD_{T1} = 2.17; SD_{T2} = 4.00). However, scripted (M_{T1} = 8.32; M_{T2} = 12.18; SD_{T1} = 2.48; SD_{T2} = 4.92) and unscripted (M_{T1} = 7.46; M_{T2} = 11.46; SD_{T1} = 1.78; SD_{T2} = 2.98) learners did not differ significantly with respect to their application of knowledge on formal quality of single arguments, *Wilks' λ* = .99, $F(1, 26)$ = .01, $p = .92$. In other words, on the basis of written analyses, the collaborative learning phase facilitated the application of knowledge on formal quality of single arguments, but the difference between scripted and unscripted learners was not significant (see table 5.4).

Table 5.4: Mean scores of knowledge acquisition for scripted and unscripted learners by degree of formal structure of single arguments and argumentation sequences.

Dependent variable	Condition	Mean	SD	Mean	SD
		Pre-test		Post-test	
Application of formal quality of single arguments on the basis of written analyses	*Scripted*	8.32	2.48	12.18	4.92
	Unscripted	7.46	1.78	11.46	2.98
	Total	7.89	2.17	11.82	4.00
Acquisition of formal quality of single arguments (knowledge tests)	*Scripted*	4.11	.76	5.43	.47
	Unscripted	4.11	.52	4.54	.46
	Total	4.11	.64	4.98	.64
Acquisition of formal quality of argumentation sequences (knowledge tests)	*Scripted*	3.39	.84	5.00	.94
	Unscripted	3.46	.71	3.96	.41
	Total	3.42	.78	4.48	.89

Results for Research Question 3

In this section we will present our findings on individual knowledge acquisition.

Scripted and unscripted learners differed significantly with respect to the individual acquisition of domain-specific knowledge, $F(1, 26) = 4.46$, $p < .05$, $\eta^2 = .15$, but this difference was only small. The average scores for individual acquisition of domain-specific knowledge were higher for scripted ($M = 20.39$, $SD = 4.82$, $Max = 32$, $Min = 14$) than unscripted ($M = 16.78$, $SD = 4.20$, $Max = 32$, $Min = 11$) learners. Specifically, scripted learners provided more correct and relevant relations between theoretical concepts and case information in their written analysis test after the collaborative learning phase.

Results for Research Question 4

In this section we will present our findings on collaborative knowledge construction.

Similar to individual domain-specific knowledge acquisition, scripted and unscripted learners differed significantly with respect to collaborative knowledge construction, $F(1, 26) = 8.82$, $p < .01$, $\eta^2 = .25$. Again, the average scores for collaborative knowledge construction were higher for scripted ($M = 27.79$, $SD = 4.58$, $Max = 36$, $Min = 20$) than unscripted ($M = 22.21$, $SD = 5.32$, $Max = 31$, $Min = 14$) pairs of learners. Specifically, scripted pairs of learners provided more correct and relevant relations between theoretical concepts and case information in their joint analysis during the collaborative learning phase.

157

Discussion

We found that the quality of argumentative discourse activities can be fostered by means of a transactive discussion script in a multidisciplinary CSCL environment. Various forms of argumentative scripts positively facilitate various aspects of the argumentative discourse and structure (see Jermann & Dillenbourg, 2003; Stegmann et al., 2007 & 2012). As expected, the question prompts for argumentation analysis facilitated the construction of formal quality of single arguments during online discussion. Specifically, scripted learners were able to construct sound arguments based on various elements of the simplified version of Toulmin's (1958) model (claim, ground, and qualification) as each learner was asked to repeatedly paraphrase and analyse his/her learning partner's argumentation. This is in line with the findings of Stegmann et al. (2007 & 2012) showing the positive effects of the scripts for construction of single arguments on formal quality of single arguments. However, the design of our transactive discussion script for facilitation of formal quality of single arguments was rather different from Stegmann et al. (2007 & 2012). In the current study, we provided scripted learners with the question prompts for argumentation analysis and then asked them to analyse and paraphrase their learning partners' arguments in pre-structured boxes. Whereas in studies by Stegmann et al. (2007 & 2012), learners were asked to construct their own arguments in pre-structured boxes for construction of sound explicit arguments within the interface of the discussion board. In the current study, scripted learners became aware of the characteristics of the sound arguments when they paraphrased their learning partners' arguments according to the main components of a sound single argument. As our results show, this intervention also led learners to produce better arguments themselves (i.e. more supported, limited, or both, than unscripted learners).

We also found that neither scripted nor unscripted learners provided "limited" claims during discourse. The plausible reason for this is that the design of the learning task required learning partners to analyse, discuss, and solve an authentic problem case during the collaborative phase, which lasted only 80 minutes. The learning partners may have felt more need for analysing partners' arguments and engaging in sequential argumentation rather than providing limitations for their own arguments. As a result, the lack of limited claims in both conditions should not be attributed to limited knowledge on argumentation, since post-test analysis results show that students were aware of the characteristics of the sound single arguments.

The question prompts for building counter-arguments and interactive arguments facilitated the construction of formal quality of argumentation sequences during online discussion. This is in line with the findings of Kollar et al. (2007) and Stegmann et al. (2007), who report on the positive effects of scripts for construction of argumentation sequences on formal quality of argumentation sequences during a collaborative learning phase. Again, the design of our transactive discussion script for facilitation of formal quality of argumentation sequences was different from previous studies. In the study by Stegmann et al. (2007), subjects of the reply messages were pre-structured automatically by the script for the construction of specific argumentation sequences of argument, counter-argument, and integration. Kollar et al. (2007) provided learners with pre-structured text boxes (e.g. argument, counter-argument, integration) for facilitation of formal quality of argumentation sequences; whereas, for scripted learners in the current study the subjects of the reply messages were pre-structured with question prompts for the construction of argumentation sequences. Embedding these prompts in the interface of the platform helped scripted learners engage in more interactive arguments and hence make transitions from various components of argumentation sequences.

Mixed results were reported with regard to the effect of the transactive discussion script on knowledge on argumentation. We found that the transactive discussion script fostered only the acquisition (and not the application) of knowledge on single arguments in a multidisciplinary CSCL environment. In other words, scripted learners acquired knowledge on formal quality of single arguments but they were not able to apply their acquired knowledge on argumentation in a comparable problem-solving task after the collaboration. As we expected, in line with Stegmann et al. (2007 & 2012) as well as Kollar et al. (2007), scripted learners gained more knowledge (pre-test to post-test gain) on formal quality of single arguments than unscripted learners. However, this acquisition of knowledge on formal quality of single arguments did not re-emerge in learners' written analysis after collaboration. This could be plausibly justified by the multidisciplinary context and the time constraints set by this study: Unlike the monodisciplinary context of the Stegmann et al. (2007 & 2012) and Kollar et al. (2007), learners in the current study came from two different disciplinary backgrounds and were required to learn about the complementary expertise of their learning partners in order to design an effective plan for fostering sustainable behaviour. This was necessary to adequately apply and relate theoretical concepts of both learning partners' domains of expertise in the joint solution plans. Therefore, theoretically, there was a possibility for a trade-off between domain-specific knowledge acquisition and the acquisition of knowledge on argumentation.

Due to the time constraints set by this study, learners in their individual written analyses tended to focus more on applying the theoretical concepts of their learning partners and relating them to their own domain concepts and to the problem case rather than focusing on construction of sound explicit arguments.

We also found that the individual knowledge acquisition on argumentation sequences can be fostered by means of a transactive discussion script in a multidisciplinary CSCL environment. This is in line with Stegmann et al. (2007 & 2012), Noroozi and Teasley et al. (in press), as well as Kollar et al. (2007), who reported a positive effect of argumentation scripts on individual knowledge acquisition on argumentation sequences. Specifically, scripted learners were prompted to build counter-arguments for every argument raised by the learning partner and also engage in interactive arguments to agree upon the issue at stake. Scripted learners gained more knowledge on formal quality of argumentation sequences than unscripted learners as the result of exchanging argumentation on the basis of Leitão's (2000) model of argumentation sequences (i.e. argument–counterargument–integrative argument) in collaborative learning. The Leitão's model of argumentation sequences "argument-counterargument-integrative argument" (see Leitão, 2000 & 2003) is analogous to Hegel's triadic dialectic of "thesis-antithesis-synthesis" (see Hegel, 1975; Inwood, 2002; Magee, 2001; Walsh, 2005) in the sense that they both can be considered as dialectical approaches that embrace conflicting ideas as the seeds for generating new ideas about the issue at stake. As assumed by Baker (2003), argumentation-related cognitive processing in argumentative discourse is positively related to quality of argumentation and acquisition of knowledge on argumentation (Stegmann et al., 2012).

We found that the individual acquisition of domain-specific knowledge can be fostered by means of a transactive discussion script in a multidisciplinary CSCL environment. This is not consistent with other findings (e.g. Baker & Lund, 1997; Kollar et al., 2007; Stegmann et al., 2007 & 2012), since these studies did not report a positive impact of various types of argumentative scripts on acquisition of domain-specific knowledge. For example in studies by Kollar et al. (2007) and Stegmann et al. (2007 & 2012), construction of single arguments and argumentation sequences were facilitated by argumentative scripts without positive impact on the acquisition of domain-specific knowledge as the individual learning performance. The plausible explanation was that scripted learners mostly devoted their cognitive capacity to constructing sound arguments directly responding to the affordances put forward by the argument structure represented in the given text boxes; hence little cognitive effort and time

160

were allocated to elaborate on the learning materials and additional resources for enhanced domain-specific knowledge acquisition. The transactive nature and the design of the discussion script in the current study could explain this difference. In the current study, we gave equal weight to elaborations of domain-general and domain-specific activities during the discourse activities. Whilst the question prompts (for analysis of the learning partner's arguments and for building counter-arguments and integration) aimed at improving learners' knowledge on argumentation, the acquisition of domain-specific knowledge (for elaboration of the learning materials and taking advantage of the knowledge of the learning partner) was facilitated through question prompts for feedback analysis (clarification aspects of the case) and extension of the argument (further explanation and development of the arguments). In the scripted condition, argumentative activities were followed by clarifications and elaborations of the learning materials for enhanced domain-specific knowledge acquisition. We thus sought to prevent learners from getting stuck on only one activity at the expense of other aspects. This may explain why scripted learners acquired as much domain-specific knowledge as knowledge on argumentation.

We found that collaborative knowledge construction can be fostered by means of a transactive discussion script in a multidisciplinary CSCL environment. The findings on collaborative knowledge construction are indicators of the higher quality of discourse for scripted than unscripted learners. During the discourse activities, the scripted learners were guided to follow a set of instructions that could lead into transactive discussions and argumentations. For example, they were guided to make analyses of the argument(s) being put forward by their learning partner and construct arguments that relate to already externalized arguments (reasoning based on the reasoning of the learning partners). They were also guided to engage in sequential argumentation and to extend their arguments along with feedback provided by the learning partner. These transactions helped learners reason based on the reasoning of the learning partners and engage in critical and constructive discussions and argumentations. Transactivity has been regarded as one of the main "engines of collaborative knowledge construction" and is related to the coordination of learning activities and interactions among learners for cognitive elaboration of the learning materials and available resources and hence knowledge construction (e.g. Teasley, 1997; Noroozi & Teasley et al., in press; Weinberger, 2011). When learners engage in more transactive discussions and argumentations, they benefit to a greater extent from the external memories available, such as contributions of their learning partners (e.g. Teasley, 1997; Weinberger et al., 2007a & 2007b). That is why scripted

161

learners compared with unscripted learners in the current study were better able to integrate concepts acquired in their studies along with newly acquired concepts from their learning partners in their joint solution plans. Knowledge could be constructed in collaborative discourse as a result of transactive dialogic-sequential exchanging of arguments, counter-arguments, and integrations (Baker, 1999 & 2003; Leitão, 2000).

In summary, construction of a sound single argument using grounds to support a claim and also consideration of multiple perspectives to qualify the claim are related to elaboration of deep cognitive processes, which may foster argumentative knowledge construction (see Baker, 2003; Noroozi & Teasley et al., in press; Stegmann et al., 2012). Construction of complete argumentation sequences and structuring the dialogic-sequential exchange are also assumed to be related to elaboration of deep cognitive processes, which may foster knowledge construction (Leitão, 2000; Stegmann et al., 2007; Noroozi & Teasley et al., in press).

Implications, Limitations, and Suggestions for Future Research

This study shows that the construction of single arguments and argumentation sequences is fostered not only by scripts for constructing one's own single arguments and exchanging them in argumentation sequences but also by scripts for analysing and evaluating learning partners' arguments and exchanging them in dialogic-sequential argumentation in a multidisciplinary CSCL setting. With an innovative script designed differently than most prior scripts, this study contributes to accumulating evidence that computer-supported collaboration scripts work well to foster argumentative knowledge construction. Awareness about argument quality when analysing someone else's arguments leads to construction of better arguments and enhancement of learners' knowledge on argumentation. These continuous argument constructions and receptions followed by peer clarifications and elaborations of the materials enhance learners' knowledge about the topic. This might explain why this script also facilitated both individual and collaborative acquisitions of domain-specific knowledge in a CSCL problem-solving setting. So, scripts may be particularly efficient and effective when providing less structure for learners' activities, but rather entail knowledge about argumentation and rules for changing expectations of learners co-regulating each other and being transactive with each other's contributions (see Noroozi & Teasley et al., in press).

The content analysis approach used in the current study to assess argumentative knowledge construction comprises qualitative steps since dialogue is ambiguous and subject to

interpretation. Quantification in terms of determining inter-rater agreement and categorizing the respective argumentative moves across the overall discourse corpus builds on prior work methodologically and serves to test hypotheses that have been generated in prior qualitative research work. In this vein, analysis of argumentative knowledge construction can benefit from applying multiple methods to investigate respective different research questions. In contrast to the eristic connotations of "having an argument", argumentative knowledge construction is a sharing and social testing of opinions based on reason. We build here on the approach of learning through socio-cognitive conflict, which entails that learners identify diverging views in dialogue and resolve the differences on a social and ultimately on a cognitive plane oriented towards logic and reason, rather than pseudo-resolution of conflicts through ridiculing the peer, ad-hominem attacks, disregarding/ignoring the conflict, superficial and momentary agreement, etc. Historically and philosophically, this alludes, for instance, to a Thomas of Aquinas approach to reasoned debate (in this case on the cosmological argument) that builds on a dialectic of reasonably arguing for the opponent's standpoint and then successively dissecting these arguments.

Although in the current study high values for various coding schemes in terms of argumentative knowledge construction were obtained, there are other aspects of argumentation that could also be measured including the dynamic construction of argument content and the structure quality of the argument (Joiner et al., 2008; North et al., 2008). It would be insightful to explore how interactive and ideational aspects of the discussion patterns of student messages during collaborative argumentation influence both collaborative and individual knowledge construction. We therefore recommend using measures such as strategic and structural analysis (Joiner et al., 2008; Noroozi et al., 2011) as well as exchange structure analysis (North et al., 2008) for assessing the quality of the argument during collaborative argumentation. Furthermore, we advise applying qualitative techniques in addition to quantitative approaches for assessing in-depth analysis of the quality of collaborative argumentation. This would enable researchers to shed light on how students argue with one another and how interaction patterns of collaborative argumentation influence performance. In doing so, we advise using instruments such as individual and group in addition to the quantitative analysis of argumentation to understand how "argument" is applied during the discourse and manifested in actual practices (Mitchell et al., 2008). "Key event recall" interviews to explore the experience of learners with collaborative argumentation and also challenges during discourse could be insightful (Wegerif et al., 2010).

We only administrated short-term individual measurement to account for the domain-specific knowledge acquisition in a multidisciplinary setting. This may have resulted in a misleading boost in the short-term individual learning performance measures without fostering deeper processing that encourages long-term retention (see Noroozi & Busstra et al., 2012). Furthermore, the multidisciplinary nature of the study could have influenced the acquisition of domain-specific knowledge since there is evidence that collaborative argumentation is more productive for learning groups made up of individuals with different disciplinary backgrounds than for those whose members have the same disciplinary background (see Joiner et al., 2008). It remains to be investigated to what extent the short-term effects of scripts also translate into the long-term impacts of such a script on argumentative knowledge construction, not only in multidisciplinary but also in single disciplinary settings. We suggest that follow up research be aimed at this question.

In this study, the effects of various types of question prompts on various process and outcome categories of argumentative knowledge construction were tested in combination (through a transactive discussion script as a whole) for scripted learners and not separately in various experimental conditions. We are therefore not certain about the additive or interaction effects of each set of question prompts on various aspects of argumentative knowledge construction. For example, although we expect that the question prompts for building counter-arguments and integrations facilitate formal quality of argumentation sequences, it is still practically possible that these question prompts had effects on other aspects of argumentative knowledge construction such as formal quality of single arguments. Previous studies (see Kollar et al., 2007; Stegmann et al., 2007), however, failed to confirm interaction and/or additive effects of these scripts when they were used separately under different experimental conditions. Since the design of the transactive discussion script in this study is rather different from that in previous studies, we advise that future studies focus on the interaction and/or additive effects of various question prompts for argumentative knowledge construction.

Acknowledgments

Chapter

6

Facilitating Learning in Multidisciplinary Groups with Transactive CSCL Scripts*

Abstract

Knowledge sharing and transfer are essential for learning in groups, especially when group members have different disciplinary expertise and collaborate online. Computer-Supported Collaborative Learning (CSCL) environments have been designed to facilitate transactive knowledge sharing and transfer in collaborative problem-solving settings. This study investigates how knowledge sharing and transfer can be facilitated using CSCL scripts supporting transactive memory and discussion in a multidisciplinary problem-solving setting. We also examine the effects of these CSCL scripts on the quality of both joint and individual problem solution plans. In a laboratory experiment, 120 university students were randomly divided into pairs based only on their disciplinary backgrounds (each pair had one partner with a background in water management and one partner with a background in international development studies). These dyads were then randomly assigned to one of four conditions: transactive memory script, transactive discussion script, both scripts, or no scripts (control). Learning partners were asked to analyse, discuss, and solve an authentic problem case that required knowledge of both their domains (i.e. applying the concept of community-based social marketing in fostering sustainable agricultural water management). The results showed interaction effects for the transactive memory and discussion scripts on transactive knowledge sharing and transfer. Furthermore, transactive memory and discussion scripts individually, but not in combination, led to better quality demonstrated in both joint and individual problem solutions. We discuss how these results advance the research investigating the value of using scripts delivered in CSCL systems for supporting knowledge sharing and transfer.

Introduction

Learning processes and outcomes for students who are asked to collaborate with peers have been of interest to many researchers in psychology, learning sciences, and education. Given the increasingly global nature of the workplace and the need for multidisciplinary expertise to solve today's complex issues, helping students learn how to work together in groups to share their knowledge, expertise, and experiences from different disciplinary perspectives is a priority for higher education.

Previous research has demonstrated that multidisciplinary groups can be advantageous to learning when students leverage one another's complimentary expertise to create new ideas and products in a way that would have been difficult with single disciplinary thinking (e.g. Boix-Mansilla, 2005; Noroozi & Biemans et al., 2013; Noroozi & Weinberger et al., 2013; Spelt et al., 2009). Although considering a problem from various viewpoints can be productive, some studies have shown that multidisciplinary groups do not always produce good problem solutions (e.g. Barron, 2003; Vennix, 1996). In this study, we aim to provide solutions for challenges that are inherent to multidisciplinary collaborative problem-solving settings using a transactivity approach. Transactivity is a term derived from Berkowitz and Gibbs (1983) and introduced to collaborative learning by Teasley (1997) meaning "reasoning operating on the reasoning of the other".

There are two main reasons that multidisciplinarity may not always be an advantage. First, individual members of multidisciplinary groups need to establish common ground, which is vital to team performance but difficult and time consuming to achieve (Beers et al., 2005 & 2007; Courtney, 2001). Group members may engage in non-productive discussions of information that may already be known to all members (Stasser & Titus, 1985). As a consequence, some groups work together for extended periods before actually starting to work efficiently on pooling their unshared knowledge. This outcome is striking since in order for productive collaborative problem-solving to succeed, group members need to effectively pool and process their unshared complementary knowledge and information rather than engage in discussion of the information that is already shared among team members from the start (e.g. Kirschner et al., 2008; Rummel & Spada, 2005; Rummel et al., 2009). Speeding up the process of pooling unshared information is more likely to be achieved when group members have meta-knowledge about the domain expertise and knowledge of their learning partners

(e.g. Noroozi & Biemans et al., 2013; Rummel et al., 2009). This process has been described as developing a transactive memory system (TMS; Wegner, 1987 & 1995).

Second, due to divergent domains of expertise, group members may have difficulties building arguments for and against those being put forward by their learning partner(s); and therefore avoid engaging in transactive discussions. In order to make decisions leading to joint solution(s) in collaborative problem-solving settings, learning partners need to engage in transactive discussion and to critically evaluate the given information from different perspectives on the basis of their domains of expertise (e.g. Rummel et al., 2009) before they reach an agreement and consensus about solution(s). Facilitation of transactive discussions is more likely to be achieved when group members are guided to elaborate, build upon, question, construct arguments for and counter-arguments against the contributions of their learning partners in order to reach shared solution(s) for the learning task (Stegmann et al., 2007; Teasley, 1997; Noroozi & Weinberger et al., 2013).

In summary, there seem to be two types of collaborative discussion that support group learning: First, effective collaborative learning has been found to be related to the process by which learners gain meta-knowledge about the domain expertise of their partners and use this knowledge to pool and process unshared information, thus establishing a TMS. Second, effective collaborative learning depends on how learners engage in transactive discussion when they elaborate, build upon, question, construct arguments and give counter-arguments against the contributions of their learning partners (Noroozi & Weinberger et al., 2013). Given these research findings, platforms for online learning environments such as ICT tools or CSCL systems have been designed to increase knowledge sharing and transfer as well as argumentative knowledge construction (Weinberger & Fischer, 2006; Weinberger et al., 2007a). Scripts have been shown to be a promising approach to orchestrate various roles and activities of learners. CSCL scripts can be used as an approach for procedural scaffolding of specific interaction patterns implemented into online learning environments (Fischer et al., 2007; Weinberger, 2011). This study aims to foster transactive knowledge sharing and domain-specific knowledge transfer in a multidisciplinary CSCL setting using transactive memory and discussion scripts. A transactive memory script is a set of "role-by-expertise" prompts for building awareness about a learning partner's expertise, assigning and accepting task responsibility, and forming a collaboratively shared system of retrieving information based on specialized expertise. A transactive discussion script is a set of "elicit-and-integrate" prompts for making analyses of the argument(s) put forward by learning partners and

constructing arguments that relate to already externalized arguments. In addition, we examine the individual and combined effects of these two kinds of scripts on the quality of both joint and individual problem solutions.

Collaborative Learning

In an increasingly global economy, it is inevitable that professionals in all fields will be confronted with rapidly changing problems and complex issues. These complexities call for appropriate specialization of domain knowledge, but they also make it necessary for qualified professionals and experts from different disciplines to collaborate in new learning and working contexts. This reality has consequences for education, especially for providing students with ample experience working in multidisciplinary groups. In educational settings, collaborative learning tasks are designed to provide group members with experience working together on complex and authentic tasks (Dillenbourg, 1999), and elaborating on materials without immediate or direct intervention by the teacher (Cohen, 1994). Through this process, students generally contribute individually to solving the problem, partake in discussion of all contributions, and arrive at joint solutions by working together (Roschelle & Teasley, 1995).

Building on Stahl (2006), in collaborative communities, learning takes place at the level of groups and communities as well as on an individual level. Collaborative learning can be viewed with a focus on individual cognitions that can be exchanged in the form of discourse contributions between individual members in the group. Through this process, learners generally contribute individually to solving the problem, partake in discussion of all contributions, and arrive at joint solutions by working together (Roschelle & Teasley, 1995). Some evidence has been collected on the role of individual cognition and discourse in collaborative learning showing that deep cognitive elaboration is a good predictor for learning outcomes, which can sometimes diverge from the quality of the arguments brought forward (Stegmann et al., 2012).

However, there is a contrasting approach that views collaborative learning as integral to group cognition. This approach focuses on the interactional understanding of referencing and meaning making outside the individual minds in collaborative communities. Based on the notion of group cognition in collaborative learning communities, knowledge building relies on the collective, distributed cognition of a group/community, as a whole unit, rather than individual mental representations (Bereiter, 2002; Stahl, 2006). From this perspective,

collaborative knowledge building often could not be attributed to individuals or even a combination of individual contributions, but instances of group cognition as a whole. Although there has been some conceptual grounding on learning through discourse and recent work has focused on group-level phenomena of collaborative learning (e.g. Paus et al., 2012), there is yet little research on how individual contributions emerge and re-emerge in discourse and may become part of individual knowledge structures as a result of that exchange.

Despite the diversity of theories and different nuances in the socio-cognitive theories employed to understand the process of collaborative learning (see Stahl, 2011b), there has been a consensus among researchers that learning is the result of interaction or transaction between the partners in a group (De Lisi & Goldbeck, 1999; Michinov & Michinov, 2009). In the following paragraphs, we describe how both TMS and transactivity are considered to be important for collaborative learning in multidisciplinary groups with divergent knowledge. Whilst TMS (Wegner, 1987 & 1997) refers to coordination of the distributed knowledge among members of a group, transactivity (Teasley, 1997) refers to the extent to which learners operate on the reasoning of their peers during collaborative learning.

Transactive Memory System (TMS) in Collaborative Learning

Wegner (1987) was one of the pioneers of the concept of TMS. His theory of TMS was used originally to describe how couples and families in close relationships coordinate their memories and tasks at home. A TMS is based on the interaction between individuals' internal and externally supported memory systems, in the form of communication between group members (Wegner, 1987 & 1995). Internal memory is defined as unshared information located in the individual mind, whilst external memory is knowledge represented outside the mind of a group member that can be shared through knowledge-relevant communication processes among group members (Wegner, 1987 & 1995). In TMS, group members need to look for external memories to identify the existence, location, and mechanisms for retrieval of knowledge held by other group members. TMS can be described as a system which combines the knowledge stored in each individual's memory with meta-memory on knowledge structures of the learning partner(s) for developing a shared awareness of who knows what in the group (Moreland et al., 1996 & 1998; Wegner, 1987 & 1995).

Specifically, TMS refers to group members' awareness of one another's knowledge, the accessibility of that knowledge, and the extent to which group members take responsibility for

providing knowledge in their own area of expertise and retrieval of information held by other group members in the group (Lewis, 2003; London et al., 2005; Wegner, 1995). These processes can result in the forming of a collaboratively shared system of encoding, storing, and retrieving information in the group as a whole for enhancing group performance (Noroozi & Biemans et al., 2013; Wegner, 1995). Following Wegner's work (1987 & 1995), group members work best when they first discover and label information distributed in the group, then store that information with the appropriate individual(s) who has/have the specific expertise and, finally, retrieve the needed information from each individual when performing a task some time later (see Noroozi & Biemans et al., 2013, for a full description of various processes of a TMS). Establishment of a TMS in a group helps members start a productive discussion in order to pool and process learning partners' unshared information and knowledge resources, leading to successful completion of a collaborative learning task (Moreland & Myaskovsky, 2000; Rummel et al., 2009; Stasser et al., 1995).

Information pooling and processing can be facilitated through TMS since members of a group are asked to externalize their own unshared knowledge for learning partners and then, on the basis of this externalized information, they can ask critical and clarifying questions in order to elicit information from learning partner(s) (e.g. Fischer et al., 2002; Webb, 1989; Weinberger et al., 2007a & 2007b). Elicitation of information (e.g. asking questions to receive information from learning partners) could again lead to externalization of information (e.g. through explanations by learning partners) which may lead to a successful exchange of unshared information among members of a group in collaborative problem-solving (King, 1999; Weinberger & Fischer, 2006). Both externalization of one's own knowledge and elicitation of a learning partner's knowledge are considered to be mechanisms that support learning due to the facilitation of information pooling among members of a group in collaborative settings (Fischer et al., 2002; King, 1999; Noroozi & Biemans et al., 2013; Rosenshine et al., 1996).

Transactivity in Collaborative Learning

Transactivity, meaning "reasoning operating on the reasoning of the other" is a term derived from Berkowitz and Gibbs (1983) and introduced to collaborative learning literature by Teasley (1997). Transactivity indicates to what extent learners build on, relate to, and refer to what their learning partners have said or written during the interaction. Transactivity has been regarded as one of the main engines of collaborative knowledge construction and is connected to the level of cognitive elaboration and individual knowledge construction. Specifically, the

more learners build on the reasoning of their learning partners, the more they benefit from learning together (Teasley, 1997). Successful collaboration typically requires that learners engage in transactive discussions and argumentation sequences before reaching an agreement with their peers on joint solution(s) (Teasley, 1997; Noroozi & Biemans et al., 2013; Noroozi & Weinberger et al., 2013; Rummel et al., 2009).

Failure of group members to build on the reasoning of their learning partners may prohibit them from engaging in critical and transactive discussions, as they too quickly accept the contributions of their peers (Weinberger & Fischer, 2006). This quick consensus building represents the lowest level of transactivity as learners immediately accept the contributions of their partner(s) without further discussion. This often happens when learners want to manage the interaction and continue the discussion focused on other aspects of the task, rather than because they are already in agreement (Clark & Brennan, 1991; Weinberger & Fischer, 2006).

By contrast, when learners operate on the reasoning of their learning partners, they integrate and synthesize one another's perspectives and ideas in order to jointly make sense of the learning task (Nastasi & Clements, 1992; Noroozi & Weinberger et al., 2013; Weinberger & Fischer, 2006). This form of transaction has been called "integration-oriented consensus building" as learners engage in persuasive argumentation with partner(s) in order to revise, modify, and adjust their initial contributions on the basis of their partner(s)' contributions (Fischer et al., 2002; Weinberger & Fischer, 2006). In another form of transactivity, called "conflict-oriented consensus building", learners closely operate on the reasoning of their partners based on their socio-cognitive conflicts about their individual positions on the solution(s). This form of consensus building happens when learners engage in a highly transactive discussion and critical argumentations with their partner(s), which can lead to disagreements and therefore modifications of the perspective of the partners (Fischer et al., 2002; Weinberger & Fischer, 2006). Conflict-oriented consensus building is regarded as an important type of consensus for leading toward a successful collaborative learning experiences (Doise & Mugny, 1984; Fischer et al., 2002; Weinberger et al., 2005a & 2005b).

Computer-Support Systems to Facilitate TMS and Transactivity

In the last 15 years, virtual environments in the form of ICT tools or online support systems have been found to facilitate information pooling and knowledge awareness, and to support transactive discussions. Despite all the problems and challenges that are inherent to

collaboration in online and networked learning environments such as production of descriptive and surface-level knowledge (see Häkkinen & Järvelä, 2006) as well as difficulties for achievement of reciprocal understanding and shared values (see Järvelä & Häkkinen, 2002), CSCL environments in which learners collaborate in teams have been found to support knowledge construction and learning. The two most prominent approaches in CSCL used to facilitate transactivity are knowledge representation tools and computer-supported collaboration scripts (see Noroozi & Weinberger et al., 2012, for an overview). The most popular knowledge representation tools to facilitate knowledge awareness and sharing in the group are graphical concept maps (e.g. Dehler et al., 2008 & 2011; Engelmann & Hesse, 2010 & 2011; Noroozi & Biemans et al., 2011 & 2012; Noroozi & Busstra et al., 2012; Schreiber & Engelmann, 2010). There is an assumption that group awareness is a prerequisite for initiation of TMS in collaborative settings. For example, Schreiber & Engelmann (2010) found that using concept maps to visualize collaborators' knowledge structures (see also Engelmann et al., 2009) can initiate processes of TMS development, which is in turn beneficial for group performance in newly formed ad hoc groups.

The effects of computer-supported collaboration scripts on knowledge awareness and sharing for facilitation of TMS in multidisciplinary collaborative settings are still unclear. This is striking since scripts can be textually implemented into the CSCL platform in a variety of forms such as cues, prompts, input text boxes etc. to foster both collaborative and individual learning (e.g. Fischer et al., 2002; Rummel & Spada, 2005; Schellens, & Valcke, 2006; Schellens et al., 2007 & 2009; Stegmann et al., 2007; Weinberger et al., 2005a & 2005b). The notion of scripting was inspired by the early success of using scripted cooperation to promote collaborative learning activities within the context of natural sciences (O'Donnell, 1999). Collaboration scripts provide detailed and explicit guidelines for small groups of learners to clarify what, when, and by whom certain activities need to be executed (Weinberger et al., 2007b). CSCL scripts have often been realized through prompts which are mostly embedded in the graphical user-interface of the collaboration tool (Baker & Lund, 1997). Prompts may sometimes take the form of sentence starters or question stems, and provide learners with guidelines, hints, and suggestions that facilitate the enacting of scripts (Noroozi & Weinberger et al., 2012; Weinberger et al., 2007b).

Scripts have not yet been related to the construction of TMS in spite of the fact that scripts distribute resources and roles explicitly and hence enhance learners' awareness of how knowledge is distributed within a group (Weinberger, 2011). Scripts have been designed to

foster transactive talk and discourse and have been found to substantially facilitate individual learning outcomes as well as knowledge convergence within a group of learners (Noroozi & Weinberger et al., 2013; Weinberger et al., 2007a & 2007b). Despite the research on the role of collaboration scripts and its promising findings on various aspects of learning mechanisms – especially the facilitation of transactive talk and discourse – in monodisciplinary groups, only few research studies have so far reported on the effects of these scripts on learning for groups comprised of members with different disciplinary backgrounds (see Noroozi & Weinberger et al., 2013). Studies by Beers and colleagues (2005 & 2007), Kirschner et al. (2008), as well as Rummel and Spada (2005) and Rummel et al. (2009) focused on the role of ICT tools and online support systems for facilitation of collaborative learning in multidisciplinary settings. However, the focal points of these studies were not on the effects of CSCL scripts on TMS and transactive discussions.

Research Questions

To date, research has not focused systematically on the joint operation of the TMS and transactivity in a CSCL environment with appropriate support measures. It is unclear how transactive knowledge sharing and domain-specific knowledge transfer can be facilitated in a multidisciplinary CSCL setting. The picture is even less clear when it comes to whether and how transactive memory and discussion scripts improve the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting. Therefore, the following research questions were formulated to address these issues:

1. To what extent is the quality of student messages during the collaborative phase in terms of transactive knowledge sharing affected by a transactive memory script, a transactive discussion script, and their combination in a multidisciplinary CSCL setting?

It was expected that the transactive memory script would facilitate coordination of the distributed knowledge, which in turn would facilitate transactive knowledge sharing in terms of externalization of each participant's own knowledge and elicitation of their learning partner's knowledge. It was also expected that the transactive discussion script would facilitate collaborative discussions and argumentations, which in turn would facilitate transactive knowledge sharing in terms of integration and conflict-oriented consensus

building. Furthermore, we expected that when offered in combination the scripts would each have these same effects, but we did not expect any interaction effects.

2. To what extent is domain-specific knowledge transfer (individual-to-group, group-to-individual, and shared knowledge transfer) affected by a transactive memory script, a transactive discussion scrip, and their combination in a multidisciplinary CSCL setting?

It was expected that facilitation of both coordination of the distributed knowledge and collaborative discussions and argumentations would be reflected in the domain-specific knowledge transfer. We expected no interaction effects of the two scripts when offered in combination.

3. To what extent is the quality of joint and individual problem solution plans affected by a transactive memory script, a transactive discussion script, and their combination in a multidisciplinary CSCL setting?

It was expected that both scripts would improve quality of joint and individual problem solution plans. We expected no interaction effects of the two scripts when offered in combination.

Method

Context and Participants

The study took place at Wageningen University in the Netherlands, which has an academic focus on the Life Sciences, especially food and health, sustainability, and a healthy living environment. The study participants were 120 students from two disciplinary backgrounds: 1) international land and water management studies, and 2) international development studies. These two complementary domains of expertise were required to successfully accomplish the learning task in this study. The mean age of the participants was 24.73 ($SD = 3.43$) years; 57% were female and 43% were male. The group of participants was made up of an approximately even number of Dutch and foreign students. Students were compensated €50 for their participation in this study.

The participants were assigned to partners based on disciplinary backgrounds, so that one partner had a water management disciplinary background and the other an international

development disciplinary background. The participants in each pair did not know each other beforehand. Next, each pair was randomly assigned to one of four experimental conditions in a 2×2 factorial design, each of which included 15 pairs. Participants in three conditions were given scripts – either transactive memory, transactive discussion, or a combined script – and the control group was not given a script. The experimental conditions differed only with respect to the components of transactive memory and discussion scripts that were implemented in the platform using the interface of the online learning environment (see description below).

Learning Materials

Students participating in the study were asked to learn the concept of Community-Based Social Marketing (CBSM) and its application in Sustainable Agricultural Water Management (SAWM). Specifically, the participants were asked to apply the concept of CBSM in fostering sustainable behaviour among farmers in terms of the principles of SAWM. In the collaborative learning phase (see table 6.1), learners were asked to analyse and discuss the problem case and to design an effective plan for fostering sustainable behaviour for SAWM. They were asked to take into account the farmers' various perspectives on the need – or lack thereof – of implementing SAWM. The learning task was authentic and complex, and allowed learners to construct different arguments based on the concepts of CBSM and/or SAWM. (see Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013 for a full description of the theoretical concepts of the CBSM and SAWM as well as the learning task). Students with an international development background were expected to have knowledge on CBSM. To be included in the study, they must have passed at least two courses in which the concept of CBSM or related topics had been studied ($M = 3.79$; $SD = 1.61$). Students with an international land and water management background were expected to have knowledge on SAWM. To be included in the study, they must have passed at least two courses in which the concept of SAWM or related topics had been studied ($M = 3.45$; $SD = 1.09$).

In order for the learning partners to understand each other and to be efficient in a multidisciplinary setting, all learners were provided with a three-page description of both CBSM and SAWM, and the demographic characteristics of the farmers and geographical characteristics of the location. This three-page description helped learners to share some knowledge that was useful to master the learning task. The description of the problem case

and theoretical background were embedded in the platform during collaboration, so that the learners could study them when interacting with their partners.

Learning Environment

The partners in each dyad were located in two separate laboratory rooms. An asynchronous text-based discussion board called SharePoint was customized for the purpose of our study for the collaboration phase (see figure 6.1). Immediate (chat-like) answers were not enabled in the learning environment. Instead, the interactions were asynchronous, resembling e-mail communication for the exchange of text messages (see figure 6.1). During the collaborative phase, the learners' task was to collaboratively analyse, discuss, and solve the problem case on the basis of the theoretical background and to arrive at a joint solution. The goals were for the partners to (1) learn from each other with respect to the domain-specific theoretical concepts of their learning partners, (2) share as much knowledge as possible during collaboration, and (3) to discuss and elaborate on the theoretical concepts in each partner's specific domain to collectively design sound (individual and joint) solution plans for the problem case. In other words, participants were expected to combine their complementary domain-specific knowledge, and then to discuss and elaborate on this information such that it could be applied for designing solution plans for the problem case.

Each message sent to a partner consisted of a subject line, date, time, and the message body. While the SharePoint platform set author, date, time, and subject line automatically, the learners had to enter the content of the message as in any typical discussion board. The platform was modified to allow for textual implementation of computer-supported collaboration scripts. The CSCL environment for learners in the experimental conditions was the same as for the control group, except for the presence of a transactive memory script, a transactive discussion script, or combined scripts, which structured the discussion phase in the platform (see Noroozi & Biemans et al., 2013; Noroozi & Weinberger, 2013). The conditions were distinguished and implemented as follows:

The control group

The learning partners received no further support beyond being asked to analyse, discuss, and solve the problem case on the basis of the theoretical background provided by the platform and to type their arguments into a blank text box.

Transactive memory script

The platform in this condition was the same as in the control group except for the addition of a transactive memory script. Building on Wegner (1987), we developed a script that spanned three phases: encoding, storage, and retrieval (see Noroozi & Biemans et al., 2013). For each phase, specific types of prompts were embedded in the platform; however, all replies by learning partners were not structured by a prompt. In the encoding phase, learners were given 10 minutes to introduce themselves, compose a portfolio of their expertise, and indicate what aspects of their expertise applied to the given case. They were prompted to present their specific expertise, not general knowledge, in the portfolio message. Therefore, the content of the initial messages was pre-structured with prompts (e.g. "Briefly sketch the knowledge areas you have mastered in your studies so far..."; "Indicate what aspects of your expertise apply to this case..."; "Indicate what other knowledge might be relevant to this case...").

In the storage phase, the dyad members were given 15 minutes to read the portfolios and discuss the case with the goal of distributing responsibility for various aspects of the learning task. Respective prompts aimed at helping the students to identify what expertise should be applied to what aspect of the task and to take responsibility for those aspects that matched their own expertise. The content of the initial messages in this phase were pre-structured with prompts, such as: "The following aspects of the task should be analysed by..."; "I will take responsibility for the following aspects of the learning task...". The dyad members were asked to compose at least one task distribution and one acceptance of responsibility message.

In the retrieval phase, the dyad members were given 15 minutes to analyse and solve previously assigned parts of the task based on their specific expertise. Again, the content of the initial messages was pre-structured with prompts (e.g. "The task aspects related to expertise XY are addressed as follows…"; "The task aspects related to expertise YX are addressed as follows…").

The learners were then given 40 minutes and guided to combine their solutions on the basis of their specialized domains of expertise. They received prompts to construct a joint solution, to consider both areas of expertise in a balanced way, and to indicate agreement on the solution. The content of their initial messages was pre-structured with prompts such as "The two aspects of the task interact in the following way..."; "To adjust and combine our solutions, I suggest that...".

Transactive discussion script

The platform in this condition was the same as in the control group except for the addition of a transactive discussion script, which structured the replied messages in text windows (see Noroozi & Weinberger et al., 2013). Every dyad member was first asked to individually analyse the problem case and then to submit that analysis into a blank text box. The learning partners were then asked to discuss the case on the basis of one another's individual analysis while receiving a respective prompt that applied to every reply they sent. Building on a modified coding scheme from Berkowitz and Gibbs (1983), four types of prompts were automatically embedded into the reply messages in the text windows, each of which was expected to facilitate transactive knowledge sharing. Specifically, each participant was asked to paraphrase, criticize, ask clarifying/extension questions, give counter-arguments, and propose integration of arguments in response to each message that had been posted by the learning partner until they reached consensus and indicated agreement on the solutions. Learners could either start a new topic by posting a new message or reply to messages that had been posted previously. The structure of the four prompts was as follows:

1) The prompt for argumentation analysis and paraphrasing the elements for the construction of a single argument in accordance with a simplified version of Toulmin's (1958) model (claim, ground, and qualification). Learners were first asked to analyse the case and write their own argument(s) in the discussion board (see Noroozi & Weinberger et al., 2013). They were then required to make analyses of the argument(s) being put forward by their partners and paraphrase them in pre-structured boxes. Therefore, the subjects of the reply messages were pre-structured with prompts (e.g. "You claim..."; "Building on the reason..."; "The noted limitation of your claim is..."). Learners were encouraged to construct sound, explicit analyses of their partners' arguments.

2) The prompt for feedback analysis focusing on clarification of the problem case on the basis of individual analysis of the learning partners' arguments (see Noroozi & Weinberger et al., 2013; Weinberger et al., 2005a, 2005b, & 2010). The subjects of the reply messages were pre-structured with prompts for feedback analysis (e.g. "I (do not) understand or agree with the following aspects of your position..."; "Could you please elaborate on that..."; "... is not yet clear to me; what do you mean by that..."). Figure 6.1 shows an example of the prompt for feedback analysis.

179

3) The prompt for extension of the argument focusing on further explanation and development (see Noroozi & Weinberger et al., 2013). The subjects of the reply messages were pre-structured with prompts for extension of the argument (e.g. "Here's a further thought or an elaboration offered in the spirit of your position ...").

4) The prompt for building counter-arguments and interactive arguments for different areas of expertise in accordance with Leitão's (2000) model of argumentation sequence (argument–counterargument–integrative argument...) (see Noroozi & Weinberger et al., 2013; Stegmann, 2007). The subjects of the reply messages were pre-structured with prompts for construction of argumentation sequences (e.g. "Here's a different claim and the reasoning behind it from my area of expertise..."; "To adjust and combine our solutions, I would suggest that...").

The combined script

The CSCL platform in this condition was the same as in the control group except for the addition of the combined scripts (see Noroozi & Weinberger et al., 2013). The subjects of the original messages were pre-structured with various prompts as in the transactive memory script. Each reply was also pre-structured with the four types of prompts as in the transactive discussion script.

Figure 6.1: Screenshot of the transactive discussion script initiated by a prompt for feedback analysis.

Procedure

Before carrying out the experimental study, a pilot test was conducted with eight learners to determine the feasibility of the study with respect to learning task, materials, instruments, scripts, and the platform. These eight learners were divided into four pairs, and then three pairs were given their own scripts – either transactive memory, transactive discussion, or combined script – and one group, the control group, was not given a script. This pilot study resulted in a slight modification of the learning task and materials as well as the functionality of the platform. For instance, in the pilot study, learners appeared to need more information on the farmers and location characteristics for elaborating on the learning materials. Therefore, in the actual experiment, learners were provided with more information on demographic characteristics of the farmers and geographical features of the location. Moreover, the platform was equipped with a notification of new messages from the partners, since in the pilot study participants complained that it was not clear when exactly a new message had been posted. Furthermore, the pilot study helped us design the problem case in such a way that it would be neither too difficult nor too easy for learners on the basis of their disciplinary backgrounds. The data from the pilot study were excluded in the final analysis.

Overall, the experimental session took about 3.5 hours and consisted of four main phases with a 10-minute break between phases two and three (see table 6.1). During the (1) introduction and pre-test phase, which took 35 minutes, individual learners received introductory explanations about the experiment for 5 minutes. They were then asked to complete several questionnaires on demographic variables, computer literacy, argumentation skills, prior experience with and attitude towards collaboration (30 minutes). The data from these questionnaires were used to ensure that randomization did in fact lead to an even distribution of participants (see the Control Measures section).

During the (2) individual phase, learners first received an introductory explanation of how to analyse the case (5 minutes). They were then given 5 minutes to read the problem case and 10 minutes to study a three-page summary of the theoretical text regarding SAWM and CBSM and also demographic characteristics of the farmers and the location of the case study. Learners were allowed to make notes and to keep the text and their notes during the experiment. Prior to collaboration, learners were asked to individually analyse the problem case and design an effective plan (20 minutes) for fostering sustainable behaviour on the basis of their own domain of expertise. Specifically, learners with an international development

background were asked to design an effective plan for fostering sustainable behaviour among Nahavand farmers taking into account the concept of CBSM, whereas learners with an international land and water management background were asked to design an effective plan for fostering SAWM. The data from this pre-test served two purposes: to assess learners' prior knowledge regarding SAWM or CBSM, and to help us check for the randomization of learners in terms of prior knowledge over various conditions.

After a 10-minute break, the (3) collaborative learning phase (90 minutes) began. First, learners were oriented to the CSCL platform and acquainted with the procedure of the collaboration phase (10 minutes). Subsequently, learners were asked to discuss and support their analyses and design plans in pairs (80 minutes). Specifically, they were asked to analyse and discuss the same problem case as in the pre-test and to jointly design an effective plan for fostering SAWM based on the concept of CBSM. This collaborative outcome served as the criteria for assessing quality of the joint problem solution plan.

Table 6.1: Overview of the procedure of the experimental study.

Phase	Description	Duration
(1)	*Introduction and pre-test phase*	*35 min*
	Introductory explanations	5 min
	Assessment of personal data (questionnaires)	10 min
	Assessment of collaboration and computer experiences, learning style, argumentation skill etc. (questionnaires)	20 min
(2)	*Individual learning phase*	*40 min*
	Introductory remarks	5 min
	Individual study phase of the theoretical text (conceptual space and problem case)	15 min
	Pre-test of domain-specific prior knowledge (individual analysis)	20 min
(3)	*Collaborative learning phase*	*90 min*
	Introduction to the CSCL platform	5 min
	Explanation of the procedure	5 min
	Collaborative learning phase (online discussion)	80 min
(4)	*Post-tests and debriefing*	*45 min*
	Individual analysis of the problem case	20 min
	Assessment of satisfaction with the learning effects and experiences	20 min
	Debriefing	5 min
Total time		*3.5 hrs.*

During the (4) post-test and debriefing phase (45 minutes), learners were first asked to work on a comparable case-based assignment individually (20 minutes) based on what they had learnt in the collaboration phase. They were asked to analyse and design an effective plan for fostering sustainable behaviour among Nahavand wheat farmers in terms of irrigation methods that could be applied for fostering SAWM as a CBSM advisor. This individual task was used for assessing the quality of the individual problem solution plan. Furthermore, learners were asked to fill out several questionnaires to assess various aspects of their satisfaction with the learning experiences and its outcomes (20 minutes). Finally, the participants got a short debriefing for about 5 minutes.

Measurements, Instruments, and Data Sources

Assessing transactive knowledge sharing during the collaborative phase

The learners' online messages during the collaborative learning phase were analysed by means of an adapted coding scheme developed by Weinberger and Fischer (2006). Specifically, we analysed transactive knowledge sharing by focusing on the function or social mode of messages (i.e. how learners refer to each others' messages). Every message posted during the online discussion was coded as one of the following: no reaction, externalization, acceptance, elicitation, integration, or conflict. When learners did not respond to questions (and other forms of elicitation) from their learning partners, we coded the chronologically next message as "no reaction (to learning partner)". When learners formally replied to a (mother) message of a learning partner (i.e. they hit the reply button after reading a message by their learning partner, but did not refer at all to what their learning partner had said in the (mother) message they were replying to), we coded their (daughter) message as "no reaction". When learners displayed their knowledge without reference to earlier messages, for instance when they composed the first analysis in the discussion board or typically also the first messages in a discussion thread, we coded the message as externalization. Sometimes learners might juxtapose externalizations (i.e. reply to earlier externalizations by a further externalization). When learners asked for, or invited a reaction from their learning partners, we coded the message as elicitation. Typically, this took the form of questions. However, learners often forgot the question marks or made proposals rather than asking directly. If an elicitation was not responded to, the next message was coded as "no reaction". When learners agreed to what had been said before without any modification by repeating what had been said, we coded the message as acceptance. Learners might have taken over perspectives from

their peers and built syntheses of (various) arguments and counter-arguments that learning partners had uttered before, which we coded as integration. Any rejection, denial, or negative answer/evaluation was coded as conflict. Beyond saying "No" or "I disagree", any kind of modification or replacement of what had been said before was also coded as conflict. Thus, smaller repairs and additions to a learning partner's utterances were coded as conflict. This included taking note of the phenomenon of alleviating critiques by initializing responses with phrases such as "I totally agree, but...". Several of these social modes could be found within one message. Therefore, we coded the discourse hierarchically. For example, if the message contained a conflict, the message was coded as conflict regardless of what else could be found in the message. The hierarchy was as follows: conflict, integration, elicitation, acceptance, externalization, or no reaction (see table 6.2 for coding procedure and examples).

Two trained coders coded three discourse corpora in each condition to determine the reliability index of inter-rater agreement. The inter-rater agreement computed on the basis of this overlapping coding was sufficiently high (*Cohen's κ = .88*). Moreover, intra-coder test-retest reliability was calculated for 10% of the discourse corpora. This resulted in identical scores in 93% of the contributions. For each pair, we counted the sum of messages that were coded as conflict, integration, elicitation, acceptance, externalization, or no reaction as an indicator of transactive knowledge sharing. The scores on this measure were then transformed into proportions in relation to the total number of messages during the collaborative phase. Therefore, we analysed the proportion of various categories of transactive knowledge sharing for each dyad in all conditions.

Table 6.2: Coding scheme for assessing transactive knowledge sharing by social modes.

Code	Description	Example
No reaction	*When learners do not respond to questions (and other forms of elicitation) of their learning partners.* *When learners formally reply to a (mother) message of a learning partner but do not refer at all to what their learning partner has said in the (mother) message they are replying to.*	A: "I doubt if furrow, border strip, or basin irrigation is a good system in the east part of the area due to the sandy nature of its soil. Sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications." B: "No reply" A: "I think surface irrigation is a good system in the North of Nahavand since the type of soil in that area is clay with low infiltration rates." B: "Let's wrap up the discussion due to the time constraint."
Externalization	*When learners outline their knowledge without reference to earlier messages, for instance when they compose the first analysis in the discussion board or typically also the first messages in a discussion thread.* *When learners juxtapose externalizations (i.e. reply to earlier externalizations with an externalization).*	"I would encourage farmers to use the drip irrigation method since there is a steep slope in the area and this method could prevent runoff." A: "I would encourage farmers to use the drip irrigation method since there is a steep slope in the area and this method could prevent runoff." B: "Drip irrigation could (also) save a lot of water in this water-scarce area by preventing deep percolation or evaporation."
Acceptance	*When learners agree to what has been said before without further elaboration.* *When learners agree to what has been said before without any modification by repeating what has been said.*	A: "The type of crop is a very important consideration when choosing a beneficial irrigation method." B: "I agree", or something similar. A: "The type of crop is a very important consideration when choosing a beneficial irrigation method" B: "We need to consider the type of products and their value in relation to the various irrigation methods used by farmers."
Elicitation	*When learners ask for or invite a reaction from their learning partners. Typically, this is done by asking questions.* *However, learners often forget the question marks or make proposals rather than asking directly.*	"What are the possible technical problems in the area in terms of implementing the sprinkler irrigation method"? "We should also talk about the external barriers for behaviour change."
Integration	*When learners adopt the perspectives of their peers and build syntheses of (various) arguments and counter-arguments that learning partners have uttered before.*	A: "Farmers rarely accept the drip irrigation method due to the technical requirements for implementing it on the farm." B: "For the technical requirements we could provide farmers with short and long-term training sessions to teach them how to install, apply, and maintain the system."

Conflict	*When learners reject, deny, or give a negative answer to evaluation of what has been said before.*	A: "I would encourage farmers to use the drip irrigation method since there is a steep slope in the area." B: "No" or "I disagree", etc.
	When learners modify or replace what has been said before.	A: "I would encourage farmers to use sprinkler and drip irrigation. Because of the high capital investment required per hectare, these are mostly used for high-value cash crops such as vegetables and fruit trees." B: "Drip irrigation could be a complete waste of water in the south of Nahavand when you take the soil minerals and toxicity into account."
		A: "Farmers would not accept a drip irrigation system due to their lack of technical knowledge." B: "They also would not easily accept drip irrigation due to the huge initial costs for implementing the system."
	When learners slightly amend or add to the learning partners' utterances.	A: "Surface irrigation is preferred if the irrigation water contains much sediment, which can clog drip or sprinkler irrigation systems." B: "I totally agree, but…"

Measuring domain-specific knowledge transfer (individual-to-group, group-to-individual, and shared knowledge transfer)

We operationalized knowledge transfer as an interaction between domain-specific knowledge of the individual learner and his/her partner in terms of individual-to-group, group-to-individual, and shared knowledge transfer (see Noroozi & Biemans et al., 2013). An expert solution for the task was used to analyse the domain-specific knowledge transfer. This expert solution included all the possible theoretical concepts of SAWM and CBSM, and their relation to the problem cases. The next step of the analysis involved characterizing the content of both of the problem solutions generated in the two individual phases of the study, both prior to (pre-test) and after collaboration (post-test), as well as the joint solution generated by the dyads in the collaborative phase. Learners received a score of 1 for each adequately applied theoretical concept and for relating it appropriately to the problem cases in their joint and individual problem solution plans leading to a sum score in the end. Both inter-rater agreement between two coders (*Cohen's* $\kappa = .88$) and intra-coder test-retest reliability for each coder for 10% of the data (90% identical scores) were sufficiently high.

Individual-to-group knowledge transfer

Building on Noroozi and Biemans et al. (2013), the impact that each individual had on the joint solution plan was estimated by the total number of his/her own individual representations that s/he managed to transfer to the joint solution plan. The indicator of individual-to-group knowledge transfer for each participant was then the sum score of all relevant and correct applications of that participant's own theoretical concepts that were transferred to the dyad's joint solution plan.

Group-to-individual knowledge transfer

Building on Noroozi and Biemans et al. (2013), the impact that participating in a dyad had on the individual learner was estimated by the total number of relevant and correct applications of a learning partner's theoretical concepts that emerged in the collaborative process and re-emerged in the individual problem solutions. The indicator of group-to-individual knowledge transfer for each participant was then the sum score of all relevant and correct applications of a learning partner's theoretical concepts that were transferred to the individual's own solution plan in the post-test.

Shared knowledge transfer

Successful collaboration depends not only on the extent to which learners (co)construct knowledge, but also the extent to which knowledge is shared by the participants in the group (Stahl & Hesse, 2009). We used individual problem solution plans in the post-test to measure shared knowledge transfer between dyad members. Building on Noroozi and Biemans et al. (2013), the indicator of shared knowledge transfer for each dyad was the sum score of all relevant and correct applications of theoretical concepts in relation to the problem case, which both dyad members appropriately shared in their individual representations in the post-test (see also Fischer & Mandl, 2005).

Measuring quality of joint and individual problem solution plans

The measure of group performance was operationalized as the quality of the joint problem solution plan produced by the dyad during their collaboration. Building on Noroozi and Biemans et al. (2013), the measure of individual performance was operationalized as the quality of the individual problem solution plan produced by each learner after collaboration in the post-test. In contrast to the quantitative analyses on domain-specific knowledge transfer measurements that focused on the numerical applications of the theoretical concepts in relation to the problem cases, the qualitative strategy adopted for measuring the quality of joint and individual problem solution plans was to focus on the extent to which pairs and individual learners were able to support their theoretical assumptions in relation to the case with justifiable arguments, discussions, and sound interpretations that contributed to the advancement of the problem solution plans (see Noroozi & Biemans et al., 2013, for a full description of the qualitative measurement).

Both joint and individual problem solution plans were independently rated by two expert coders on a scale ranging from "inadequate problem solution plan" to "high-quality problem solution plan". Both inter-rater agreement between two coders (*Cohen's κ* = .84) and intra-coder test-retest reliability for each coder for 10% of the data (89% identical scores) were sufficiently high. We then assigned 0 points for inadequate problem solution plans, 1 point for low quality, 2 points for rather low quality, 3 points for rather high quality, and 4 points for high-quality problem solution plans. Based on these points, we calculated the mean quality score for the joint (group values) and individual (aggregated individual values) problem solution plans in all conditions.

Control Measures

Various factors of a learner's background and experience have been discussed as being relevant and important in CSCL settings, such as computer literacy and prior experience with and attitude towards collaboration (see Noroozi & Biemans et al., 2011 & 2012; Noroozi & Busstra et al., 2012). We therefore checked whether the participants were equally distributed over the four conditions for these measures (see Noroozi & Weinberger et al., 2013, for full description of these measurements).

Unit of Analysis

The unit of analysis, either at the individual or dyad level, depended on the research question addressed. We used single individual as the unit of analysis to check for the equal distribution of the learners over the four conditions in terms of prior knowledge, number of passed courses, computer literacy, prior experience with collaboration, and learners' attitudes towards collaboration. We used the dyads (group values) as the unit of analysis for the research question 1 concerning transactive knowledge sharing, part of research question 2 addressing shared knowledge transfer, and for part of research question 3 regarding the quality of joint problem solution plans which are directed to the discourse and to the collaborative solution of the learning task. In contrast, the individual as the unit of analysis (aggregated individual values) was used to measure individual-to-group and group-to-individual knowledge transfer for research question 2, and the part of research question 3 addressing the quality of individual problem solution plans (see Fischer et al., 2002; Kapur, 2008; Noroozi & Weinberger et al., 2013; Raudenbush & Bryk, 2002). Although these measurements were taken individually, the individual scores within each dyad were not independent observations due to the collaboration that preceded it (Kapur, 2008; Raudenbush & Bryk, 2002; Noroozi & Biemans et al., 2013; Noroozi & Weinberger et al., 2013) and also the design of the platform, which supported group rather than individual work (Stahl, 2010 & 2011a). Therefore, we used aggregated individual values for these measurements.

Data Analysis and Statistical Tests

The scores of four pairs of learners (one pair in each condition) were excluded from the analyses due to the limited number of their contributions. Therefore, for data analyses, 112 learners (14 pairs in each of the four conditions) were included in the study. ANOVA tests were used to compare the prior knowledge, number of passed courses, computer literacy,

prior experience with collaboration, and learners' attitudes towards collaboration among learners. MANOVA was used to analyse the proportion of various types of messages in terms of transactive knowledge sharing: for these tests, the absolute scores were transformed into proportions. Univariate analyses were used as a post-hoc analysis to examine statistical differences among the conditions. MANOVA was conducted to analyse domain-specific knowledge transfer measures. Univariate analyses for each of these knowledge transfer measures (individual-to-group, group-to-individual, and shared knowledge transfer measures) were then conducted as follow-up tests. MANOVA was again conducted to compare mean differences between learners in terms of quality of problem solution plans. Univariate analyses for each of these problem solution plans (joint and individual problem solution plans) were then conducted as follow-up tests to the MANOVA. Furthermore, simple effects analyses were conducted as follow-up tests only when the interaction was significant.

Results

Learning Prerequisites and Control Measures

The learners with an international development background in the four conditions showed no differences with respect to prior knowledge, $F(3, 52) = .45$, $p > .2$ ($M = 10.93$, $SD = 2.72$, $Max = 16$, $Min = 7$), and number of passed courses ($M = 3.78$, $SD = 1.61$, $Max = 7$, $Min = 2$) on CBSM and related topics, $F(3, 52) = .23$, $p > .2$. The same was true for the learners with an international land and water management background regarding prior knowledge, $F(3, 52) = .42$, $p > .2$ ($M = 7.70$, $SD = 2.77$, $Max = 14$, $Min = 2$), and number of passed courses ($M = 3.44$, $SD = 1.09$, $Max = 6$, $Min = 2$) on SAWM and related topics, $F(3, 52) = .56$, $p > .2$.

Furthermore, learners in the four conditions showed no differences regarding the mean scores of computer literacy, $F(3, 108) = .67$, $p > .2$, and prior experience with collaboration, $F(3, 108) = .76$, $p > .2$. The same was true for the learners' attitudes towards collaboration, $F(3, 108) = .91$, $p > .2$. These results show that the random assignment of learners to the four conditions led to no significant differences in terms of learners' prior knowledge, background requirements, and individual prerequisites.

Descriptive Information for the Script Effects on Various Dependent Variables

Table 6.3 shows the script effects for various experimental conditions with regard to all of the dependent variables in this study, including the number and quality of student messages

during the collaborative phase in terms of transactive knowledge sharing (conflict, integration, elicitation, acceptance, externalization, no reaction), domain-specific knowledge transfer (individual-to-group, group-to-individual, and shared knowledge transfer measures), as well as quality of problem solution plans (joint and individual). In total, participants with the transactive memory or discussion script separately produced a higher quality of transactive knowledge sharing during discourse, constructed and transferred more domain-specific knowledge, and achieved a higher quality of joint and individual problem solution plans than participants in the combined script and control group conditions. In other words, when both scripts were offered at the same time, a lower quality of messages was exchanged, less domain-specific knowledge was transferred, and lower quality of problem solution plans was produced than when these scripts were offered separately.

Results for Research Question 1

The first research question was: To what extent is the quality of student messages during the collaborative phase in terms of transactive knowledge sharing affected by a transactive memory script, transactive discussion script, and their combination in a multidisciplinary CSCL setting? In this section we will first present the findings on the overall quantity and quality of student messages during the collaborative phase in terms of transactive knowledge sharing. Next, we will present results for various categories of the transactive knowledge sharing (conflict, integration, elicitation, acceptance, externalization, no reaction) according to the coding scheme described in the method section.

Table 6.3: Descriptions of various dependent variables for each of the four conditions: means (M) and standard deviations (SD).

Dependent variable	Item	Control Group (CG)		Transactive Memory Script (TMS)		Transactive Discussion script (TDS)		Both scripts (BS)		Significant at .05 level	Significant at .01 level
		M	SD	M	SD	M	SD	M	SD		
Number of messages	*Number of messages*	23.71	5.78	26.64	4.48	27.86	4.60	20.14	4.74		
Transactive knowledge sharing	*No reaction (%)*	4.71	6.03	4.30	5.12	1.04	2.16	12.93	15.17	BS > TDS	BS > TMS
	Externalization (%)	27.68	7.08	44.35	11.63	18.12	9.01	36.03	10.36	CG > TDS	TMS > CG; TMS > TDS; BS > CG; BS > TDS; BS > TDS
	Acceptance (%)	10.92	5.15	6.67	5.58	6.81	3.59	11.76	8.81	CG > TMS; CG > TDS; BS > TMS; BS > TDS	
	Elicitation (%)	14.68	5.43	27.99	7.26	18.75	7.78	21.47	13.41	TMS > BS	TMS > CG; TDS > TDS
	Integration (%)	10.85	8.58	12.79	6.59	29.97	9.23	12.02	11.83	TMS > CG	TDS > TMS; TDS > CG; TDS > BS
	Conflict (%)	1.56	2.68	3.89	4.72	11.31	5.09	5.48	8.65	BS > CG	TDS > CG; TDS > TMS; TDS > BS
Knowledge transfer measures	*Individual-to-group*	15.14	3.86	16.64	3.77	18.64	3.23	12.64	4.18	TDS > CG	TMS > BS; TDS > BS
	Group-to-individual	3.93	1.07	6.14	1.70	5.93	2.09	3.14	1.61		TMS > CG; TMS > BS; TDS > CG; TDS > BS
	Shared knowledge	7.50	1.95	11.79	3.12	11.36	3.98	6.00	3.23		TMS > CG; TMS > BS; TDS > CG; TDS > BS
Quality of solution plans	*Joint solution plan*	2.21	.58	3	.78	3.36	.84	1.93	.73		TMS > CG; TMS > BS; TDS > CG; TDS > BS
	Individual solution plan	2.43	.43	2.93	.76	3.14	.99	2.00	.62	TDS > CG	TMS > BS; TDS > BS

Number of messages during collaborative phase

Learners showed significant differences with respect to the number of messages contributed in the collaborative phase, $F(3, 52) = 6.80$, $p < .01$, $\eta^2 = .28$. The main effect of the transactive memory script on the total number of messages contributed to the discourse was just below the significant level, $F(1, 52) = 3.30$, $p = .08$, $\eta^2 = .06$, with scripted learners ($M = 23.40$) scoring about the same as unscripted learners ($M = 25.79$). This main effect was not significant for the transactive discussion script, $F(1, 52) = .80$, $p = .37$, with scripted learners ($M = 24.00$) scoring about the same as unscripted learners ($M = 25.18$). However, the interaction effect, $F(1, 52) = 16.32$, $p < .01$, $\eta^2 = .24$, was significant. For participants who received the transactive memory script, a higher number of messages was authored when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 12.17$, $p < .01$, $\eta^2 = .19$. For participants who did not receive the transactive memory script, a higher number of messages was authored when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 4.94$, $p < .05$, $\eta^2 = .90$. For participants who received the transactive discussion script, a higher number of messages was authored when the transactive memory script was not offered than when it was offered, $F(1, 52) = 17.14$, $p < .01$, $\eta^2 = .25$. For participants who did not receive the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = 2.47$, $p = .12$.

Quality of messages during the collaborative phase in terms of transactive knowledge sharing

Learners in the four conditions showed significant differences with respect to the overall quality of messages contributed during the collaborative phase in terms of transactive knowledge sharing. Specifically, the main effect of the transactive memory script on transactive knowledge sharing was significant, *Wilks' λ* = .20, $F(3, 52) = 30.76$, $p < .01$, $\eta^2 = .80$. The same was true for the transactive discussion script, *Wilks' λ* = .45, $F(3, 52) = 9.46$, $p < .01$, $\eta^2 = .55$. Furthermore, the interaction effect, *Wilks' λ* = .43, $F(3, 52) = 10.47$, $p < .01$, $\eta^2 = .57$, was significant, indicating that the script effects were not the same regarding transactive knowledge sharing.

Concerning no reaction to messages, the main effect of the transactive memory script was significant, $F(1, 52) = 4.26$, $p < .05$, $\eta^2 = .08$, with scripted learners ($M = .08$) scoring higher than unscripted learners ($M = .04$). This main effect was not significant for the transactive discussion script, $F(1, 52) = .48$, $p = .49$, with scripted learners ($M = .07$) scoring about the

193

same as unscripted learners ($M = .05$). The interaction effect was significant, $F(1, 52) = 8.61$, $p < .01$, $\eta^2 = .14$. For participants who received the transactive memory script, a higher proportion of "no reaction messages" was identified when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 6.59$, $p < .05$, $\eta^2 = .11$. For participants who did not receive the transactive memory script, the transactive discussion script had no effect, $F(1, 52) = 2.50$, $p = .12$. For participants who received the transactive discussion script, a higher proportion of "no reaction messages" was identified when the transactive memory script was offered than when it was not offered, $F(1, 52) = 12.49$, $p < .01$, $\eta^2 = .19$. For participants who did not receive the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = .38$, $p = .54$.

Regarding knowledge externalization, the main effect of the transactive memory script was significant, $F(1, 52) = 53.29$, $p < .01$, $\eta^2 = .51$. Learners with the transactive memory script ($M = .39$) produced a higher proportion of "knowledge externalization messages" than unscripted learners ($M = .22$) during discourse. The same was true for the transactive discussion script, $F(1, 52) = 7.70$, $p < .01$, $\eta^2 = .13$. Learners with the transactive discussion script ($M = .27$) produced a higher proportion of messages for knowledge externalization than unscripted learners ($M = .34$) during discourse. However, no interaction effect, $F(1, 52) = .11$, $p = .76$, was found.

Concerning acceptance, the main effect of the transactive memory script was not significant, $F(1, 52) = .01$, $p = .96$, with scripted learners ($M = .09$) scoring the same as unscripted learners ($M = .09$). This main effect was also not significant for the transactive discussion script, $F(1, 52) = .01$, $p = .95$, with scripted learners ($M = .09$) scoring the same as unscripted learners ($M = .09$). However, the interaction effect, $F(1, 52) = 10.03$, $p < .01$, $\eta^2 = .16$, was significant. For participants who received the transactive memory script, a higher proportion of "acceptance messages" was produced when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 4.80$, $p < .05$, $\eta^2 = .09$. For participants who did not receive the transactive memory script, a higher proportion of "acceptance messages" was produced when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 5.23$, $p < .05$, $\eta^2 = .09$. For participants who received the transactive discussion script, a higher proportion of "acceptance messages" was identified when the transactive memory script was offered than when it was not offered, $F(1, 52) = 5.18$, $p < .05$, $\eta^2 = .09$. For participants who did not receive the transactive discussion script, a higher proportion of

"acceptance messages" was identified when the transactive memory script was not offered than when it was offered, $F(1, 52) = 4.85$, $p < .05$, $\eta^2 = .08$.

Concerning knowledge elicitation, the main effect of the transactive memory script was significant, $F(1, 52) = 11.84$, $p < .01$, $\eta^2 = .16$, with scripted learners ($M = .26$) scoring higher than unscripted learners ($M = .17$). This main effect was not significant for the transactive discussion script, $F(1, 52) = 1.00$, $p = .32$, with scripted learners ($M = .20$) scoring about the same as unscripted learners ($M = .23$). The interaction effect, $F(1, 52) = 5.52$, $p < .05$, $\eta^2 = .10$, was significant. For participants who received the transactive memory script, a higher proportion of "elicitation messages" was produced when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 5.60$, $p < .05$, $\eta^2 = .10$. For participants who did not receive the transactive memory script, the transactive discussion script had no effect, $F(1, 52) = .91$, $p = .34$. For participants who received the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = .60$, $p = .44$. For participants who did not receive the transactive discussion script, a higher proportion of "elicitation messages" was identified when the transactive memory script was offered than when it was not offered, $F(1, 52) = 16.76$, $p < .01$, $\eta^2 = .24$.

Regarding knowledge integration, the main effect of the transactive memory script was significant, $F(1, 52) = 5.74$, $p < .05$, $\eta^2 = .10$, with scripted learners ($M = .13$) scoring lower than unscripted learners ($M = .19$). This main effect was significant for the transactive discussion script, $F(1, 52) = 19.57$, $p < .01$, $\eta^2 = .27$, with scripted learners ($M = .21$) scoring higher than unscripted learners ($M = .11$). The interaction effect, $F(1, 52) = 28.20$, $p < .01$, $\eta^2 = .35$, was also significant. For participants who received the transactive memory script, the transactive discussion script had no effect, $F(1, 52) = .39$, $p = .53$. For participants who did not receive the transactive memory script, a higher proportion of "integration messages" was identified when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 47.38$, $p < .01$, $\eta^2 = .48$. For participants who received the transactive discussion script, a higher proportion of "integration messages" was produced when the transactive memory script was not offered than when it was offered, $F(1, 52) = 29.71$, $p < .01$, $\eta^2 = .36$. For participants who did not receive the transactive discussion script, a higher proportion of "integration messages" was produced when the transactive memory script was offered than when it was not offered, $F(1, 52) = 4.24$, $p < .05$, $\eta^2 = .08$.

Concerning conflict-oriented knowledge building, the main effect of the transactive memory script was not significant, $F(1, 52) = 1.73$, $p = .19$, with scripted learners ($M = .04$) scoring about the same as unscripted learners ($M = .06$). However, this main effect was significant for the transactive discussion script, $F(1, 52) = 19.26$, $p < .01$, $\eta^2 = .27$, with scripted learners ($M = .08$) scoring higher than unscripted learners ($M = .02$). The interaction effect, $F(1, 52) = 7.45$, $p < .01$, $\eta^2 = .13$, was also significant. For participants who received the transactive memory script, the transactive discussion script had no effect, $F(1, 52) = 1.37$, $p = .27$. For participants who did not receive the transactive memory script, a higher proportion of "conflict-oriented messages" was produced when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 25.33$, $p < .01$, $\eta^2 = .33$. For participants who received the transactive discussion script, a higher "conflict-oriented messages" was produced when the transactive memory script was not offered than when it was offered, $F(1, 52) = 8.19$, $p < .01$, $\eta^2 = .14$. For participants who did not receive the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = .10$, $p = .32$.

Results for Research Question 2

The second research question was: To what extent is the domain-specific knowledge transfer affected by a transactive memory script, transactive discussion scrip, and their combination in a multidisciplinary CSCL setting? In this section we will first present the findings on the overall domain-specific knowledge transfer. Next we will present the findings separately on individual-to-group, group-to-individual, and shared knowledge transfer measures.

Overall domain-specific knowledge transfer

The main effect of the transactive memory script on the overall domain-specific knowledge transfer was not significant, *Wilks' λ* = .91, $F(3, 52) = 1.65$, $p = .19$. The same was true for the transactive discussion script, *Wilks' λ* = .97, $F(3, 52) = .43$, $p = .73$. The interaction effect, *Wilks' λ* = .55, $F(3, 52) = 13.77$, $p < .01$, $\eta^2 = .45$, was significant, indicating that the script effects were not the same regarding overall domain-specific knowledge transfer.

Individual-to-group knowledge transfer

The main effect of the transactive memory script on individual-to-group knowledge transfer was significant, $F(1, 52) = 4.97$, $p < .05$, $\eta^2 = .09$, with scripted learners ($M = 14.64$) scoring lower than unscripted learners ($M = 16.90$). In other words, a script that organized learners

into roles by their expertise resulted in collaborative solutions with more ideas from each partner compared with unscripted learners. This main effect was not significant for the transactive discussion script, $F(1, 52) = .06$, $p = .80$, with scripted learners ($M = 15.64$) scoring about the same as unscripted learners ($M = 15.89$). The interaction effect, $F(1, 52) = 13.81$, $p < .01$, $\eta^2 = .21$, was significant. For participants who received the transactive memory script, a higher "individual-to-group" knowledge transfer was achieved when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 7.86$, $p < .01$, $\eta^2 = .13$. For participants who did not receive the transactive memory script, a higher "individual-to-group" knowledge transfer was achieved when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 6.02$, $p < .05$, $\eta^2 = .10$. For participants who received the transactive discussion script, a higher "individual-to-group" knowledge transfer was achieved when the transactive memory script was not offered than when it was offered, $F(1, 52) = 17.68$, $p < .01$, $\eta^2 = .25$. For participants who did not receive the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = 1.10$, $p = .30$.

Group-to-individual knowledge transfer

The main effect of the transactive memory script on group-to-individual knowledge transfer was not significant, $F(1, 52) = .41$, $p = .52$, with scripted learners ($M = 4.64$) scoring about the same as unscripted learners ($M = 4.93$). The same was true for the transactive discussion script, $F(1, 52) = 1.27$, $p = .26$, with scripted learners ($M = 4.54$) scoring about the same as unscripted learners ($M = 5.04$). However, the interaction effect, $F(1, 52) = 31.75$, $p < .01$, $\eta^2 = .38$, was significant. For participants who received the transactive memory script, a higher "group-to-individual" knowledge transfer was achieved when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 22.86$, $p < .01$, $\eta^2 = .30$. For participants who did not receive the transactive memory script, a higher "group-to-individual" knowledge transfer was achieved when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 10.16$, $p < .01$, $\eta^2 = .16$. For participants who received the transactive discussion script, a higher "group-to-individual" knowledge transfer was achieved when the transactive memory script was not offered than when it was offered, $F(1, 52) = 19.71$, $p < .01$, $\eta^2 = .27$. For participants who did not receive the transactive discussion script, a higher "group-to-individual" knowledge transfer was achieved when the transactive memory script was offered than when it was not offered, $F(1, 52) = 12.46$, $p < .01$, $\eta^2 = .19$. In total, with no script or both scripts at the same time, individual solutions reused fewer ideas from the collaborative solution than with transactive memory or discussion scripts offered separately.

Shared knowledge transfer

The main effect of the transactive memory script on shared knowledge transfer was not significant, $F(1, 52) = .40$, $p = .53$, with scripted learners ($M = 8.90$) scoring about the same as unscripted learners ($M = 9.43$). The same was true for the transactive discussion script, $F(1, 52) = 1.31$, $p = .26$, with scripted learners ($M = 8.68$) scoring about the same as unscripted learners ($M = 9.64$). However, the interaction effect, $F(1, 52) = 32.73$, $p < .01$, $\eta^2 = .39$, was significant. For participants who received the transactive memory script, a higher "shared knowledge" transfer was achieved when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 23.56$, $p < .01$, $\eta^2 = .31$. For participants who did not receive the transactive memory script, a higher "shared knowledge" transfer was achieved when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 10.47$, $p < .01$, $\eta^2 = .17$. For participants who received the transactive discussion script, a higher "shared knowledge" transfer was achieved when the transactive memory script was not offered than when it was offered, $F(1, 52) = 20.20$, $p < .01$, $\eta^2 = .28$. For participants who did not receive the transactive discussion script, a higher "shared knowledge" transfer was achieved when the transactive memory script was offered than when it was not offered, $F(1, 52) = 12.93$, $p < .01$, $\eta^2 = .20$.

Results for Research Question3

The third research question was: To what extent is the quality of joint and individual problem solution plans affected by a transactive memory script, transactive discussion scrip, and their combination in a multidisciplinary CSCL setting? In this section we will first present the findings on the overall quality of problem solution plans. Next, we will present separate results on the quality of joint and individual problem solution plans.

Overall quality of problem solution plans

The main effect of the transactive memory script on overall quality of problem solution plans was not significant, *Wilks' λ* = .94, $F(3, 52) = 1.66$, $p = .20$. The same was true for the transactive discussion script, *Wilks' λ* = .98, $F(3, 52) = .71$, $p = .74$. However, the interaction effect, *Wilks' λ* = .61, $F(3, 52) = 16.00$, $p < .01$, $\eta^2 = .39$, was significant. This interaction effect indicates that the script effects were not the same regarding overall quality of problem solution plans.

Quality of joint problem solution plans

The main effect of the transactive memory script on quality of joint problem solution plans was not significant, $F(1, 52) = 2.64$, $p = .11$, with scripted learners ($M = 2.46$) scoring about the same as unscripted learners ($M = 2.79$). This was also true for the transactive discussion script, $F(1, 52) = .03$, $p = .86$, with scripted learners ($M = 2.64$) scoring about the same as unscripted learners ($M = 2.61$). However, the interaction effect, $F(1, 52) = 31.31$, $p < .01$, $\eta^2 = .38$, was significant. For participants who received the transactive memory script, a higher quality of joint problem solution plans was achieved when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 14.66$, $p < .01$, $\eta^2 = .22$. For participants who did not receive the transactive memory script, a higher quality of joint problem solution plans was achieved when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 16.68$, $p < .01$, $\eta^2 = .24$. For participants who received the transactive discussion script, a higher quality of joint problem solution plans was achieved when the transactive memory script was not offered than when it was offered, $F(1, 52) = 26.06$, $p < .01$, $\eta^2 = .33$. For participants who did not receive the transactive discussion script, a higher quality of joint problem solution plans was achieved when the transactive memory script was offered than when it was not offered, $F(1, 52) = 7.88$, $p < .01$, $\eta^2 = .13$.

Quality of individual problem solution plans

The main effect of the transactive memory script on quality of individual problem solution plans was not significant, $F(1, 52) = 2.71$, $p = .11$, with scripted learners ($M = 2.46$) scoring about the same as unscripted learners ($M = 2.79$). The same was true for the transactive discussion script, $F(1, 52) = .30$, $p = .58$, with scripted learners ($M = 2.57$) scoring about the same as unscripted learners ($M = 2.68$). The interaction effect, $F(1, 52) = 17.82$, $p < .01$, $\eta^2 = .26$, was significant. For participants who received the transactive memory script, a higher quality of individual problem solution plans was achieved when the transactive discussion script was not offered than when it was offered, $F(1, 52) = 11.38$, $p < .01$, $\eta^2 = .18$. For participants who did not receive the transactive memory script, a higher quality of individual problem solution plans was achieved when the transactive discussion script was offered than when it was not offered, $F(1, 52) = 6.74$, $p < .05$, $\eta^2 = .12$. For participants who received the transactive discussion script, a higher quality of individual problem solution plans was achieved when the transactive memory script was not offered than when it was offered, $F(1,

52) = 17.24, $p < .01$, $\eta^2 = .25$. For participants who did not receive the transactive discussion script, the transactive memory script had no effect, $F(1, 52) = 3.30$, $p = .07$.

Discussion

We found interaction effects for the transactive memory and discussion scripts on knowledge sharing and transfer, as well as for the quality of the joint and individual problem solution plans in a multidisciplinary CSCL environment. This means that transactive memory and discussion scripts separately, but not in combination, positively impacted the targeted dependent variables in this study (see Noroozi & Biemans et al., 2013; Noroozi & Weinberger et al., 2013). Specifically, the transactive memory or discussion script conditions separately led to higher levels of transactive knowledge sharing and transfer as well as a higher quality of joint and individual problem solution plans, than combined script and control group conditions. In the following paragraphs, we discuss how the transactive memory and discussion scripts separately facilitated problem-solving in a multidisciplinary CSCL setting and why offering the two scripts together was not beneficial.

Regarding the transactive memory script, following step-by-step guidelines and instructions embedded in the platform for each process of the TMS (encoding, storage, retrieval) helped learners to quickly become aware of their learning partners' expertise, to coordinate the collaborative learning activities by assigning and sharing task responsibilities, and finally to retrieve needed information from the learning partner with the appropriate specialization during the collaborative phase (Noroozi & Biemans et al., 2013; Rulke & Rau, 2000; Wegner, 1987). Formation of a collaboratively shared system for encoding, storage, and retrieving knowledge in the dyad fosters the integrative usage of information based on a heightened awareness of distributed knowledge resources, which is beneficial for transactions of unshared information in the forms of elicitation and externalization during collaborative discussion (Rummel & Spada, 2005; Rummel et al., 2009).

These transactions amounted to a successful exchange of unshared information between dyad members in a collaborative problem-solving setting (King, 1999). Since elicitation could lead to externalization of information and vice versa (Weinberger et al., 2005a & 2007b), scripted learners were able to pool and process more unshared information resulting in facilitation of transactive knowledge sharing in terms of knowledge externalization and elicitation. Transactions of unshared information were followed by elaboration on and integration of one

another's perspectives and ideas (see Noroozi & Biemans et al., 2013). This allowed participants to gain knowledge about their partners' domain expertise (Dillenbourg, 1999) that could also be applied for designing similar problem solution plans in the subsequent individual learning task. Scripted learners were better able to externalize their own information for the learning partner and elicit information from him/her, resulting in the transfer of concepts from individual to dyad and from dyad representation into their individual post-test representations. Furthermore, in collaborative learning, groups whose members are aware of one another's knowledge and expertise develop a shared understanding of who knows what in the group (Wegner, 1987) and thus perform better than groups whose members do not possess such knowledge (e.g. Moreland et al., 1998; Moreland & Argote, 2003).

The significance of shared knowledge for collaborative learning activities especially among heterogonous groups has been widely acknowledged in the scientific literature (see Hollingshead, 2000; Liang et al., 1995) since learners typically influence one another when learning together (e.g. De Lisi & Golbeck, 1999). Accordingly, the findings of this study corroborate other research results showing a positive impact of developing a collaboratively shared system for encoding, storage, and retrieving knowledge on performance in collaborative problem-solving settings (e.g. Stasser et al., 1995; Liang et al., 1995; Moreland et al., 1996). Furthermore, externalization of one's own knowledge and elicitation of a learning partner's knowledge have been regarded as important for improving learning performance (Fischer et al., 2002; King, 1999; Rosenshine et al., 1996; Teasley, 1995).

Regarding the transactive discussion script, following step-by-step guidelines and instructions embedded in the platform for collaborative discussion (argumentation analysis, feedback analysis, extension of the argument, and construction of argumentation sequences) helped learners to elaborate on and integrate one another's perspectives and ideas on the basis of the reasoning of peers before reaching consensus (see Noroozi & Weinberger et al., 2013). Specifically, scripted learners were able to engage in deep cognitive processing for learning and discovering complementary knowledge of the learning partner in order to jointly accomplish the task. The various prompts in the transactive discussion script helped the dyads avoid quick consensus building that may result in a division of labour/task in what can be called "cooperation" in contrast to "collaboration" (Dillenbourg, 1999, p. 8). In cooperation, learning partners typically split the task, and individually take responsibility for part of the task based on their expertise and then assemble the partial results into the final output (Dillenbourg, 1999).

In the current study, unscripted learners took advantage of the knowledge of their learning partners only in a cooperative manner for accomplishing the learning task, rather than collaborating to learn and gain in-depth knowledge about each other's domain expertise. As a result, unscripted learners may have avoided engaging in critical and transactive discussions and immediately accepted their learning partners' contributions without further discussion. In contrast, scripted learners used their meta-knowledge in a collaborative rather than cooperative manner by elaborating on the learning materials, integrating and synthesizing one another's perspectives and ideas in order to jointly make sense of the learning task (Fischer et al., 2002; Nastasi & Clements, 1992; Weinberger & Fischer, 2006). For successful collaboration, it is important that individuals contribute to the joint product (in a cooperative manner), but also that all group members understand these contributions and realize what is taking place at the group level (in a collaborative manner) (Stahl, 2011a).

Scripted learners were thus better able to paraphrase, criticize, ask clarifying/extension questions, give counter-arguments, and propose an integration of arguments in response to each message that had been posted by the learning partner until they reached consensus and indicated agreement on the solutions (see Noroozi & Weinberger et al., 2013). The transactive discussion script appeared to facilitate transactive knowledge sharing in terms of integration and conflict-oriented consensus building. Due to the integrative usage of information for clarification and/or elaboration of the learning materials, scripted learners were able to transfer their own domain expertise to their dyads and from their dyads to their individual representations in the post-test. Furthermore, analysing their learning partners' argument(s), constructing arguments that relate to already-externalized arguments, and engaging in sequential argumentation to extend their arguments, along with feedback provided by their partners, helped scripted learners to reason based on the reasoning of their partners and engage in critical and constructive discussions and argumentations. When learners engage in more transactive discussions and argumentations, they benefit to a greater extent from the external memories available, such as contributions of their partners (e.g. Teasley, 1997; Weinberger et al., 2005a & 2007b). In the current study, the scripted learners demonstrated a higher level of integration of concepts acquired in their own studies with newly acquired concepts from their partners in their solution plans.

In terms of interaction effects, offering both transactive memory and discussion scripts at the same time hindered transactive knowledge sharing and transfer as well as the quality of joint and individual problem solution plans. This is striking since individual implementation of

these scripts had a positive impact on various aspects of transactive knowledge sharing and transfer as well as on the quality of problem solution plans. The transactive memory script facilitated learning by coordination of the distributed knowledge, whereas the transactive discussion script facilitated learning by fostering transactive discussion and argumentation during the collaborative phase. It was expected that when used in concert, these two types of scripts would retain their individual positive effects; and no interaction effect was expected (see Noroozi & Biemans et al., 2013; Noroozi & Weinberger et al., 2013). Possible explanations for the negative interaction effect observed include the effects of "over-scripting", the short duration of the study, and its multidisciplinary context.

With respect to over-scripting, limiting students' degrees of freedom may negatively impact their learning processes and outcomes, particularly in CSCL settings. Indeed, previous studies have questioned the use of overly detailed scripts in CSCL environments (Dillenbourg, 2002; Jermann & Dillenbourg, 2003; Tchounikine, 2008). The results of these publications suggest that overly rigid scripts may inhibit and spoil the richness of natural interaction between learners during collaborative learning (Dillenbourg & Tchounikine, 2007). Following Dillenbourg (2002), in the current study when the scripts were combined, learners may have allocated a considerable proportion of their activities to the "syntax" of the instructions (i.e. various sub-tasks imposed by scripts, steps, and labour roles) rather than the "semantics" (the actual collaboration with the aim of learning from one another). This could have led the script components and elements to become requirements for fulfilling the learning task rather than promoting collaboration with the aim of learning (see Onrubia & Engel, 2012).

Due to the multidisciplinary nature of the learning task studied here, the learners needed the complementary expertise of their partners in each dyad in order to jointly make sense of the learning task and to design a joint problem solution plan during the collaborative learning task, which lasted only 80 minutes. Due to the time constraints set by this study, students who were offered both scripts may have felt the need to choose between them. There was, therefore, a possibility for a trade-off between coordination of the distributed task (transactive memory script) and collaborative discussion and argumentation (transactive discussion script). These dyads thus seemed to focus more on following the guidelines and the procedures imposed by the combined scripts than on coordination of the learning task and engaging in collaborative discussions and argumentation in order to jointly make sense of the learning task and to design a joint problem solution plan.

Conclusion, Implications, Limitations and Suggestions for Future Research

Implementation of a transactive memory script appeared to facilitate transactive knowledge sharing in terms of externalization of one's own knowledge and elicitation of a learning partner's knowledge. The transactive memory script facilitated the transfer of domain-specific knowledge (individual-to-group, group-to-individual, and shared knowledge transfer), which in turn resulted in higher-quality learning demonstrated in both joint and individual problem solution plans. Implementation of a transactive discussion script also appeared to facilitate transactive knowledge sharing in terms of integration and conflict-oriented consensus building. Furthermore, the transactive discussion script facilitated the transfer of domain-specific knowledge (individual-to-group, group-to-individual, and shared knowledge transfer), which in turn resulted in higher-quality learning demonstrated in both joint and individual problem solution plans. However, offering transactive memory and discussion scripts at the same time hindered transactive knowledge sharing and transfer as well as the quality of joint and individual problem solution plans. This failure of the two scripts when offered in concert could be due to the effects of over-scripting, the short study duration and the multidisciplinary context, or some combination of these three factors.

The results presented in this study should be interpreted with some caution. First, this study was conducted in a controlled laboratory setting, which entails specific advantages and disadvantages. The experimental setting provided us with the opportunity to carefully control for individual learners' characteristics and rule out alternative explanations for the differences found. Due to the authenticity of the multidisciplinary learning scenario being part of the standard curriculum as they are required for solving these kinds of complex tasks, we assume that these effects could be replicated in the standard curricular educational settings. This is an empirical question, however, since collaborative learning in online environments is often difficult to be realized especially in ad-hoc contexts when learners embark on collaborative experiences who have not worked together before (see Häkkinen, 2002 & 2004; Häkkinen et al., 2010). We therefore suggest that the specific conditions, corresponding effects and learner perceptions of such a scripted environment in a multidisciplinary class be further investigated. The interaction effects in particular should be examined in future research with similar types of CSCL scripts and learning task to better understand why they occurred.

The effects of the scripts used in this study could be tested in real educational settings with students who engage in sustained inquiry-based innovations as has been reported elsewhere

(e.g., Weinberger et al., 2009). Such classrooms build on a collaborative learning culture so the students know one another and evolve social norms about how to inquire and collaborate. Zhang et al. (2009) found that for learners who engage in longer collaboration and knowledge building, a less scripted and more opportunistic collaboration structure can be more productive. It would be insightful to investigate whether such CSCL scripts (as used in this study) would be beneficial in real classrooms for students who engage in sustained inquiry-based innovations. We suggest that follow up research be aimed at this question.

This study used a mixed quantitative and qualitative approach to analyse various dependent variables. We used an adapted coding scheme to analyse quality of student messages during the collaborative phase in terms of transactive knowledge sharing. The inter-rater reliability values of this instrument has been satisfactory in prior studies (e.g. Weinberger et al., 2005a & 2007b) and was even higher in the present study. We also used a content analysis approach to analyse domain-specific knowledge transfer measures as well as individual and group learning performance. Quantitative analyses were used for assessing domain-specific knowledge transfer variables next to the qualitative approach for assessing the joint and individual problem solution plans. Although high inter-rater reliability and intra-coder test-retest reliability values for these measurements were obtained, we recommend using course exams to measure learners' achievement in educational settings outside of the lab. Further analysis is needed to determine the extent to which the results of course exams (mid-term and final exams) are consistent with the results obtained in this study. If they are not consistent, and the psychometric properties of the exams pass the minimum quality thresholds, further calibration of the content analysis coding schemes (like the one we used) could be necessary.

The collaboration in this study was realized in the form of dyadic interactions. The scientific literature suggests that the nature of collaborative learning differs depending on group size, since active participation can be much higher and common ground can be established much faster and easier in dyads than in triads or larger groups (see Noroozi & Weinberger et al., 2012). For example, communication and coordination difficulties increase with group size (Steiner, 1972). This is especially important with respect to coordination of the learning task and knowledge specialization in the group, since it may take longer for learners to efficiently coordinate the distributed knowledge resources for improving performance in larger than in smaller groups. For example, Michinov and Michinov (2009) showed that dyads and triads differed in the way the coordination of specialized knowledge influenced enhancement of performance. It would be revealing to test the effects of transactive memory and discussion

scripts on learning processes and outcomes using different-sized groups in order to better understand the relationship between group size and successful collaborative learning.

Contrary to most research studies on CSCL scripts, which mostly report on learning outcomes in relation to either individual or group performance (e.g. Weinberger et al., 2005a, 2005b, 2007a, & 2007b), this study presents separate data on the quality of both joint and individual problem solution plans. This is important since success in group performance does not always mirror individual performance. Group members may employ strategies that enhance their group product, but this is not necessarily the same as individual performance (Prichard et al., 2006; Weinberger & Fischer, 2006). For example, more active or knowledgeable members in the group may complete the task on behalf of the group Less active or knowledgeable members (so-called free riders) may fail to enhance their individual performance (Prichard et al., 2006). This is particularly interesting when the CSCL script targets the construction of a transactive memory system (TMS) in the group. As found in a study by Lewis et al. (2005), the TMS transfers across tasks; hence groups with a strong TMS develop it further on subsequent tasks. Such a transfer, however, happens only when group members maintain the same division of cognitive labour and roles across tasks.

In the current study, although the division of labour and roles was absent in the subsequent individual learning task, comparable results were achieved for the effects of the CSCL scripts on both quality of joint and individual problem solution plans. However, individual performance was measured immediately after the collaborative learning phase with a comparable problem case. This may have resulted in a misleading boost in the short-term individual performance measures that may not have been realized if the individual post-test had been conducted some time later with a rather different learning task (see Noroozi & Busstra et al., 2012). Domain-specific dependence, especially in a multidisciplinary collaborative setting, might take away the responsibility of individuals for learning new information that falls in another group member's area of specialization (see Lewis et al., 2005). This domain-specific dependence may thus hinder performance for comparable learning tasks that need complementary expertise and have to be subsequently solved individually without the presence of the domain expertise of the learning partner. It remains to be investigated to what extent the effects of CSCL scripts on joint product translate into the long-term impacts of such scripts on individual outcomes. Therefore we suggest that follow-up research be aimed at this question. This could have consequences not only for the design

principles of such scripts, but also for the transfer of learning from group to individuals in a long-term study.

We found interaction effects for the transactive memory and discussion scripts on various dependent variables in this study. We attributed these interaction effects to (the combination of) over-scripting, the short duration of the study, and the multidisciplinary context. Scientific literature suggests that scripts could be faded out to avoid cognitive overload and frustration in overly scripted collaborative learning tasks (Dillenbourg, 2002; Jermann & Dillenbourg, 2003). The collaborative phase of the current study only lasted 80 minutes and within such a short period of time it was not possible to fade out the transactive memory and discussion scripts. Now that we know that both scripts work well individually in a multidisciplinary setting in a rather short time period, we advise that follow-up studies fade out such scripts to possibly rule out the interaction effects of such scripts over a relatively long period of time. Longer duration studies would allow researchers to fade out such CSCL scripts to avoid over-scripting. This is an important issue since overly rigid scripts would inhibit and spoil the richness of natural interaction, whereas overly flexible scripts would fail to elicit the intended interaction (Dillenbourg & Tchounikine, 2007). We suggest that further research focus on how, when, and under what conditions CSCL scripts need to be employed and then faded out to avoid over-scripting, prevent frustration, and foster learning in multidisciplinary groups.

Chapter

7

General Conclusion and Discussion

Introduction

This final chapter summarizes and combines the results of the studies described in previous chapters. Since the results of each study are discussed successively in chapters 2 to 6, this chapter goes a step further by discussing the main findings in light of the literature, methodology, future research directions, and practical implications. To do so, the first section summarizes the main findings and recaps how the presented studies have answered the underlying research questions as formulated in the introduction. Afterwards, the relevance of the results for theory is addressed and the results are discussed in a broader sense. Next, the strengths and the weaknesses of the studies are discussed. Specific attention is paid to methodological issues. In consideration of the limitations of the studies, suggestions are made for future research. Finally, this chapter ends with implications for educational practice.

Main Findings of the Literature Review and the Empirical Studies

Argumentation is an essential objective in education. Learning to argue is a prerequisite for solving complex problems in groups, especially when they collaborate online. Online support systems for sharing, constructing and representing arguments constitute what is called Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL), which is seen as a promising environment for students in which to collaborate and argue in teams for facilitation of argumentative knowledge construction, collaborative argumentation, and learning. Despite many empirical research studies in ABCSCL, no overview of this research was currently available. Furthermore, it was still unclear from the literature what factors constitute and influence the results of ABCSCL. Therefore, the first research question of this thesis was: *Based on the current state of the art what factors influence and constitute the results of ABCSCL?*

Chapter 2 of this thesis dealt with this research question. This chapter gave an overview of this field of research, synthesized the findings, proposed a tentative theoretical framework for factors that influence and constitute the results of ABCSCL, and suggested areas in which more research is required. Biggs' (2003) model of teaching and learning in universities was used as a frame of reference for developing our tentative framework. This model consisted of four interdependent components including student, learning environment, processes, and outcomes. The review of the literature was based on specific inclusion criteria and a total of 108 articles were selected for systematic analysis.

The quantitative analysis of research into ABCSCL revealed that empirical publications outnumber conceptual ones (89 empirical and 19 conceptual publications), since scholars have been mostly interested in testing instructional interventions rather than relying on only fundamental theories for describing a variety of pedagogical phenomena under examination. The analysis showed that ABCSCL has not only been designed for controlled laboratory studies but also for quasi-experimental field settings that require argumentative skills in science education. The educational context of the reported empirical studies varied in terms of educational level (primary and secondary schools and universities), curricula (both hard and soft subjects) and geographic location; however, there was a strong emphasis on Western countries. This wide variety shows the importance and growing nature of this body of scholarship. A limited number of reviewed publications reported on both learning processes and outcomes, whereas most publications in ABCSCL reported on specific aspects of the learning processes and activities. Small group size (dyads and triads) has been prioritized in ABCSCL studies, and the selection of group size has depended on the learning goals, time constraint, complexity of the learning task, and the technological design. Almost equal attention has been paid to synchronous and asynchronous modes of communication since each has advantages and disadvantages.

The next step in the literature review involved extracting factors that influence and constitute the results of ABCSCL from the reviewed publications and categorizing them into four inter-related components (student; learning environment; learning process; and learning outcomes) based on Biggs' (2003) model. The component student can be described as characteristics brought into the ABCSCL by the student such as gender, openness to argue, learning style, willingness to argue, and internal argumentative script as well as prior knowledge and skills (argumentation and collaboration skills, prior knowledge, and computer skills). Each student has his/her own characteristics that are used for arguing, discussing, analysing, conceptualizing, synthesizing, and concluding along with his/her partners while solving learning tasks in ABCSCL. Learning environment addresses situational characteristics in ABCSCL that are set by curriculum developers, such as resources and settings (learning task, group composition, group size, and CSCL platform) and instructional support (knowledge representations and collaboration scripts). Orchestration of successful ABCSCL environments depends on the manipulation of both technological settings and instructional interventions. The process level consists of learning processes (construction of single arguments and argumentation sequences) and activities (learning activities in relation to scaffolding).

Learners approach tasks differently depending on the technological settings and instructional interventions. At the outcome level, learning outcomes are based on the expected goals in ABCSCL. These include knowledge construction, which can be the acquisition of both domain-specific knowledge and domain-general knowledge, such as knowledge on argumentation as well as complex problem-solving. This review study led to a comprehensive picture of the ABCSCL, which was presented in chapter 2 followed by practical implications and avenues for future research in this field.

As stated in chapter 1, a comprehensive picture of the relations between learning processes and outcomes in terms of argumentative knowledge construction in CSCL was lacking. This is striking since scientific evidence suggests that differences in learning outcomes are related to differences in learning processes and activities (e.g. Noroozi et al., 2011; Russell, 1999; Koschmann, 1996; Reimann, 2007). Therefore, the second research question of this thesis was: *What are the differences in learning processes between successful and less successful pairs of students in terms of argumentative knowledge construction in CSCL environments?*

Chapter 3 of this thesis dealt with this research question. The results of the exploratory study revealed that the learning processes of successful and less successful students in a CSCL environment differ in terms of relevance, width and depth of discussion, as well as justification and reasoning. Successful pairs of students constructed discourse that was more relevant, wider and deeper, more convincing and more logical than the discourse of less successful pairs. In other words, the findings showed that individuals who engage in a "fruitful discussion" (more relevant, wider and deeper, etc.) gain more knowledge than individuals whose discussion is less fruitful. This exploratory study led to a clear picture of relationships between student learning processes and outcomes in CSCL environments in relation to argumentative knowledge construction. These results suggest that in order to improve students' learning outcomes in CSCL, one should pay explicit attention to the nature of their learning processes in these environments in terms of relevance, correctness, width and depth of discussion, as well as justification and reasoning.

In the experimental study, based on the results of the literature review and also the exploratory study, explicit attention was paid to the nature of the argumentative knowledge construction processes and activities in multidisciplinary groups of learners. The reasoning is that it could be problematic for a multidisciplinary group of learners to establish a transactive memory system (TMS) for engaging in collaborative discussion and argumentation due to

divergent domains of expertise and difficulties for coordination of the distributed knowledge in the group. Multidisciplinary learners suffer from having little knowledge about how expertise is distributed within a group (Rummel et al., 2009; Stasser et al., 1995) and this can negatively affect the exchange and distribution of unshared information and knowledge in the group (see Stasser et al., 2000). The results of the exploratory study revealed that computer-supported collaboration scripts can be designed to facilitate coordination of the distributed knowledge in the group. Following Wegner's (1987 & 1995) ideas, establishing a TMS in a group involves three interdependent processes: encoding, storage, and retrieval. Therefore, a transactive memory script was developed that spanned three interdependent processes: encoding, storage, retrieval. Accordingly, the third research question of this thesis was: *What are the effects of a transactive memory script on the construction of the TMS, transactive knowledge sharing and transfer, as well as the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?*

Chapter 4 of this thesis dealt with this research question. The results showed that the transactive memory script not only facilitates the construction of various aspects of a TMS, but also improves learners' group-to-individual and shared knowledge transfer, as well as the quality of joint and individual problem solution plans. Specialization and coordination aspects of the TMS were shown to be mediators for the impacts of transactive memory script on joint but not individual problem solution plans. When learners make an appropriate estimation of the learning partner(s)' knowledge, they are able to effectively distribute the task based on specialized expertise, coordinate the distributed knowledge by assigning and accepting task/role responsibilities. When learners coordinate the learning activities, they can effectively pool and process one another's unshared information (elicitation and externalization), give feedback, ask clarifying questions, and elaborate on one another's ideas in relation to the problem case. Thus, specialization and coordination help learners elaborate on the learning materials, integrate and synthesize one another's perspectives and ideas in order to jointly make sense of the learning task (Fischer et al., 2002; Nastasi & Clements, 1992; Schoor & Bannert, 2011). The learners make integrative usage of meta-knowledge in a collaborative manner rather than just cooperate (Dillenbourg, 1999), resulting in a higher quality of joint problem solution plans. The various aspects of the TMS mediated the impacts of the transactive memory script on joint but not individual problem solution plans. The reason is that domain-specific dependence, especially in a multidisciplinary collaborative setting, might take away the responsibility of individuals for learning new information that falls in another

group member's area of specialization (Lewis et al., 2005). This domain-specific dependence may thus hinder performance for comparable learning tasks that need complementary expertise and have to be solved individually without the presence of the domain expertise of the learning partner. Overall, these results suggest that scripts can be designed in such a way as to facilitate the construction of a TMS in a multidisciplinary collaborative problem-solving setting, which can foster the quality of the joint product.

As described in chapter 1 of this thesis, despite the positive effects of various CSCL scripts on the argumentative knowledge construction during the collaborative phase, these scripts have not all fostered the acquisition of domain-specific knowledge (see Baker & Lund, 1997; Jermann & Dillenbourg, 2003; Stegmann et al., 2007). According to recent literature on CSCL research, both argumentative discourse activities and domain-specific knowledge acquisition could be facilitated if learners sufficiently elaborate on the learning materials in a transactive manner when making analyses of the argument(s) being put forward by their partners and constructing arguments that relate to already externalized arguments. Building on Berkowitz and Gibbs (1983), a transactive discussion script was developed that included four types of prompts (i.e. for argumentation analysis, feedback analysis, extension of the argument, and construction of argumentation sequences) to facilitate argumentative knowledge construction in such a way as to facilitate domain-specific knowledge acquisition. Accordingly, the fourth research question of this thesis was: *What are the effects of a transactive discussion script on the processes and outcomes of argumentative knowledge construction, domain-specific knowledge, as well as the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?*

Chapter 5 of this thesis dealt with this research question. With an innovative transactive discussion script designed differently than most prior scripts, this study contributes to accumulating evidence that computer-supported collaboration scripts work well to foster argumentative knowledge construction. Awareness about argument quality when analysing someone else's arguments leads to construction of better arguments and enhancement of learners' knowledge on argumentation. These continuous argument constructions and receptions followed by peer clarifications and elaborations of the learning materials enhance learners' knowledge about the topic. This might explain why this script also facilitated both individual and collaborative acquisitions of domain-specific knowledge in a multidisciplinary CSCL setting. So, scripts may be particularly efficient and effective, not when providing more structure for learners' activities, but rather when they entail knowledge about argumentation

and rules for co-regulating each other and being transactive with each others' contributions. These results suggest that the construction of single arguments and argumentation sequences can be fostered not only by scripts for constructing one's own single arguments and exchanging them in argumentation sequences, but also by scripts for analysing and evaluating learning partners' arguments and exchanging them in dialogic-sequential argumentation.

Effective collaborative learning not only depends on the process by which learners gain meta-knowledge about learning partners to pool and process unshared information, that is a TMS, but also on how they engage in transactive discussion when they elaborate, build upon, question, construct arguments, and give counter-arguments against the contributions of their learning partners. Therefore, it is important to know how the transactive memory script (for facilitation of TMS) and transactive discussion script (for facilitation of collaborative argumentation) interact with one another in a multidisciplinary setting. Accordingly, the fifth research question of this thesis was: *To what extent are transactive knowledge sharing and transfer, as well as quality of problem solution plans affected by a transactive memory script, a transactive discussion script, and their combination in a multidisciplinary CSCL setting?*

Chapter 6 of this thesis dealt with this research question. The results of the experimental study showed interaction effects for the transactive memory and discussion scripts on knowledge sharing and transfer, as well as on the quality of the joint and individual problem solution plans in a multidisciplinary CSCL environment. This means that transactive memory and discussion scripts separately, but not in combination positively impacted the targeted dependent variables (see Noroozi & Biemans et al., 2013; Noroozi & Teasley et al., in press; Noroozi & Weinberger et al., 2013). The interaction effects for transactive memory and discussion scripts in relation to various dependent variables were attributed to the notion of "over-scripting", the short study duration, and the multidisciplinary context of the study. In the combined condition, overly detailed scripts or over-scripting in such a short study duration in a multidisciplinary setting in which students need more time to gain meta-knowledge about the learning partner's domain of expertise led to a trade-off between coordination of the distributed task (transactive memory script) and collaborative discussion and argumentation (transactive discussion script). This is why no significant differences were found between students in the combined condition and students in the control condition. These results suggest a further need for research in designing such combined scripts as part of the advancement of the research in CSCL systems.

Research Findings in an Integrated Perspective

This thesis consisted of three main studies including a review study and two empirical studies, one of which was an exploratory study in a real educational setting and the other an experimental study in a laboratory setting, intended to contribute to the advancement of the use of CSCL systems in terms of collaborative argumentation and argumentative knowledge construction. In this section, the main findings of these studies are discussed in combination.

The results of the review study presented in chapter 2 led to a tentative framework for the factors that influence and constitute the results of ABCSCL and suggested avenues for future research. In line with Biggs' model (2003), ABCSCL can be seen an interactive process, whereby the components student, learning environment, and learning process determine the component learning outcomes. The review study of this thesis suggested that in such an integrative process, effective learning takes place in a whole system when all component parts of this system support each other and are interdependent. This integrative nature of ABCSCL was taken into account both in the exploratory and empirical studies in this thesis. In this integrative approach, this thesis paid explicit attention to the relation between students' learning processes/environments and their learning outcomes in CSCL environments in which they argue together to solve authentic learning tasks (see chapter 3). Furthermore, the results of the review study suggested that explicit attention be paid to argumentative knowledge construction processes and outcomes in multidisciplinary settings. Accordingly, an integrative approach was used for designing computer-supported collaboration scripts to facilitate both various aspects of the TMS (see chapters 4 and 6) as well as transactive discussion and argumentation (see chapters 5 and 6) in a multidisciplinary setting.

The exploratory study presented in chapter 3 concerned differences in learning process variables between less successful and successful pairs of students in CSCL in terms of argumentative knowledge construction. This is in line with the results of the review study that suggested the need to consider student, learning processes, and outcomes as a whole in ABCSCL environments. This integrative approach in the exploratory study revealed that successful pairs of students construct more relevant, wider and deeper, more convincing, and more logical contributions during argumentative learning processes and activities in CSCL than less successful pairs of students in terms of argumentative knowledge construction. Students who engage in a "fruitful discussion" gain more knowledge than individuals whose discussion is less fruitful. When learners engage in transactive discussions and

216

argumentations, they benefit to a greater extent from the external memories available, such as contributions of their learning partners (e.g. Teasley, 1997). There is a consensus among scholars that engaging in more relevant, sound, and on-task activities, making better elaborated and justified contributions to discussions, and making broader and deeper arguments (see Buder & Bodemer, 2008; Crossa et al., 2008) lead to a better quality of learning than engaging in off-task activities and contributing less-elaborated and justified, and more narrow and superficial arguments and discussions. The reasoning is that construction of a sound argument using grounds to support a claim and also consideration of multiple perspectives to qualify the claim are related to elaboration of deep cognitive processes, which may foster argumentative knowledge construction (see Baker, 2003; Stegmann et al., 2012). Construction of complete argumentation sequences and structuring the dialogic-sequential exchange are also assumed to be related to elaboration of deep cognitive processes, which may foster knowledge construction (Leitão, 2000; Stegmann et al., 2007).

This integrative picture of differences in learning process variables between less successful and successful pairs of students made it possible to examine what kinds of interaction appear to aid learning and argumentative knowledge construction in a CSCL environment. Without appropriate instructional support in CSCL, one cannot expect that students will broaden and deepen the space of debate with justified and reasonable arguments to a high extent. Furthermore, this exploratory study guided this thesis to determine crucial kinds of appropriate interactions during the learning process that open the door for specific interventions aimed at improving the quality of argumentative knowledge construction in CSCL environments. In line with the review study, the experimental study suggested that learning outcomes in CSCL environments depend on how students engage in discussions and argumentations during the learning processes. The exploratory study, for example, showed that success in CSCL environments depends on how well learning partners construct sound arguments supported by logical reasoning and justifications in argumentation sequences, which broadens and deepens their knowledge about the topic at stake. Based on these results, the exploratory study suggested the scripting approach as an instructional support technique to help students in CSCL environments to construct discourse that is relevant, broad, deep, convincing, and logical based on the contributions of the learning partners. Accordingly, relevant and respective instructional interventions in the form of computer-supported collaboration scripts were designed and their separate and combined effects on various aspects of the learning processes and outcomes were discussed in chapters 4, 5, and 6.

Taking into account the result of the review study, which suggested focusing CSCL research on multidisciplinary groups of learners, the separate and combined effects of various computer-supported collaboration scripts (as suggested by the results of the exploratory study) on various aspects of the learning processes and outcomes were tested in a multidisciplinary problem-solving setting. Based on the results of the review and exploratory studies, there appeared to be a strong need for designing and developing a set of computer-supported collaboration scripts that could help multidisciplinary groups of learners promptly pool and process their unshared information by coordinating the distributed knowledge in the group (the TMS), and then help them engage in critical and transactive discussions. Accordingly, transactive memory and discussion scripts were designed and tested separately and also in combination. Explicit suggestions of the exploratory study were taken into account for designing transactive memory and discussion scripts. For example, based on the results of the exploratory study, a transactive discussion script was designed in such a way as to guide students to broaden, deepen, and justify their arguments based on the contributions of the learning partner. Furthermore, a transactive memory script was designed in such a way as to facilitate coordination of the distributed knowledge for engaging in relevant aspects of the learning task and therefore avoiding off-task activities.

The results of the experimental study showed interaction effects for the transactive memory and discussion scripts on knowledge sharing and transfer. Furthermore, transactive memory and discussion scripts individually, but not in combination, led to better quality as demonstrated in both joint and individual problem solution plans. This is striking since, as discussed previously, implementation of each of these scripts positively impacted various aspects of transactive knowledge sharing and transfer, as well as the quality of problem solution plans. The transactive memory script facilitated learning by coordinating the distributed knowledge in the dyad, whereas the transactive discussion script facilitated learning by fostering transactive discussion and argumentation during the collaborative phase. When the two types of scripts are offered together, one could expect that their positive effects on the various aspects of the learning processes and outcomes would be retained, but that there would be no negative interaction effect. Possible (combined) explanations for the observed interaction effects of transactive memory and discussion scripts in relation to various dependent variables could involve the notion of "over-scripting", the short study duration, and the multidisciplinary context of the study (see also chapter 6). Based on the concept of "over-scripting", limiting students' degrees of freedom could negatively impact

their learning processes and outcomes, particularly in CSCL settings. The reasoning is that overly rigid scripts would inhibit and spoil the richness of natural interaction between learners during collaborative learning (Dillenbourg & Tchounikine, 2007). Due to the time constraint set by this study for the multidisciplinary collaborative phase, which lasted only 80 minutes, students who were offered both transactive memory and discussion scripts focused more on following the guidelines and the procedures imposed by the scripts than on the actions they were meant to elicit: coordination of the learning task and collaborative discussions and argumentation in order to jointly make sense of the learning task during collaborative phase. It could be that the step-by-step guidelines and instructions embedded in the platform for both coordination of the distributed knowledge and transactive discussion and argumentation during collaborative learning task were too restricting and time consuming given the allotted time. The results of this empirical study suggest that more research needs to be done in this field on how to improve the technological settings and instructional strategies for multidisciplinary groups of learners taking into account the notion of "over-scripting".

Strengths, Weaknesses, and Suggestions for Future Research

This thesis used a mixed set of studies including a review study, an exploratory study in a real educational setting, and an empirical laboratory experiment to contribute to the advancement of the use of CSCL systems for facilitation of collaborative argumentation and argumentative knowledge construction. At this point, it is relevant to discuss some strengths and weaknesses of the thesis along with directions for future research.

The review study presented in chapter 2 built on a renowned conceptual framework involving essential aspects of teaching and learning (Biggs, 2003). This study provided an overview of the field and contributed to a growing body of knowledge on designing ABCSCL environments. The review covered a selected time span, language, variety of relevant scientific literature databases, and adopted a search strategy that provided a representation of research carried out in this field in the last 15 years. In this review study, however, the effects of various forms of instructional support (knowledge representational tools and computer-supported collaboration scripts) and interventions on the various components of the learning outcomes in ABCSCL (e.g. acquisition and application of domain-general and domain-specific knowledge, complex problem-solving, knowledge transfer measures) were not reported as such. It would be insightful if another literature review focused on the empirical evidence to report on the (intra) relationships between specific instructional interventions and

learning outcomes in order to demonstrate the interactive nature of components within teaching and learning in ABCSCL. Future research therefore could focus on in-depth quantitative meta-analysis on the topic to examine how, under which conditions, and which instructional interventions in ABCSCL directly determine various components of learning outcomes within the proposed framework. This would enable researchers to draw conclusions on whether and how a particular type of intervention has a real effect on the intended dependent variable. Furthermore, future review studies could aim at answering specific questions with respect to each particular dimension of argumentative knowledge construction. For example, future review studies should categorize and then analyse ABCSCL publications on the basis of their argumentation focus (e.g. quality of single argument, argumentation sequence, reasoning, argumentative discourse, interactions) to draw conclusions on the effects of collaborative argumentation on various types of learning outcomes: problem-solving, knowledge construction, higher order skills, learning of subject contents, etc. This would enable researchers to draw conclusions on whether and how collaborative argumentation leads to learning in ABCSCL. To develop a more prescriptive model, future research would have to be organized not by factor but by factor-factor pairings (e.g. student-learning outcome, learning environment-learning process, learning environment-learning outcome, student-learning process). Such research would not only help us understand the nature of these relationships, the optimal combination of conditions, the influence of one factor on another, and the stability of such an influence, but also lead to a further understanding of how ABCSCL can be designed more effectively.

The exploratory study presented in chapter 3 led to a clear picture of students' learning processes and outcomes in a CSCL environment in a real educational setting (high ecological validity) and not in an artificial experimental setting. This provided the opportunity to shed light on the differences in the learning processes between successful and less successful students as they occur in authentic learning situations (direct practical relevance). However, the authentic setting of this study put some constraints on the possibilities to experiment. For example, student characteristics which could potentially influence learning processes and outcomes (age, prior domain-specific and domain-general knowledge, cultural and educational background, experience with CSCL, etc.) were not explicitly taken into account. These factors can influence the effectiveness of CSCL environments, according to the results of the review study presented in chapter 2. Further research was therefore needed to validate the findings of this study through other experimental studies in which students' backgrounds

and other characteristics were taken into account in more controlled conditions. Knowing that the successful and less successful students engaged in argumentative knowledge construction differently in a real course in the CSCL environment, it was deemed insightful to conduct research studies under more stringent conditions (regarding pre-testing, familiarization of students with the platform, and use of various discussion functionalities) and in similar types of courses with more students to test the extent to which the results could be generalized.

Therefore, the empirical study presented in chapters 4, 5, and 6 of this thesis was conducted in a laboratory setting under more stringent conditions. This empirical study led to a more comprehensive picture of the separate and combined effects of computer-supported collaboration scripts (i.e. transactive memory and discussion scripts) on various aspects of students' learning processes and outcomes in a multidisciplinary CSCL environment. The control-based experiment provided us with the opportunity to take individual students' characteristics (computer literacy, prior experience with and attitude towards collaboration, prior domain-specific and domain-general knowledge etc.) into account. These measurements guaranteed that the observed differences between learners in the various conditions were indeed due to our intervention and not due to the biased or false distribution of learners over the conditions in terms of students' characteristics. Furthermore, as the students in the experimental study were chosen from two complementary university backgrounds in terms of regular educational programmes, and as the learning task was authentic for multidisciplinary contexts, it was assumed that comparable results would be achieved in curricular educational settings with a high ecological validity. This is not certain, however, and it could potentially have consequences for the ways in which students perform in a real multidisciplinary course in an authentic educational setting. Therefore, further research with more direct practical relevance with similar types of CSCL scripts is needed to test the extent to which the results of this empirical study can be generalized in real educational settings.

In both empirical studies in this PhD thesis, only short-term measurements were administrated to account for various types of individual performance such as domain-specific knowledge acquisition and application, as well as argumentative knowledge acquisition, and quality of problem solution plans. In all cases, individual performance variables were measured immediately after the collaborative learning phase with comparable problem cases. This may have resulted in a misleading boost in the short-term individual learning performance measures without fostering deeper processing that encourages long-term retention. It remains to be investigated to what extent the short-term results of the studies also translate into long-

term learning outcomes to other more or less related learning tasks. Therefore follow-up research needs to be aimed at answering this question. This could have consequences not only for the design principles of CSCL scripts, but also for the transfer of learning from group to individuals in a long-term study.

Collaboration in both empirical studies in this PhD thesis was realized in the form of dyads. Scientific literature and also the results of the review study presented in chapter 2 suggest that the nature of collaborative learning differs depending on group size, since active participation can be much higher and common ground can be established much faster and easier in dyads than triads or larger groups (see Noroozi & Weinberger et al., 2012). Communication difficulties therefore increase with group size (Steiner, 1972). This is especially important with respect to task coordination and knowledge specialization in the group, since it may take longer for learners to efficiently coordinate the distributed knowledge resources for improving performance in larger than in smaller groups. It would be insightful to test and accordingly adjust the effects of various types of CSCL scripts on learning processes and outcomes in terms of argumentative knowledge construction in different-sized groups in order to maximize the likelihood of successful collaborative learning.

Contrary to most research studies on the CSCL scripts, which mostly report on learning outcomes in relation to either individual or group performance, the empirical studies in this PhD thesis present separate data on the quality of collaborative and individual performance. This is important since success in group performance does not always mirror individual performance. The reasoning is that group members may employ strategies that enhance their group product, but this is not necessarily the same as individual performance (Prichard et al., 2006; Weinberger & Fischer, 2006). For example, more active or knowledgeable members in the group may complete the task on behalf of the group; as a result, less active or knowledgeable members (so-called free riders) may fail to enhance their individual performance (Prichard et al., 2006). Furthermore, as found in a study by Lewis and colleagues (2005), the transactive memory system (TMS) transfers across tasks; hence groups with a strong TMS develop it further on subsequent learning tasks. Such a transfer, however, happens only when group members maintain the same division of cognitive labour and roles across tasks. The reason is that domain-specific dependence, especially in a multidisciplinary collaborative setting, might take away the responsibility of individuals for learning new information that falls in another group member's area of specialization (Lewis et al., 2005). This domain-specific dependence may thus hinder performance of comparable learning tasks

that need complementary expertise and have to be solved individually without the presence of the domain expertise of the learning partner. It remains to be investigated to what extent the effects of CSCL scripts on group performance also translate to individual outcomes especially in long study durations. Therefore follow-up research could be aimed at this question. This is especially an important issue with regard to the TMS since this theory is typically described based on relatively long-term collaboration within groups that continually develops and increases over the history of a group. In this PhD thesis media-specific affordances in online collaboration, e.g. a CSCL script, was used to facilitate the construction of the TMS without longer-lasting interaction and communication. This idea was in line with the research study of Schreiber and Engelmann (2010), who found that using CSCL concept maps to visualize collaborators' knowledge structures can lead to the construction of TMS in newly formed groups, without longer-lasting interaction and communication. Now that we know that the CSCL script can be designed for facilitation of the TMS in multidisciplinary settings in a rather short time period, follow-up research could test the impacts of such a script on construction of the TMS over a relatively long period of time. This could have consequences not only for the design principles of the CSCL scripts in relation to various aspects of the TMS, but also for the knowledge transfer from individuals-to-group and also group-to-individuals in a long-term study.

In chapter 6 of this thesis, interaction effects were reported for the transactive memory and discussion scripts on various dependent variables. These interaction effects were attributed to the notion of "over-scripting", the multidisciplinary context, and the short study duration of the empirical study. These interaction effects as such should be examined in future research with similar types of CSCL scripts and learning tasks to better understand why it occurred. Scientific literature suggests that scripts could be faded out to avoid cognitive overload and frustration in overly scripted collaborative learning tasks (Dillenbourg, 2002; Jermann & Dillenbourg, 2003). The collaborative phase of the empirical study only lasted 80 minutes and within such a short period of time it was not possible to fade out the transactive memory and discussion scripts. Now that it is clear that transactive memory and discussion scripts work well individually in multidisciplinary settings in a rather short time period, follow-up studies could be designed to fade out such scripts to possibly rule out their interaction effects over a relatively long period of time. Longer duration studies allow researchers to fade out scripts that may otherwise result in "over-scripting". Therefore further research could focus on how,

when, and under what conditions CSCL scripts need to be faded out to avoid over-scripting and to thereby ensure that the intended learning outcomes can be achieved.

This PhD thesis used a variety of qualitative and quantitative approaches, instruments, and different adjusted and self-made coding schemes to analyse various dependent variables. For example, for the review study presented in chapter 2, both qualitative and quantitative methods were used to synthesize research in ABCSCL environments. For the exploratory study presented in chapter 3, learning outcomes were analysed using a slightly revised version of an already available coding scheme developed by Veldhuis-Diermanse (2002), which had already been used in several other empirical studies. Moreover, to analyse the students' learning processes, CSCL literature was reviewed and important aspects of learning processes were taken into account in developing a new coding scheme. For the empirical study presented in chapters 4, 5, and 6, an already available coding scheme was adapted to analyse quality of student messages during the collaborative phase in terms of transactive knowledge sharing and transfer. In chapter 4, a mixed approach was used to analyse the TMS, since such an approach for measuring the TMS has been recommended in the scientific literature (e.g. Moreland et al., 2010). A validated questionnaire instrument (Lewis, 2003) was adapted for measuring various aspects of the TMS. A content analysis scheme was also adjusted (Rummel & Spada, 2005; Rummel et al., 2009) and used to look at the interaction data during collaborative discourse to directly measure the construction of various aspects of the TMS. This approach was used to mitigate the effect of social desirability bias inherent in self-reporting responses, such as those elicited by a questionnaire (Huber & Power, 1985). In chapter 5, an already available coding scheme (e.g. Kollar et al., 2007; Leitão, 2000; Stegmann et al., 2007; Weinberger & Fischer, 2006) was adapted to analyse quality of argumentative discourse activities (e.g. construction of single arguments and argumentation sequences). In chapter 6, various self-made content analysis coding schemes were developed to analyse domain-specific knowledge transfer measures as well as individual and group learning performance. A new quantitative analysis approach was used to assess domain-specific knowledge transfer variables in addition to a self-made qualitative approach for assessing the joint and individual problem solution plans.

The inter-rater reliability and values of all these instruments have been reported as being satisfactory, and these values were even higher in this thesis. Despite high inter-rater reliability and intra-coder test-retest reliability values for the measurements that were used in this thesis, the extent to which the results of these measurements are consistent with student

achievement in real educational settings is still unclear and under-investigated. Further analysis needs to determine the extent to which the results of course exams (mid-term and final exam) are consistent with the results obtained through the coding schemes in this thesis. If they are not consistent, and the psychometric properties of the exams pass the minimum quality thresholds, calibration of the content analysis coding schemes (like the ones used in this thesis) could be necessary. Therefore follow-up research could be aimed at this question.

Implications for Educational Practice

The results of various chapters of this thesis have several important implications for educational practice. As stated in chapter 1, students of all ages need to learn to clearly explain their informed opinions and give reasons for the way in which they carry out tasks and solve authentic problems to manage today's complex issues and actively participate in knowledge societies. Despite the presence of argumentation in everyday life situations, students in academic settings need to be taught to reason properly, to generate well-established interactive argumentation, and to collectively contribute reasons and evidence from different viewpoints in order to build up a shared understanding of the issue at stake. This PhD thesis provides various types of scaffolding approaches (e.g. computer-supported collaboration scripts and knowledge representational tools) to facilitate argumentative knowledge construction and elaboration of the learning materials for enhanced domain-specific knowledge acquisitions. Various positive effects of these scaffolding approaches on a variety of learning aspects in this thesis indicate that ABCSCL environments can be implemented in educational settings especially in higher education to prepare and train students to become capable and qualified professionals who can analyse, conceptualize, synthesize, and cope with complex and authentic problems.

This study showed that when designing ABCSCL, consideration must be given to not only the learning environment, processes, and outcomes but also specific individual characteristics of the students. In line with Biggs' (2003) model of teaching and learning, in ABCSCL environments, as students differ, the ways in which they navigate and engage in the learning processes differ as well. Various individual characteristics of students have been discussed and deemed important for solving learning tasks in ABCSCL environments (see theoretical framework of this thesis in chapter 1). For example, for a successful collaborative argumentation, students should have at least a minimum level of computer literacy, collaboration and argumentation skills, as well as prior knowledge about the topic to be

discussed in ABCSCL. This framework indicates that for enhancing the effects of ABCSCL on a variety of learning aspects (problem-solving, argumentative knowledge construction, domain-specific and domain-general learning etc.), these individual characteristics should be taken into consideration. Various approaches (e.g. presentation and hand-out materials, providing guidelines, training and exercises with the CSCL platform and its various functionalities prior to collaboration etc.) can be used to maximize the likelihood of success in ABCSCL environments. For educational practice, pre-evaluation of students' individual characteristics would enable course developers and teachers to provide adequate and sufficient training and preparations for students in ABCSCL.

The study showed that it is possible to facilitate multidisciplinary learning processes and the outcomes of collaborative argumentation and argumentative knowledge construction with CSCL scripts in a rather short study period. This approach is advantageous compared to a traditional face-to-face multidisciplinary setting, since learners with divergent disciplinary backgrounds may not be able to effectively and promptly combine and integrate their knowledge in a rather short time especially for solving authentic and complex problems. This may have important implications for integrating CSCL environments in higher education since for constructing solutions for, coping with, adjusting to, and solving many of today's complex problems in the knowledge and networked society, students and professionals need to collaborate in multidisciplinary teams.

Despite the positive separate effects of the CSCL scripts on a variety of learning processes and outcomes, this study showed interaction effects for the transactive memory and discussion scripts on various dependent variables. The possible combined reasons for these interaction effects were the concept of "over-scripting", multidisciplinary context, and short duration of the study. Limiting students' degrees of freedom and autonomy could negatively impact their learning processes and outcomes particularly in CSCL settings. This could have consequences for educational practice by opening our eyes to the negative impact of overly rigid scripts that may contradict the ultimate purpose of education by serving as a barrier to the freedom and creativity of students. Furthermore, this could have important implications for the design of CSCL scripts in multidisciplinary settings. To improve educational practice, this PhD thesis suggests giving students more space and time in the collaborative learning phase (than allowed for in this study) and fading out the specific scripts over time so that students can learn to initiate and adapt the corresponding learning activities themselves.

Last but not least, this PhD thesis may have important implications for the design of distance learning programmes in higher education. In line with the innovation and latest developments in the field of educational technology, many universities including Wageningen University have started to develop distance learning programmes to educate MSc students, in addition to their on-campus programmes. International professionals and students are keenly interested in distance learning MSc programmes due to the possibility to combine work, family responsibilities and study, the lower annual costs, and the assumed flexibility. Like any other programmes, distance learning programmes may have their own specific risks and disadvantages, especially with respect to high student dropout rates. This study showed that not only argumentative knowledge construction processes and outcomes, but also students' satisfaction with the learning effects, experiences, and evaluations were positive for collaborative argumentation in CSCL environments. We therefore suggest that CSCL environments be integrated in distance learning programmes in higher education to help reduce the dropout rate.

References

Aleixandre-Jimenez, M. (2007). Designing argumentation learning environments. In S. Erduran., & M. Aleixandre-Jimenez (Eds), *Argumentation in science education: Perspectives from classroom-based research* (pp. 91-115). New York: Springer.

Andrew, G., & McMullen, L.M. (2000). Interpersonal scripts in the anger narratives told by clients in psychotherapy. *Motivation and Emotion, 24*(4), 271-284.

Andrews, R. (1995). *Teaching and learning argument*. London: Cassell Publishers.

Andriessen, J. (2006). Arguing to learn. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 443-460). New York: Cambridge University Press.

Andriessen, J., Baker, M., & Suthers, D. (2003). *Arguing to learn. Confronting cognitions in computer-supported collaborative learning environments.* Dordrecht: Kluwer.

Arnseth, H.C., & Ludvigsen, S. (2006). Approaching institutional contexts: Systemic versus dialogic research in CSCL. *International Journal of Computer-Supported Collaborative Learning, 1*(2), 167-185.

Asterhan, C.S.C., & Schwarz, B.B. (2007). The effects of monological and dialogical argumentation on concept learning in evolutionary theory. *Journal of Educational Psychology, 99*(3), 626-639.

Asterhan, C.S.C., & Schwarz, B.B. (2009). Transformation of robust misconceptions through peer argumentation. In: B.B. Schwarz., T. Dreyfus., & R. Hershkowitz (Eds.), *Guided transformation of knowledge in classrooms* (pp. 159-172). New York, NY: Routledge, Advances in Learning and Instruction Series.

Austin, J.R. (2003). Transactive memory in organizational groups: The effects of content, consensus, specialization, and accuracy on group performance. *Journal of Applied Psychology, 88*(5), 866-878.

Azevedo, R., & Hadwin, A.F. (2005). Scaffolding self-regulated learning and metacognition-implications for the design of computer-based scaffolds. *Instructional Science, 33*(5-6), 367-379.

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

Baker, M. (2003). Computer-mediated argumentative interactions for the co-elaboration of scientific notions. In J. Andriessen., M. Baker., & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 47-78). Kluwer, Boston.

Baker, M. (2009). Intersubjective and intrasubjective rationalities in pedagogical debates: Realizing what one thinks. In B.B. Schwarz., T. Dreyfus., & R. Hershkowitz (Eds.), *Guided transformation of knowledge in classrooms* (145-158). New York, NY: Routledge, Advances in Learning & Instruction Series.

Baker, M., Andriessen, J., Lund, K., Van Amelsvoort, M., & Quignard, M. (2007). Rainbow: A framework for analyzing computer-mediated pedagogical debates. *International Journal of Computer-Supported Collaborative Learning, 2*(3), 315-357.

Baker, M., & Lund, K. (1997). Promoting reflective interactions in a CSCL environment. *Journal of Computer Assisted Learning, 13*(3), 175-193.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *The Journal of the Learning Sciences, 9*(4), 403-436.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307-359.

Barron, K.E., & Kenny, D.A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical consideration. *Journal of Personality and Social Psychology, 51*(6), 1173-1182.

Barron, B., & Sears, D. (2002). Advancing understanding of learning in interaction: How ways of participating can influence joint performance and learning. *Proceedings of CSCL 2002*, Boulder, Colorado (pp. 593-595).

Barth, E.M., & Krabbe, E.C.W. (1982). *From axiom to dialogue: A philosophical study of logics and argumentation*. Berlin, New York: W. de Gruyter.

Beach, R., & Doerr-Stevens, C. (2009). Learning argument practices through online role-play: Toward rhetoric of significance and transformation. *Journal of Adolescent and Adult Literacy, 52*(6), 460-468.

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 Behaviour, 21*(4), 623-643.

Beers, P.J., Kirschner, P.A., Boshuizen, H.P.A., & Gijselaers, W.H. (2007). ICT-support for grounding in the classroom. *Instructional Science, 35*(6), 535-556.

Belland, B.R., Glazewski, K.D., & Richardson, J.C. (2008). A scaffolding framework to support the construction of evidence-based arguments among middle school students. *Educational Technology Research and Development, 56*(4), 401-422.

Bereiter, C. (2002). *Education and mind in the knowledge age.* Mahwah, NJ: Lawrence Erlbaum Associates.

Berkowitz, M.W., & Gibbs, J.C. (1983). Measuring the developmental features of moral discussion. *Merrill-Palmer Quarterly, 29*(4), 399-410.

Biggs, J.B. (1999). *Teaching for quality learning at university: What the student does*. St Edmundsbury: Society for Research into Higher Education and Open University Press.

Biggs, J.B. (2003). *Teaching for quality learning at university: What the student does: Buckingham*: Open University Press, (2nd edition).

Biggs, J.B., & Collis, K.F. (1982). *Evaluating the quality of learning: The SOLO taxonomy*. New York: Academic Press.

Boix-Mansilla, V. (2005). Assessing student work at disciplinary crossroads. *Change, 37*(1), 14-21.

Brooks, C.D., & Jeong, A.C. (2006). Effect of pre-structuring discussion threads on group interaction and group performance in computer-supported collaborate argumentation. *Distance Education, 27*(3), 371-390.

Buder, J., & Bodemer, D. (2008). Supporting controversial CSCL discussions with augmented group awareness tools. *International Journal of Computer-Supported Collaborative Learning,* 3(2), 123-139.

Buckingham-Shum, S. (2003). *The roots of computer supported argument visualization, Visualizing argumentation: software tools for collaborative and educational sense-making,* Springer-Verlag, London.

Cannon-Bowers, J.A., & Salas, E. (1997). Teamwork competencies: The interaction of team member knowledge skills and attitudes. In O.F. O'Neil (Ed.), *Workforce readiness: Competencies and assessment* (pp. 151-174). Hillsdale, NJ: Erlbaum.

Carmien, S., Kollar, I., Fischer, G., & Fischer, F. (2007). The interplay of internal and external scripts- a distributed cognition perspective. In F. Fischer., H. Mandl., J. Haake., & I. Kollar (Eds.), *Scripting computer-supported collaborative learning: Cognitive, computational, and educational perspectives* (pp. 303-326). New York: Springer.

Chinn, C.A., & Anderson, R.C. (1998). The structure of discussions that promote reasoning. *Teachers College Record, 100*(2), 315-368.

Cho, K.L., & Jonassen, D.H. (2002). The effects of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research and Development, 50*(3), 5-22.

Clark, D.B., D'Angelo, C.M., & Menekse, M. (2009). Initial structuring of online discussions to improve learning and argumentation: Incorporating students' own explanations as seed comments versus an augmented-preset approach to seeding discussions. *Journal of Science Education and Technology, 18*(4), 321-333.

Clark, D.B., & Sampson, V. (2007). Personally-Seeded Discussions to scaffold online argumentation. *International Journal of Science Education, 29*(3), 253-277.

Clark, D.B., & Sampson, V. (2008). Assessing dialogic argumentation in online environments to relate structure, grounds, and conceptual quality. *Journal of Research in Science Teaching, 45*(3), 293-321.

Clark, D.B., Sampson, V., Stegmann, K., Marttunen, M., Kollar, I., Janssen, J., Weinberger, A., Menekse, M., Erkens, G., & Laurinen, L. (2010). Online learning environments, scientific argumentation, and 21st century skills. In B. Ertl (Ed.), *E-Collaborative knowledge construction: Learning from computer-supported and virtual environments* (pp. 1-39). Hershey, PA: IGI Global.

Clark, D.B., Sampson, V., Weinberger, A., & Erkens, G. (2007a). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review, 19*(3), 343-374.

Clark, D.B., Stegmann, K., Weinberger, A., Menekse, M., & Erkens, G. (2007b). Technology-enhanced learning environments to support students' argumentation. In S. Erduran., & M. Aleixandre-Jimenez (Eds). *Argumentation in science education: perspectives from classroom-based research* (pp. 217-243). New York: Springer.

Clark, H.H., & Brennan, S.E. (1991). Grounding in communication. In S.D. Teasley (Ed.), *Perspectives on socially shared cognition* (pp. 127-149). Washington: American Psychologist Association.

Claudia, M., Steil, A., & Todesco, J. (2004). Factors influencing the adoption of the Internet as a teaching tool at foreign language schools. *Computers and Education, 42*(4), 353-374.

Cohen, J. (1988). *Statistical power analysis for the behaviour sciences* (2nd ed.). Routledge.

Cohen, E.G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*(1)1-35.

Coffin, C., & O'Halloran, K. (2008): Researching argumentation in educational contexts: new directions, new methods. *International Journal of Research and Method in Education, 31*(3), 219-227.

Coffin, C., & O'Halloran, A.K. (2009). Argument reconceived. *Educational Review, 61*(3), 301-313.

Conklin, J., & Begeman, M.L. (1988). gIBIS: A hypertext tool for exploratory policy discussion. *ACM Transactions on Office Information Systems, 4*(6), 303-331.

Corbel, A., Jaillon, P., Serpaggi, X., Baker, M., Quignard, M., Lund, K., & Séjourné, A. (2002). DREW: Un outil internet pour créer situations d'appretissage coopérant [DREW: An internet tool for creating cooperative learning situations]. In C. Desmoulins., P. Marquet., & D. Bouhineau (Eds), *EIAH2003 environnements informatique pour l'apprentissage humains* (pp. 109-113). Paris: INRP.

Courtney, J.F. (2001). Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS. *Decision Support Systems, 31*(1), 17-38.

Cress, U. (2008). The need for considering multilevel analysis in CSCL research: An appeal for the use of more advanced statistical methods. *International Journal of Computer-Supported Collaborative Learning, 3*(1), 69-84.

Crossa, D., Taasoobshirazib, G., Hendricksc, C., & Hickeya, D.T. (2008). Argumentation: A strategy for improving achievement and revealing scientific identities. *International Journal of Science Education, 30*(6), 837-861.

Dehler, J., Bodemer, D., & Buder, J. (2008). Knowledge convergence in CMC: The impact of convergence-related external representations. *Poster presented at the 8th international conference for the learning sciences,* Utrecht, the Netherlands.

Dehler, J., Bodemer, D., Buder, J., & Hesse, F.W. (2011). Guiding knowledge communication in CSCL via group knowledge awareness. *Computers in Human Behaviour, 27*(3), 1068-1078.

De Jong, F.P.C.M., Veldhuis-Diermanse, A.E. & Lutgens, G. (2002). Computer-supported learning in university and vocational education. In: T. Koschman., R. Hall., & N. Miyake (Eds), *CSCL 2: Carrying forward the conversation* (pp. 111-128). Hillsdale, NJ: Erlbaum.

De Laat, M., & Lally, V. (2003). Complexity, theory and praxis: researching collaborative learning and tutoring processes in a networked learning community. *Instructional Science, 31*(1-2), 7-39.

De Lisi, R., & Golbeck, S.L. (1999). Implications of Piagetian theory for peer learning. In A.M. O'Donnell., & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 3-37). Mahwah, NJ: Lawrence Erlbaum Associates.

De Vries, E., Lund, K., & Baker, M. (2002). Computer-mediated epistemic dialogue: Explanation and argumentation as vehicles for understanding scientific notions. *The Journal of the Learning Sciences, 11*(1), 63-103.

De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2007). Applying multilevel modelling on content analysis data: Methodological issues in the study of the impact of role assignment in asynchronous discussion groups. *Learning and Instruction, 17*(4), 436-447.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp. 1-19). Oxford: Elsevier.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P.A. Kirschner (Ed.), *Three worlds of CSCL. Can we support CSCL* (pp. 61-91). Heerlen: Open Universiteit Nederland.

Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. *International Journal of Computer-Supported Collaborative Learning, 3*(1), 5-23.

Dillenbourg, P., & Jermann, P. (2006). Designing integrative scripts. In: F. Fischer., I. Kollar., H. Mandl., & J. Haake (Eds.), *Scripting computer-supported collaborative learning: Cognitive, computational and educational perspectives* (pp. 275-301). New York: Springer.

Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for CSCL. *Journal of Computer Assisted Learning, 23*(1), 1-13.

Ding, N. (2009). Visualizing the sequential process of knowledge elaboration in computer-supported collaborative problem solving. *Computers and Education, 52*(2), 509-519.

Doise, W., & Mugny, G. (1984). *The social development of the intellect*. Oxford: Pergamon.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.

Edmondson, A.C. (1999). Psychological safety and learning behaviour in work teams. *Administrative Science Quarterly, 44*(2), 350-383.

Ellis, R.A., & Calvo, R.A. (2004). Learning through discussions in blended environments. *Educational Media International, 41*(3), 263-274.

Engelmann, T., Dehler, J., Bodemer, D., & Buder, J. (2009). Knowledge awareness in CSCL: a psychological perspective. *Computers in Human Behaviour, 25*(4), 949-960.

Engelmann, T., & Hesse, F.W. (2011). Fostering sharing of unshared knowledge by having access to the collaborators' meta-knowledge structures. *Computers in Human Behaviour, 27*(6), 2078-2087.

Engelmann, T., & Hesse, F.W. (2010). How digital concept maps about the collaborators' knowledge and information influence computer-supported collaborative problem solving. *International Journal of Computer-Supported Collaborative Learning, 5*(3), 299-320.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*(6), 915-933.

Erkens, G., & Janssen, J. (2008). Automatic coding of dialogue acts in collaboration protocols. *International Journal of Computer-Supported Collaborative Learning*, 3(4), 447-470.

Erkens, G., Jaspers, J., Prangsma, M., & Kanselaar, G. (2005). Coordination processes in computer supported collaborative writing. *Computers in Human Behaviour, 21*(3), 463-486.

Ertl, B., Fischer, F., & Mandl, H. (2006a). Conceptual and socio-cognitive support for collaborative learning in videoconferencing environments. *Computers and Education, 47*(3), 298-315.

Ertl, B., Kopp, B., & Mandl, H. (2006b). Fostering collaborative knowledge construction in case-based learning scenarios in videoconferencing. *Educational Computing Research, 35*(4), 377-397.

Ertl, B., Kopp, B., & Mandl, H. (2008). Supporting learning using external representations. *Computers and Education, 51*(4) 1599-1608.

Ertl, B., Reiserer, M., & Mandl, H. (2005). Fostering collaborative learning in videoconferencing: the influence of content schemes and collaboration scripts on collaboration outcomes and individual learning outcomes. *Education, Communication and Information, 5*(2), 147-166.

Felton, M., & Kuhn, D. (2001). The development of argumentative discourse skill. *Discourse Processes, 32*(2), 135-153.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction, 12*(2), 213-232.

Fischer, F., Kollar, I., Mandl, H., & Haake, J. (Eds.). (2007). *Scripting computer-supported communication of knowledge. Cognitive, computational and educational perspectives* New York: Springer.

Fischer, F., & Mandl, H. (2005). Knowledge convergence in computer-supported collaborative learning: The role of external representation tools. *The Journal of the Learning Sciences, 14*(3), 405-441.

Fritz, M.S., & MacKinnon, D.P. (2007). Required sample size to detect the mediated effect. *Psychological Science, 18*(3), 233-239.

Fritz, M.S., Taylor, A.B., & MacKinnon, D.P. (2012). Explanation of two anomalous results in statistical mediation analysis. *Multivariate Behavioural Research, 47*(1), 61-87.

Ge, X., & Land, S.M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development, 52*(2), 5-22.

Ge, X., Yamashiro, K., & Lee, J. (2000). Pre-class planning to scaffold students for online collaborative learning activities. *Educational Technology and Society, 3*(3), 1-16.

Gerber, S., Scott, L., Clements, D.H., & Sarama, J. (2005). Instructor influence on reasoned argument in discussion boards. *Educational Technology Research and Development, 53*(2), 25-39.

Golanics, J.D., & Nussbaum, E.M. (2008). Enhancing online collaborative argumentation through question elaboration and goal instructions. *Journal of Computer Assisted Learning, 24*(3), 167-180.

Grice, H.P. (1979). Logik und Konversation. In G. Meggle (Ed.), *Handlung, kommunikation, bedeutung* (pp. 243-265). Frankfurt: Suhrkamp.

Gress, L.Z.C., Fior, M., Hadwin, F.A., & Winne, H.P. (2010). Measurement and assessment in computer-supported collaborative learning. *Computers in Human Behaviour, 26*(5), 806-814.

Gross, T., Stary, C., & Totter, A. (2005). User-centered awareness in computer supported cooperative work-systems: Structured embedding of findings from social sciences. *International Journal of Human-Computer Interaction, 18*(3), 323-360.

Häkkinen, P. (2002). Internet-based learning environments for project-enhanced science learning. *Journal of Computer Assisted Learning, 18*(2), 232-237.

Häkkinen, P. (2004). What makes learning in virtual teams so difficult?. *Cyber psychology and Behaviour, 7*(2), 201-206.

Häkkinen, P., Arvaja, M., Hämäläinen, R., & Pöysä, J. (2010). Scripting computer-supported collaborative learning: Review of SCORE studies. In B. Ertl. (Ed.), E-*Collaborative knowledge construction: Learning from computer-supported and virtual environments* (pp. 180-194). IGI Global.

Häkkinen, P., Arvaja, M., & Mäkitalo, K. (2004). Prerequisites for CSCL: Research approaches, methodological challenges and pedagogical development. In K. Littleton., D. Faulkner., & D. Miell (Eds.) *Learning to collaborate and collaborating to learn* (pp. 161-175). Nova Science Publishers: New York.

Häkkinen, P., & Järvelä, S. (2006). Sharing and constructing perspectives in web-based conferencing. *Computers and Education, 47*(1/2), 433-447.

Hegel, G.W.F. (1975). *The logic of Hegel (W. Wallace, Trans.)*. Oxford: Clarendon Press.

Henry, R.A., Strickland, O.J., Yorges, S.L., & Ladd, D. (1996). Helping groups determine their most accurate member: the role of outcome feedback. *Journal of Applied Social Psychology, 26*(13), 1153-1170.

Hirsch, L., Saeedi, M., Cornillon, J., & Litosseliti, L. (2004). A structured dialogue tool for argumentative learning. *Journal of Computer Assisted Learning, 20*(1), 72-80.

Ho, M.L.C., Rappa, N.A., Chee, Y.S. (2009). Designing and implementing virtual enactive role-play and structured argumentation: promises and pitfalls. *Computer Assisted Language Learning, 22*(5), 381-408.

Hollingshead, A.B. (1998a). Communication, learning, and retrieval in transactive memory systems. *Journal of Experimental Social Psychology, 34*(5), 423-442.

Hollingshead, A.B. (1998b). Distributed knowledge and transactive processes in groups. In M.A. Neale., E.A. Mannix., & D.H. Gruenfeld (Eds.), *Research on managing groups and teams* (vol. 1). Greenwich, CT: JAI Press.

Hollingshead, A.B. (1998c). Group and individual training. The impact of practice on performance. *Small Group Research, 29*(2), 254-280.

Hollingshead, A.B. (1998d). Retrieval processes in transactive memory systems. *Journal of Personality and Social Psychology, 74*(3), 659-671.

Hollingshead, A.B. (2000). Perceptions of expertise and transactive memory in work relationships. *Group Processes and Intergroup Relations, 3*(6), 257-267.

Hollingshead, A.B. (2001). Cognitive interdependence and convergent expectations in transactive memory. *Journal of Personality and Social Psychology*, *81*(6), 1080-1089.

Hox, J.J., & Maas, C.J.M. (2002). Sample sizes for multilevel modeling. Social science methodology in the new millennium. *Proceedings of the fifth international conference on logic and methodology.* Leske and Budrich, Opladen.

Huber, G.P., & Power, D.J. (1985). Retrospective reports of strategic level managers: Guidelines for increasing accuracy. *Strategic Management Journal, 6*(2), 171-180.

Hung, D., Tan, S.C., & Chen, D.T. (2005). How the internet facilitates learning as dialog: design considerations for online discussions. *International Journal of Instructional Media, 32*(1), 37-46.

Infante, D.A., & Rancer, A.S. (1982). A conceptualization and measure of argumentativeness. *Journal of Personality Assessment, 46*(1), 72-80.

Inwood, M. (2002). Hegel and the Hermetic tradition. *International Philosophical Quarterly,42* (3), 399-401.

Jackson, B. (2000). *Evaluation of learning technology implementation*. Retrieved from: /http://lomond.icbl.hw.ac.uk/ltdi/evalstudies/esevalimp.htm.

Jacobson, M.J., & Wilensky, U. (2006). Complex systems in education: scientific and educational importance and implications for the learning sciences. *The Journal of the Learning Sciences, 15*(1), 11-34.

Järvelä, S., & Häkkinen, P. (2002). Web-based cases in teaching and learning - the quality of discussions and a stage of perspective taking in asynchronous communication. *Interactive Learning Environments, 10*(1), 1-22.

Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007). Visualization of participation: Does it contribute to successful computer-supported collaborative learning?. *Computers and Education, 49(4)*, 1037-1065.

Janssen, J., Erkens, G., Kirschner, P.A., & Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science, 38*(1), 59-88.

Jonassen, D.H., & Kim, B. (2010). Arguing to learn and learning to argue: Design justifications and guidelines. *Educational Technology Research and Development*, *58*(4), 439-457.

Jeong, A.C. (2005). The effects of linguistic qualifiers and intensifiers on group interaction and performance in computer-supported collaborative argumentation. *International Review of Research in Open and Distance Learning, 6*(3), 100-110.

Jeong, A.C. (2006a). Gender interaction patterns and gender participation in computer-supported collaborative argumentation. *American Journal of Distance Education, 20*(4), 195-210.

Jeong, A.C. (2006b). The effects of conversational language on group interaction and group performance in computer-supported collaborative argumentation. *Instructional Science, 34*(5), 367-397.

Jeong, A.C. (2007). The effects of intellectual openness and gender on critical thinking processes in computer-supported collaborative argumentation. *Distance Education, 22*(1), 1-18.

Jeong, H., & Chi, M. (2007). Knowledge convergence and collaborative learning. *Instructional Science*, *35*(4), 287-315.

Jeong, A.C., & Davidson-Shivers, G. (2006). The effects of gender interaction patterns on student participation in computer-supported collaborative argumentation. *Educational Technology Research and Development, 54*(6), 543-568.

Jeong, A.C., & Frazier, S. (2008). How day of posting affects level of critical discourse in asynchronous discussions and computer-supported collaborative argumentation. *British Journal of Educational Technology, 39*(5), 875-887.

Jeong, A.C., & Joung, S. (2007). Scaffolding collaborative argumentation in asynchronous discussions with message constraints and message labels. *Computers and Education, 48*(3), 427-445.

Jeong, A.C., & Lee, J. (2008). The effects of active versus reflective learning style on the processes of critical discourse in computer-supported collaborative argumentation. *British Journal of Educational Technology, 39*(4), 651-665.

Jeong, H., & Chi, M.T.H. (1997). Construction of shared knowledge during collaborative learning. *Proceedings of the 2nd international conference on Computer support for collaborative learning* (pp. 130-134)*.* Toronto, Ontario, Canada.

Jeong, H., & Hmelo-Silver, C.E. (2008). Use of learning resources in a technologically-mediated online PBL environment. *In Proceedings international conference on PBL 2008*. Colima, Mexico.

Jermann, P., & Dillenbourg, P. (2003). Elaborating new arguments through a CSCL script. In P. Dillenbourg (Ed.), *Learning to argue* (pp. 205-226). Dordrecht, the Netherlands: Kluwer.

Joiner, R., & Issroff, K. (2003). Tracing success: graphical methods for analysing successful collaborative problem solving. *Computers and Education 41* (4), 369-378.

Joiner, R., & Jones, S. (2003). The effects of communication medium on argumentation and the development of critical thinking. *International Journal of Educational Research, 39*(8), 861-971.

Joiner, J., Jones, S., & Doherty, J. (2008). Two studies examining argumentation in asynchronous computer mediated communication. *International Journal of Research and Method in Education, 31*(3), 243-255.

Jonassen, D.H., & Kim, B. (2010). Arguing to learn and learning to argue: Design justifications and guidelines. *Educational Technology Research and Development*, *58*(4), 439-457.

Kanselaar, G., De Jong, T., Andriessen, J., & Goodyear, P. (2000). New Technologies. In P.J.R. Simons., J.L. van der Linden., & T. Duffy (Eds.), *New Learning* (pp. 55-82). Dordrecht: Kluwer Academic Publishers.

Kapur, M. (2008). Productive failure. *Cognition and Instruction, 26*(3), 379-424.

Keefe, J.W. (1979) Learning style: An overview. *NASSP's student learning styles: Diagnosing and proscribing programs* (pp. 1-17). Reston, VA. National Association of Secondary School Principles.

Kenny, D.A., Kashy, D.A., & Bolger, N. (1998). Data analysis in social psychology. In D. Gilbert., S. Fiske., & G. Lindzey (Eds.), *The handbook of social psychology* (pp. 233-265). Boston, MA: McGraw-Hill.

Kester, L., & Paas, F. (2005). Instructional interventions to enhance collaboration in powerful learning environments. *Computers in Human Behaviour, 21*(4), 689-696.

Kim, I., Anderson, R.C., Nguyen-Jahiel, K., & Archodidou, A. (2007). Discourse patterns during children's collaborative online discussions. *The Journal of the Learning Sciences, 16*(3), 333-370.

King, A. (1999). Discourse patterns for mediating peer learning. In A. O'Donnell., & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 87-115). Mahwah, NJ: Lawrence Erlbaum.

Kirschner, F., Paas, F., Kirschner, P.A., & Janssen, J. (2011). Differential effects of problem-solving demands on individual and collaborative learning outcomes. *Learning and Instruction, 21*(4), 587-599.

Kirschner, P.A. (2002). Cognitive load theory: Implications of cognitive load theory on the design of learning. *Learning and Instruction, 12*(1), 1-10.

Kirschner, P.A., Beers, P.J., Boshuizen, H.P.A., & Gijselaers, W.H. (2008). Coercing shared knowledge in collaborative learning environments. *Computers in Human Behaviour, 24*(2), 403-420.

Kirschner, P.A., Buckingham-Shum, S.J., & Carr, C.S. (Eds.). (2003). *Visualizing argumentation: software tools for collaborative and educational sense-making.* London: Springer.

Kirschner, P.A., Strijbos, J.W., Kreijns, K., & Beers, P.J. (2004). Designing electronic collaborative learning environments. *Educational Technology Research and Development, 52*(3), 47-66.

Kitaygorodskaya, N., & Helo, P. (2006). Measurement of team knowledge: transactive memory system and team mental models. *Proceedings of the R&D management conference.* Taipei and Hsinchu, Taiwan ROC.

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning, 2*(2-3), 211-224.

Kollar, I., Fischer, F., & Hesse, F.W. (2006). Collaboration scripts-a conceptual analysis. *Educational Psychology Review, 18*(2), 159-185.

Kollar, I., Fischer, F., Slotta, D.J. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction, 17*(6), 708-721.

Koschmann, T. (1996). Paradigm shifts and instructional technology: An introduction. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm*, (pp. 1-23). Mahwah, NJ: Erlbaum.

Koschmann, T. (2003) CSCL, Argumentation, and deweyan inquiry: Argumentation is learning. In J. Andriessen., M. Baker., & D. Suthers (Eds.), *Arguing to learn. confronting cognitions in computer-supported collaborative learning environments* (pp. 1.25). Dordrecht: Kluwer.

Kuhn, D. (1991). *The skills of argument*. Cambridge University Press.

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review, 62*(2), 155-178.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*(3), 319-337.

Kuhn, D. (2005). *Education for thinking*. Harvard University Press.

Kuhn, D. (2009). Do students need to be taught how to reason? *Educational Research Review, 4*(1), 1-6.

Kuhn, D., & Goh, W.W.L. (2005). Arguing on the computer. In T. Koschmann., D. Suthers., & T.W. Chan (Eds.), *Computer supported collaborative learning 2005: The next 10 years*! (pp. 125-134). Mahwah, NJ: Lawrence Erlbaum.

Kuhn, D., Iordanou, K., Pease, M., & Wirkala, C. (2008). Beyond control of variables: What needs to develop to achieve skilled scientific thinking? *Cognitive Development*, *23*(4), 435-451.

Kuhn, D., Shaw, V., & Felton, M. (1997). Effects of dyadic interaction on argumentative reasoning. *Cognition and Instruction, 15*(3), 287-315.

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), 1245-1260.

Kuhn, D., & Udell, W. (2007). Coordinating own and other perspectives in argument. *Thinking and Reasoning, 13*(2), 90-104.

Leitão, S. (2000). The potential of argument in knowledge building. *Human Development, 43*(6), 332-360.

Leitão, S. (2003). Evaluating and selecting counter-arguments. *Written Communication, 20*(3), 269-306.

Lemus, D., Seibold, D., Flanagin, A., & Metzger, M. (2004). Argument and decision making in computer-mediated groups. *Journal of Communication*, *54*(2), 302-320.

Lewis, K. (2003). Measuring transactive memory systems in the field: scale development and validation. *Journal of Applied Psychology*, 88(4), 587-604.

Lewis, K., Lange, D., & Gallis, L. (2005). Transactive memory systems, learning, and learning transfer. *Organizational Science, 16(*6), 581-598.

Lewis, K., Belliveau, M., Herndon, B., & Keller, J. (2007). Group cognition, membership change, and performance: Investigating the benefits and detriments of collective knowledge. *Organizational Behaviour and Human Decision Processes, 103*(2), 159-178.

Li, D.D., & Lim, P.C. (2008). Scaffolding online historical inquiry tasks: A case study of two secondary school classrooms. *Computers and Education, 50*(4), 1394-1410.

Liang, D.W., Moreland, R.L., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin, 21*(4), 384-393.

Liang, R.D., & Rau, D. (2000). Investigating the encoding process of transactive memory development in group training. *Group and Organization Management, 25*(4), 373-396.

Lin, S.J., & Crawford, Y. (2007). Innovations in teaching: An online debate series for first-year pharmacy students. *American Journal of Pharmaceutical Education, 71*(1), 1-8.

Lipponen, L. (2002). Exploring foundations for computer-supported collaborative learning. In G. Stahl (Ed.), *Computer support for collaborative learning: foundations for a CSCL community* (pp. 72-871). Proceedings of CSCL 2002, Boulder, Colorado.

Littlepage, G.E., Robison, W., & Reddington, K. (1997). Effects of task experience and group experience on group performance, member ability, and recognition of expertise. *Organizational Behaviour and Human Decision Processes, 69*(2), 133-147.

Liu, C.C., & Tsai, C.C. (2008). An analysis of peer interaction patterns as discoursed by on-line small group problem-solving activity. *Computers and Education, 50*(3), 627-639.

Loll, F. (2012). *Domain-independent support for computer-based education of argumentation skills.* PhD Thesis. Clausthal University of Technology, Department of Informatics.

London, M., Polzer, J.T., & Omoregie, H. (2005). Interpersonal congruence, transactive memory, and feedback processes: an integrative model of group learning. *Human Resource Development Review, 4*(2), 114-135.

Lu, J., & Lajoie, S.P. (2008). Supporting medical decision making with argumentation tools. *Contemporary Educational Psychology, 33*(3), 425-442.

Lund, K., Molinari, J., Sejourne, A., & Baker, M. (2007). How do argumentation diagrams compare when student pairs use them as a means for debate or as a tool for representing debate? *International Journal of Computer-Supported Collaborative Learning, 2*(2-3), 273-295.

Magee, G.A. (2001). *Hegel and the Hermetic tradition.* Cornell University Press.

MacKinnon, D.P. (2008). *Introduction to statistical mediation analysis.* Mahwah, NJ: Erlbaum.

MacKinnon, D.P., Fairchild, A.J., & Fritz, M.S. (2007). Mediation analysis. *Annual Review of Psychology, 58*(1), 593-614.

MacKinnon, D.P., Lockwood, C.M., Hoffman, J.M., West, S.G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods, 7*(1), 83-104.

MacKinnon, D.P., Lockwood, C.M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioural Research, 39(1)*, 99-128.

Marttunen, M. (1997). Electronic mail as a pedagogical delivery system: An analysis of the learning of argumentation. *Research in Higher Education, 38*(3), 345-363.

Marttunen, M. (1998). Electronic mail as a forum for argumentative interaction in higher education studies. *Journal of Educational Computing Research, 18*(4), 387-405.

Marttunen, M., & Laurinen, L. (2001). Learning of argumentation skills in networked and face-to-face environments. *Instructional Science, 29*(2), 127-153.

Marttunen, M., & Laurinen, L. (2007). Collaborative learning through chat discussions and argument diagrams in secondary school. *Journal of Research on Technology in Education, 40*(1), 109-126.

Marttunen, M., & Laurinen, L. (2009). Secondary school students' collaboration during dyadic debates face-to-face and through computer chat. *Computers in Human Behaviour, 25*(4) 961-969.

McAlister, S., Ravenscroftw, A., & Scanlon, E. (2004). Combining interaction and context design to support collaborative argumentation using a tool for synchronous CMC. *Journal of Computer Assisted Learning, 20*(3), 194-204.

McCutchen, D. (1987). Children's discourse skill: form and modality requirements of schooled writing. *Discourse Processes, 10*(3), 267-289.

McDonald, J. (2003). Assessing online collaborative learning: Process and product. *Computers and Education, 40*(4), 377-391.

McEvily, B., Perrone, V., & Zaheer, A. (2003). Trust as an organizing principle. *Organization Science, 14*(1), 91-103.

McLaren, B.M., Scheuer, O., & Mikšátko, J. (2010). Supporting collaborative learning and e-Discussions using artificial intelligence techniques. *International Journal of Artificial Intelligence in Education, 20*(1), 1-46.

Michinov, E. (2007). Validation of the French version of the Transactive Memory Scale and its adaptation to an academic context. *European Review of Applied Psychology*, 57(1), 59-68.

Michinov, N., & Michinov, E. (2009). Investigating the relationship between transactive memory and performance in collaborative learning. *Learning and Instruction, 19*(1), 43-54.

Mirza, N.M., Tartas, V., Perret-Clermont, A.P., & De Pietro, J. (2007). Using graphical tools in a phased activity for enhancing dialogical skills: An example with Digalo. *International Journal of Computer-Supported Collaborative Learning, 2*(2-3), 247-272.

Mitchell, S., Prior, P., Bilbro, R., Peake, K., See, B.H., & Andrews, R. (2008). A reflexive approach to interview data in an investigation of argument. *International Journal of Research and Method in Education, 31*(3), 229-241.

Mohammed, S., & Dumville, B.C. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behaviour, 22*(2), 89-106.

Monteserin, A., Schiaffino, S., & Amandi, A. (2010). Assisting students with argumentation plans when solving problems in CSCL. *Computers and Education, 54*(2), 416-426.

Moreland, R.L., & Argote, L. (2003). Transactive memory in dynamic organizations. In R. Peterson., & E. Mannix (Eds.), *Leading and managing people in the dynamic organization* (pp. 135-162). Mahwah, NJ: Erlbaum.

Moreland, R.L., Argote, L., & Krishnan, T. (1996). Social shared cognition at work: Transactive memory and group performance. In J.L. Nye., & A.M. Brower (Eds.), *What's social about social cognition? Research on socially shared cognition in small groups* (pp. 57-84). Thousand Oaks, CA: Sage.

Moreland, R.L., Argote, L., & Krishnan, R. (1998). Training people to work in groups. In L.H.R.S. Tindale., J. Edwards., E.J. Posvac., F.B. Byant., Y. Sharez-Balcazar., E. Henderson-King., & R. Myers (Ed.), *Theory and research on small groups* (pp. 37-60). New York: Plenum.

Moreland R.L., & Myaskovsky, L. (2000). Exploring the performance benefits of group training: transactive memory or improved communication? *Organizational Behaviour and Human Decision Processes, 82*(1), 117-133.

Moreland, R.L., Swanenburg, K.L., Flagg, J.J., & Fetterman, J.D. (2010). Transactive memory and techonology in work groups and organizations. In B. Ertl (Ed.), *E-collaborative knowledge construction: Learning from computer-supported and virtual environments* (pp. 244-274). Geneva: IGI Global Press.

Morgan, A. (2006). Argumentation, geography education and ICT. *Geography, 91*(2), 11-19.

Morris, R., Hadwin, A.F., Gress, C.L.Z., Miller, M., Fior, M., Church, H., & Winne, PH. (2010). Designing roles, scripts, and prompts to support CSCL in gStudy. *Computers in Human Behaviour,* 26(5), 815-824.

Munneke, L. (2007). *Arguing to learn. Supporting interactive argumentation through computer-supported collaborative learning*. PhD dissertation, Utrecht University, The Netherlands.

Munneke, L., Andriessen, J., Kanselaar, G., & Kirschner, P. (2007). Supporting interactive argumentation: Influence of representational tools on discussing a wicked problem. *Computers in Human Behaviour, 23*(3), 1072-1088.

Munneke, L., Van Amelsvoort, M., & Andriessen, J. (2003). The role of diagrams in collaborative argumentation-based learning. *International Journal of Educational Research, 39*(1-2), 113-131.

Muukkonen, H., Lakkala, M., & Hakkarainen, K. (2005). Technology-mediation and tutoring: how do they shape progressive inquiry discourse? *The Journal of the Learning Sciences, 14*(4), 527-565.

Nastasi, B.K., & Clements, D.H. (1992). Social-cognitive behaviours and higher-order thinking in educational computer environments. *Learning and Instruction, 2*(3), 215-238.

Newman, D.R., Webb, B., & Cochrane, C. (1995). A content analysis method to measure critical thinking in face-to-face and computer supported group learning. *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century, 3*(2), 56-77.

Noroozi, O., Biemans, H.J.A., Busstra, M.C., Mulder, M., & Chizari, M. (2011). Differences in learning processes between successful and less successful students in computer-supported collaborative learning in the field of human nutrition and health. *Computers in Human Behaviour, 27*(1), 309-318.

Noroozi, O., Biemans, H.J.A., Busstra, M.C., Mulder, M., Popov, V., & Chizari, M. (2012). Effects of the Drewlite CSCL platform on students' learning outcomes. In A. Juan., T. Daradoumis., M. Roca., S.E. Grasman., & J. Faulin. (Eds.), *Collaborative and distributed E-research: Innovations in technologies, strategies and applications* (pp. 276-289). IGI Global.

Noroozi, O., Biemans, H.J.A., Weinberger, A., Mulder, M., & Chizari, M. (2013). Scripting for construction of a transactive memory system in a multidisciplinary CSCL environment. *Learning and Instruction, 25*(1), 1-12. doi:10.1016/j.learninstruc.2012.10.002.

Noroozi, O., Busstra, M.C., Mulder, M., Biemans, H.J.A., Tobi, H., Geelen, M.M.E.E., van't Veer, P., & Chizari, M. (2012). Online discussion compensates for suboptimal timing of supportive information presentation in a digitally supported learning environment. *Educational Technology Research and Development, 60*(2), 193-221.

Noroozi, O., Teasley, S.D., Biemans, H.J.A., Weinberger, A., & Mulder, M. (in press). Facilitating learning in multidisciplinary groups with transactive CSCL scripts. *International Journal of Computer-Supported Collaborative Learning.*

Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2012). Argumentation-based computer supported collaborative learning (ABCSCL). A systematic review and synthesis of fifteen years of research. *Educational Research Review, 7*(2), 79-106.

Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2013). Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers and Education, 61*(2), 59-76.

Nussbaum, E.M. (2002). How introverts versus extroverts approach small-group argumentative discussions? *The Elementary School Journal*, *10*(3), 183-197.

Nussbaum, E.M. (2005). The effect of goal instructions and need for cognition on interactive argumentation. *Contemporary Educational Psychology, 30*(3), 286-313.

Nussbaum, E.M. (2008a). Collaborative discourse, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology, 33*(3), 345-359.

Nussbaum, E.M. (2008b). Using argumentation vee diagrams (AVDs) for promoting argument/counterargument integration in reflective writing. *Journal of Educational Psychology, 100*(3), 549-565.

Nussbaum, E.M., & Bendixen, L.D. (2003). Approaching and avoiding arguments: The role of epistemological beliefs, need for cognition, and extraverted personality traits. *Contemporary Educational Psychology, 28*(4), 573-595.

Nussbaum, E.M., & Edwards, O.V. (2011). Critical questions and argument stratagems: A framework for enhancing and analyzing students' reasoning practices. *The Journal of the Learning Sciences, 20*(3), 443-488.

Nussbaum, E.M., & Schraw, G. (2007). Promoting argument-counterargument integration in students' writing. *Journal of Experimental Education, 76*(1), 59-92.

Nussbaum, E.M., Hartley, K., Sinatra, G.M., Reynolds, R.E., & Bendixen, L.D. (2004). Personality interactions and scaffolding in on-line discussions. *Educational Computing Research, 30*(1-2), 113-137.

Nussbaum, E.M., & Kardash, C.M. (2005). The effects of goal instructions and text on the generation of counter-arguments during writing. *Journal of Educational Psychology, 97*(2), 157-169.

Nussbaum, E.M., Sinatra, M.G., & Poliquin, A. (2008). Role of epistemic beliefs and scientific argumentation in science learning. *International Journal of Science Education, 30*(15), 1977-1999.

Nussbaum, E.M., Winsor, D.L., Aqui, Y.M., & Poliquin, A.M. (2007). Putting the pieces together: Online argumentation vee diagrams enhance thinking during discussions. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 479-500.

O'Donnell, A.M., & Dansereau, D.F. (1992). Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In R. Hertz-Lazarowitz., & N. Miller (Eds.), *Interactions in cooperative groups. The theoretical anatomy of group learning* (pp. 120-141). Cambridge, MA: University Press.

Oestermeier, U., & Hesse, F. (2000). Verbal and visual causal arguments. *Cognition, 75*(1), 65-104.

Oh, S., & Jonassen, D.H. (2006). Scaffolding online argumentation during problem solving. *Journal of Computer Assisted Learning, 23*(2), 95-110.

Onrubia, J., & Engel, A. (2012). The role of teacher assistance on the effects of a macro-script in collaborative writing tasks. *International Journal of Computer-Supported Collaborative Learning, 7*(1), 161-186.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463-466.

Overdijk, M., & Van Diggelen, W. (2008). Appropriation of a graphical shared workspace: Organizing principles and their application. *International Journal of Computer-Supported Collaborative Learning, 3*(2), 165-192.

Palincsar, A., & Brown, A. (1989). Guided, cooperative learning and individual knowledge acquisition. In L.B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser* (pp. 393-451). Hillsdale, NJ: Lawrence Erlbaum.

Paus, E., Werner, C.S., & Jucks, R. (2012). Learning through online peer discourse: Structural equation modeling points to the role of discourse activities in individual understanding. *Computers and Education, 58*(4), 1127-1137.

Pea, R.D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The Journal of the Learning Sciences, 13*(3), 423-451.

Pena-Shaff, J., Martin,W., & Gay, G. (2001). An epistemological framework for analyzing student interactions in computer mediated communication environments. *Journal of Interaction Learning Research*, *12*(1), 41-68.

Pinkwart, N., Aleven, V., Ashley, K., & Lynch, C. (2006). Toward legal argument instruction with graph grammars and collaborative filtering techniques. In M. Ikeda., K. Ashley., & T.W. Chan (Eds.), *Proceedings of the 8th International Conference on Intelligent Tutoring Systems (ITS 2006)* (pp. 227-236). Berlin: Springer.

Pinkwart, N., Aleven, V., Ashley, K., & Lynch, C. (2007). Evaluating legal argument instruction with graphical representations using largo. In R. Luckin., K.R. Koedinger., & J. Greer (Eds.), *Proceedings of the 13th International Conference on Artificial Intelligence in Education (AI-ED 2007)* (pp. 101-108). Amsterdam: IOS.

Preacher, K.J., & Hayes, A.F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behaviour Research Methods, 40*(3), 879-891.

Prichard, J.S., & Ashleigh, M.J. (2007). The effects of team-skills training on transactive memory and performance. *Small Group Research, 38*(6), 696-726.

Prichard, J.S., Stratford, R.J., & Bizo, L.A. (2006). Team-skills training enhances collaborative learning. *Learning and Instruction, 16*(3), 256-265.

Prinsen, F.R., Volman, M.L.L., & Terwel, J. (2006). The influence of learner characteristics on degree and type of participation in a CSCL environment. *British Journal of Educational Technology, 38*(6), 1037-1055.

Prinsen, F.R., Volman, M.L.L., Terwel, J., & Van den Eeden, P. (2009). Effects on participation of an experimental CSCL-programme to support elaboration: Do all students benefit? *Computers and Education, 52*(1), 113-125.

Rau, D. (2005). The influence of relationship conflict and trust on the transactive memory: Performance relation in top management teams. *Small Group Research, 36*(6), 746-771.

Raudenbush, S.W., & Bryk, A.S. (2002). *Hierarchical linear models*. Thousand Oaks, CA: Sage publications.

Ravenscroft, A. (2007). Promoting thinking and conceptual change with digital dialogue games. *Journal of Computer Assisted Learning, 23*(6), 453-465.

Ravenscroft, A. (2011). Dialogue and connectivism: A new approach to understanding and promoting dialogue-rich networked learning. *International Review of Research in Open and Distance Learning, 12*(3), 139-160.

Ravenscroft, A., & McAlister, S. (2006). Digital games and learning in cyberspace: A dialogical approach. *E-Learning and Digital Media, 3*(1), 37-50.

Ravenscroft, A., & McAlister, S. (2008). Investigating and promoting educational argumentation: Towards new digital practices. *International Journal of Research and Method in Education, 31*(3), 317-335.

Ravenscroft, A., & Pilkington, R.M. (2000). Investigation by design: Developing dialogue models to support reasoning and conceptual change. *International Journal of Artificial Intelligence in Education, 11*(1),273-298.

Ravenscroft, A., Wegerif, R.B., & Hartley, J.R. (2007). Reclaiming thinking: Dialectic, dialogic and learning in the digital age. In J. Underwood., & J. Dockrell (Eds.), *Learning through Digital Technologies* (pp. 39-57). British Journal of Educational Psychology Monograph Series, 2(5).

Reimann, P. (2007). Time is precious: Why process analysis is essential for CSCL (and can also help to bridge between experimental and descriptive methods). *Proceedings of the 7th international conference on computer support for collaborative learning* (pp. 602-611). New Brunswick.

Reiser, B.J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences, 13*(3), 273-304.

Reznitskya, A., Anderson, R.C., McNurlin, B., Nguyen-Jahiel, K., Archodidou, A., & Kim, S.Y. (2001). Influence of oral discussion on written argumentation. *Discourse Processes, 32*(2-3), 155-175.

Roschelle, J. & Teasley, S.D. (1995). Construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69-97). New York: Springer.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research, 66*(2), 181-221.

Rourke, L., & Kanuka, H. (2007). Barriers to online critical discourse. *International Journal of Computer-Supported Collaborative Learning, 2*(1), 105-126.

Rulke, D.L., & Rau, D. (2000). Investigating the encoding process of transactive memory development in group training. *Group and Organization Management, 25*(4), 373-396.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences, 14*(2), 201-241.

Rummel, N., Spada, H., & Hauser, S. (2009). Learning to collaborate from being scripted or from observing a model. *International Journal of Computer-Supported Collaborative Learning, 26*(4), 69-92.

Russell, T. (1999). *The no significant difference phenomenon.* Mindspring Press. Retrieved from http://cuda.teleeducation.nb.ca/nosignificantdifference/.

Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behaviour, 21*(6), 957-975.

Schellens, T., & Valcke, M. (2006). Fostering knowledge construction in university students through asynchronous discussion groups. *Computers and Education, 46*(4), 349-370.

Schellens, T., Van Keer, H., De Wever, B., & Valcke, M. (2007). Scripting by assigning roles: Does it improve knowledge Construction in asynchronous discussion groups? *International Journal of Computer-Supported Collaborative Learning, 2*(2-3), 225-246.

Schellens, T., Van Keer, H., De Wever, B., & Valcke, M. (2009). Tagging thinking types in asynchronous discussion groups: Effects on critical thinking. *Interactive Learning Environments, 17*(1), 77-94.

Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B.M. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning, 5*(1), 43-102.

Schoor, C., & Bannert, M. (2011). Motivation in a computer-supported collaborative learning scenario and its impact on learning activities and knowledge acquisition. *Learning and Instruction, 21*(4), 560-573.

Schreiber, M., & Engelmann, T. (2010). Knowledge and information awareness for initiating transactive memory system processes of computer-supported collaborating ad hoc groups. *Computers in Human Behaviour, 26*(6), 1701-1709.

Schwarz, B.B., & De Groot, R. (2007). Argumentation in a changing world. *International Journal of Computer-Supported Collaborative Learning, 2(*2-3), 297-313.

Schwarz, B.B., & Glassner, A. (2007). The role of floor control and of ontology in argumentative activities with discussion-based tools. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 449-478.

Schwarz, B.B., & Linchevski, L. (2007). The role of task design and argumentation in cognitive development during peer interaction. The case of proportional reasoning. *Learning and Instruction, 17*(5), 510-531.

251

Schwarz, B.B., Neuman, Y., & Biezuner, S. (2000a). Two wrongs may make a right . . . If they argue together!. *Cognition and Instruction, 18*(4), 461-494.

Schwarz, B.B., Neuman, Y., Gil, J., & Ilya, M. (2000b). Construction of collective and individual knowledge in argumentative activity: An empirical study. *The Journal of the Learning Sciences, 12*(2), 219-256.

Shrout, P.E., & Bolger, N. (2002). Mediation in experimental and non-experimental studies: New procedures and recommendations. *Psychological Methods, 7*(4), 422-445.

Simon, S. (2008): Using Toulmin's Argument Pattern in the evaluation of argumentation in school science. *International Journal of Research and Method in Education, 31*(3), 277-289.

Slavin, R.E. (1986). Best-evidence synthesis: An alternative to meta-analysis and traditional reviews. *Educational Researcher*, *15*(9), 5-11.

Sobel, M.E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. In S. Leinhardt (Ed.), *Sociological methodology* (pp. 290-312). Washington: American Sociological Association.

Spatariu, A., Linda, F.Q., & Hartley, K. (2007). A review of research on factors that impact aspects of online discussions quality. TechTrends: *Linking Research and Practice to Improve Learning, 51*(3), 44-48.

Spelt, E.J.H., Biemans, H.J.A., Tobi, H., Luning P.A., & Mulder M. (2009). Teaching and learning in interdisciplinary higher education: a systematic review. *Educational Psychology Review, 21*(4), 365-378.

Spiro, R.J., & Jehng, J.C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and muli-dimensional traversal of complex subject matter. In D. Nix., & R.J. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 163-205). Hillsdale: Erlbaum.

Stahl, G. (2002). Rediscovering CSCL. In T. Koschmann., R. Hall., & N. Miyake (Eds.), *CSCL 2: Carrying forward the conversation* (pp. 169-181). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge.* Cambridge, MA: MIT Press.

Stahl, G. (2010). Guiding group cognition in CSCL. *International Journal of Computer-Supported Collaborative Learning, 5*(3), 255-258.

Stahl, G. (2011a). How to study group cognition. In S. Puntambekar., G. Erkens., & C. Hmelo-Silver (Eds.), *Analyzing interactions in CSCL: Methodologies, approaches and issues.* (pp. 107-130). New York, NY: Springer.

Stahl, G. (2011b). Theories of cognition in collaborative learning. In C. Hmelo-Silver., A. O'Donnell., C. Chan., & C. Chinn (Eds.), *International handbook of collaborative learning.* New York, NY: Taylor & Francis.

Stahl, G., & Hesse, F. (2009). Paradigms of shared knowledge. *International Journal of Computer-Supported Collaborative Learning, 4*(4), 365-369.

Stasser, G., Stewart, D.D., & Wittenbaum, G.M. (1995). Expert roles and information exchange during discussion: The importance of knowing who knows what. *Journal of Experimental Social Psychology, 31*(3), 244-265.

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during group discussion. *Journal of Personality and Social Psychology, 48*(6), 1467-1478.

Stasser, G., Vaughan, S.I., & Stewart, D.D. (2000). Pooling unshared information: The benefits of knowing how access to information is distributed among members. *Organizational Behaviour and Human Decision Processes, 82*(1), 102-116.

Stegmann, K., Wecker, C., Weinberger, A., & Fischer, F. (2012). Collaborative argumentation and cognitive processing in computer-supported collaborative learning environment. *Instructional Science, 40*(2), 297-323.

Stegmann, K., Weinberger, A., & Fischer, F. (2007). Facilitating argumentative knowledge construction with computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 421-447.

Stegmann, K., Weinberger, A., & Fischer, F. (2011). Aktives Lernen durch Argumentieren: Evidenz für das Modell der argumentativen Wissenskonstruktion in Online-Diskussionen. *Unterrichtswissenschaft, 39*(3), 231-244.

Stein, N.L., & Bernas, R. (1999). The early emergence of argumentative knowledge and skill. In J. Andriessen., & P. Corrier (Eds.), *Foundations of argumentative text processing* (pp. 97-116). Amsterdam: Amsterdam University Press.

Stein, B.S., & Bransford, J.D. (1979). Constraints on effective elaboration: Effects of precision and subject generation. *Journal of Verbal Learning and Verbal Behaviour, 18*(6), 769–777.

Steiner, I.D. (1972). *Group process and productivity*. New York: Academic.

Strijbos, J.W., Martens, R.L., & Jochems, W.M.G. (2004a). Designing for interaction: Six steps to designing computer-supported group-based learning. *Computers and Education, 42*(4), 403-424.

Strijbos, J.W., Martens, R.L., Jochems, W.M.G., & Broers, N.J. (2004b). The effect of functional roles on group efficiency: using multilevel modeling and content analysis to investigate computer-supported collaboration in small groups. *Small Group Research, 35(2), 195-229.*

Strijbos, J.W., Martens, R.L., Jochems, W.M.G., & Broers, N.J. (2007). The effect of functional roles on perceived group efficiency during computer-supported collaborative learning: A matter of triangulation. *Computers in Human Behaviour, 23(1)*, 353-380.

Suthers, D. (2001). Towards a systematic study of representational guidance for collaborative learning discourse. *Journal of Universal Computer Science, 7*(3), 254-277.

Suthers, D., & Hundhausen, C. (2003). An empirical study of the effects of representational guidance on collaborative learning. *The Journal of the Learning Sciences, 12*(2), 183-219.

Taasoobshirazi, G., & Hickey, D.T. (2005). Promoting argumentative discourse: A design-based implementation and refinement of an astronomy multimedia curriculum, assessment model, and learning environment. *Astronomy Education Review, 4*(1), 53-70.

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics* (2nd ed.). Boston: Pearson.

Taboada, M., & Mann, W. (2006a). Applications of rhetorical structure theory. *Discourse Studies, 8*(4), 567-588.

Taboada, M., & Mann, W. (2006b). Rhetorical structure theory: Looking back and moving ahead. *Discourse Studies, 8*(3), 423-459.

Tchounikine, P. (2008). Operationalizing macro-scripts in CSCL technological settings. *International Journal of Computer-Supported Collaborative Learning, 3*(2), 193-233.

Teasley, S.D. (1995). The role of talk in children's peer collaborations. *Developmental Psychology*, *31*(2), 207-220.

Teasley, S.D. (1997). Talking about reasoning: How important is the peer in peer collaboration? In L.B. Resnick., R. Saljo., C. Pontecorvo., & B. Burge (Eds.), *Discourse, tools and reasoning: Essays on situated cognition* (pp. 361-384). Berlin: Springer.

Toulmin, S. (1958). *The uses of argument*. Cambridge University Press, Cambridge, UK.

Van Amelsvoort, M. (2006). *A space for debate. How diagrams support collaborative argumentation-based learning*. PhD dissertation, Utrecht University, The Netherlands.

Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2007). Representational tools in computer-supported collaborative argumentation-based learning: How dyads work with constructed and inspected argumentative diagrams. *The Journal of the Learning Sciences, 16*(4), 485-521.

Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2008). How students structure and relate argumentative knowledge when learning together with diagrams. *Computers in Human Behaviour, 24*(3), 1293-1313.

Van Bruggen, J.M. (2003). *Explorations in graphical argumentation: the use of external representations in collaborative problem solving*. PhD dissertation, Open University, The Netherlands.

Van Bruggen, J.M., Boshuizen, H.P., & Kirschner, P.A. (2003). A cognitive framework for cooperative problem solving with argument visualization. In P.A. Kirschner., S.J. Buckingham-Shum., & C.S. Carr (Eds.), *Visualizing argumentation: Software tools for collaborative and educational sense-making* (pp. 25-49). London: Springer.

Van Bruggen, J.M., & Kirschner, P.A. (2003). Designing external representations to support solving wicked problems. In J. Andriessen., M. Baker., & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 177-204). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Van Bruggen, J., Kirschner, P., & Jochems, W. (2002). External representation of argumentation in CSCL and the management of cognitive load. *Learning and Instruction, 12*(1), 121-138.

Van der Pol, J., Admiraal, W.F., & Simons, P.R.J. (2008). Peer evaluation in online anchored discussion for an increased local relevance of replies. *Computers in Human Behaviour, 26*(3), 288-295.

Van Dinther, M., Dochy, F., & Segers, M. (2011). Factors affecting students' self-efficacy in higher education. *Educational Research Review, 6*(2), 95-108.

Van Drie, J., Van Boxtel, C., Erkens, G., & Kanselaar, G. (2005a). Using representational tools to support historical reasoning in computer-supported collaborative learning. *Technology, Pedagogy and Education, 14*(1), 25-41.

Van Drie, J., Van Boxtel, C., Jaspers, J., & Kanselaar, G. (2005b). Effects of representational guidance on domain specific reasoning in CSCL. *Computers in Human Behaviour, 21*(4), 575-602.

Van Eemeren, F.H., & Grootendorst, R. (1992). *Argumentation, communication, and fallacies: a pragma-dialectical perspective.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Van Eemeren, F.H., & Grootendorst, R. (1999). Strategic manoeuvring in argumentative discourse. *Discourse Studies, 1*(4). 479-497.

Van Eemeren, F.H., Grootendorst, R., & Henkemans, F.S. (1996). *Fundamentals of argumentation theory: A handbook of historical backgrounds and contemporary developments*. Mahwah, NJ: Erlbaum.

Van Eemeren, F.H., Grootendorst, R., & Henkemans, F.S. (2008). Dialectical profiles and indicators of argumentative moves. *Journal of Pragmatics, 40*(3), 475-493.

Van Eemeren, F.H., Grootendorst, R., & Kruiger, T. (1987). *Handbook of argumentation theory: A critical survey of classical backgrounds and modern studies*. Dordrecht, Foris Publications.

Veerman, A.L. (2000). *Computer supported collaborative learning through argumentation*. PhD dissertation, Utrecht University, The Netherlands.

Veerman, A.L. (2003). Constructive discussions through electronic dialogue. In J. Andriessen., M. Baker., & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 117-143). Amsterdam: Kluwer.

Veerman, A.L., Andriessen, J.E.B., & Kanselaar, G. (2000). Learning through synchronous electronic discussion. *Computers and Education, 34*(3-4), 269-290.

Veerman, A.L., Andriessen, J.E.B., & Kanselaar, G. (2002). Collaborative argumentation in academic education. *Instructional Science, 30*(3), 155-186.

Veldhuis-Diermanse, A.E. (2002). *CSCLearning? Participation, learning activities and knowledge construction in computer-supported collaborative learning in higher education.* PhD dissertation, Wageningen University, The Netherlands.

Veldhuis-Diermanse, A.E., Biemans, H.J.A., Mulder, M., & Mahdizadeh, H. (2006). Analysing learning processes and quality of knowledge construction in networked learning. *Journal of Agricultural Education and Extension, 12*(1), 41-58.

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

Victor, K. (1999). Learning together: Educational benefits and prospects for computer support. *The Journal of the Learning Science, 8* (3), 499-508.

Voss, J.F., Tyler, S.W., & Yengo, L.A. (1983). Individual differences in the solving of social science problems. In R.F. Dillon., & R.R. Schmeck (Eds). *Individual differences in cognition* (pp. 204-232). New York, Academic Press.

Voss, J.F., & Van Dyke, J.A. (2001). Argumentation in psychology: Background comments. *Discourse Processes, 32*(2-3), 89-111.

Walsh, D. (2005). Hegel and the Hermetic tradition. *The Review of Metaphysics, 59*(2), 440-442.

Walton, D.N. (1992). *Plausible argument in everyday conversation.* Albany, NY: State University of New York Press.

Walton, D.N. (1996). *Argumentation schemes for presumptive reasoning.* Mahwah, NJ: Lawrence Erlbaum Associates.

Walton, D.N. (2000). The place of dialogue theory in logic, computer science and communication studies. *Synthese, 123*(3), 327-346.

Walton, D.N. (2006). Examination dialogue: An argumentation framework for critically questioning an expert opinion. *Journal of Pragmatics, 38*(5), 745-777.

Wang, Q.Y., & Woo, H.L. (2007). Comparing asynchronous online discussions and face-to-face discussions in a classroom setting. *British Journal of Educational Technology, 38*(2), 272-286.

Webb, N.M. (1989). Peer interaction and learning in small groups. *International Journal of Education Research, 13*(1) 21-39.

Wegerif, R., McLaren, B.M., Chamrada, M., Scheuer, O., Mansour, N., Mikšátko, J., & Williams, M. (2010). Exploring creative thinking in graphically mediated synchronous dialogues. *Computers and Education, 54*(3), 613-621.

Wegner, D.M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen., & G.R. Goethals (Eds.), *Theories of group behaviour* (pp. 185-208). New York: Springer-Verlag.

Wegner, D.M. (1995). A computer network model of human transactive memory. *Social Cognition, 13(3),* 1-21.

Weinberger, A. (2011). Principles of transactive computer-supported collaboration scripts. *Nordic Journal of Digital Literacy, 6*(3), 189-203.

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005a). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science, 33*(1), 1-30.

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers and Education, 46*(1), 71-95.

Weinberger, A., Kollar, I., Dimitriadis, Y., Mäkitalo-Siegl, K., & Fischer, F. (2009). Computer-supported collaboration scripts. Perspectives from educational psychology and computer science. In N. Balachef., S.R. Ludvigsen., T.d. Jong., S. Barnes., & A.W. Lazonder (Eds.), *Technology-enhanced learning. Principles and products* (pp. 155-173). Berlin: Springer.

Weinberger, A., Stegmann, K., & Fischer, F. (2005b). Computer-supported collaborative learning in higher education: scripts for argumentative knowledge construction in distributed groups. In T. Koschmann., D.D. Suthers., & T.K. Chan (Eds.), *Computer supported collaborative learning: The next 10 years!* (pp. 717-726). Mahwah, NJ: Erlbaum.

Weinberger, A., Stegmann, K., & Fischer, F. (2010). Learning to argue online. Scripted groups surpass individuals (unscripted groups do not). *Computers in Human Behaviour, 28*(4), 506-515.

Weinberger, A., Stegmann, K., & Fischer, F. (2007a). Knowledge convergence in collaborative learning: Concepts and assessment. *Learning and Instruction, 17*(4), 416-426.

Weinberger, A., Stegmann, K., Fischer, F., & Mandl, H. (2007b). Scripting argumentative knowledge construction in computer-supported learning environments. In F. Fischer., H. Mandl., J. Haake., & I. Kollar (Eds.), *Scripting computer-supported communication of knowledge - cognitive, computational and educational perspectives* (pp. 191-211). New York: Springer.

Zheng, Y. (2012). Unlocking founding team prior shared experience: A transactive memory system perspective. *Journal of Business Venturing, 27*(5), 577-591.

Yiong-Hwee, T., & Churchill, D. (2007). Using sentence openers to support students' argumentation in an online learning environment. *Educational Media International, 44*(3), 207-218.

English Summary

With the arrival of the knowledge-based era, the swift growth of information and communication technology, and the rapid growth and widespread accessibility of the WorldWideWeb, it is inevitable that professionals in all fields will be confronted with rapidly changing global problems and complex issues. These complexities call for appropriate specialization of domain knowledge in which qualified professionals and experts from different disciplines need to collaborate in new learning and working contexts. This reality has consequences for education, especially in the need to provide students with ample experience collaborating in multidisciplinary groups to become capable and qualified professionals, who can analyse, conceptualize, synthesize, and cope with complex and authentic problems. In collaborative settings, students of all ages need to learn to clearly explain their informed opinions and give reasons for the way in which they carry out tasks and solve problems. Engaging students in collaborative discussion and argumentation is an educational approach for preparing them to manage today's complex issues and actively participate in knowledge societies. Despite the fact that argumentation is shaped in social conversation and also in learners' online exchanges in daily life, learners in academic settings need to be taught to reason and argue in a way that is beneficial for knowledge sharing, domain-specific learning, and knowledge construction. Online support systems for collaboration or Computer-Supported Collaborative Learning (CSCL) environments in which learners argue in teams have been found to support the sharing, constructing, and representing of arguments with the aim of learning. This type of learning arrangement is called Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) and it is seen as a promising environment in which to facilitate collaborative argumentation and learning.

Despite many empirical studies in this field, no overview of this research is currently available and it is not clear what factors influence and constitute the results of ABCSCL. An understanding of the relations between learning processes and outcomes in terms of argumentative knowledge construction in CSCL is still lacking. Furthermore, it could be problematic for a multidisciplinary group of learners to engage in collaborative discussion and argumentation due to divergent domains of expertise and difficulties for coordination of the

distributed knowledge. A multi-method approach was used to tackle these issues using a combination of review, exploratory, and experimental studies. The first objective of this thesis is to systematically provide an overview and synthesize the findings of ABCSCL. The second objective of this thesis is to explore the relations between learning processes and outcomes in this body of scholarship. The third objective of this thesis is to investigate whether, and if so how, computer-supported collaboration scripts can be designed to facilitate knowledge sharing and transfer, argumentative knowledge construction, and domain-specific learning in a multidisciplinary setting. Furthermore, the conceptualization and operationalization of these scripts and the way in which they manifest themselves in relation to argumentation knowledge construction and domain-specific learning in a multidisciplinary problem-solving setting are addressed in this thesis.

In chapter 1, the core concepts of this thesis are defined. Given the lack of an overview of the research in ABCSCL and also difficulties and complexities for collaborative argumentation, chapter 2 of this thesis addresses the following question: *Based on the current state of the art what factors influence and constitute the results of ABCSCL?* This chapter gives an overview of this field, proposes a theoretical framework for factors that influence and constitute the results of the ABCSCL, synthesizes the findings, and suggests areas in which more research is required. Biggs' (2003) model of teaching and learning in universities is used as a frame of reference for developing this framework since ABCSCL is considered to be an interactive process, whereby the components student, learning environment, and learning process determine the component learning outcomes. The review of the literature was based on specific inclusion criteria, and a total of 108 articles were selected for systematic analysis. Depended on learning goals, time constraint, nature of the learning task, the technological design etc., reported empirical studies varied in terms of research focus (learning processes and/or outcomes), mode of communication and CSCL platforms (synchronous or asynchronous), research method (qualitative and/or quantitative), design (quasi-experimental or controlled-based), group size (dyads, triads, small or large groups), educational level (primary or secondary schools or universities), curricula (hard or soft subjects), and geographic location with a strong emphasis on Western countries. This wide variety shows the importance and growing nature of this body of scholarship. The next step in the literature review involved extracting factors that influence and constitute the results of ABCSCL and categorizing them into four inter-related components (student; learning environment; learning

process; and learning outcomes) based on Biggs' (2003) model. Based on this framework, the review study addressed practical implications and avenues for research in this field.

The second study, described in chapter 3, explores the relations between learning processes and outcomes in terms of argumentative knowledge construction. Therefore, the second research question of this thesis is: *What are the differences in learning processes between successful and less successful pairs of students in terms of argumentative knowledge construction in CSCL environments?* An experimental study was conducted in a real educational setting with 44 students in the field of human nutrition and health who used a knowledge representation platform that supports collaborative argumentation. The results of this exploratory study revealed that the learning processes of successful and less successful students in a CSCL environment differ in terms of relevance, width and depth of discussion, as well as justification and reasoning. Successful pairs of students constructed discourse that was more relevant, wider and deeper, more convincing, and more logical than the discourse of less successful pairs. In other words, the findings showed that individuals who engage in a "fruitful discussion" (more relevant, wider and deeper, etc.) gain more knowledge than individuals whose discussion is less fruitful. The results of this exploratory study suggest that in order to improve students' learning outcomes in CSCL, one should pay explicit attention to the nature of their learning processes in these environments in terms of relevance, correctness, width and depth of discussion, as well as justification and reasoning.

Based on the results of the review study and also the exploratory study, computer-supported collaboration scripts were designed to facilitate multidisciplinary collaborative learning. For multidisciplinary group of learners, there seem to be two types of collaborative discussion that support group learning: coordination of the distributed knowledge as well as engaging in transactive discussions and argumentations based on the contributions of their learning partners. Accordingly, a respective transactive memory script was designed to facilitate coordination of the distributed knowledge along with a respective transactive discussion script for facilitation of transactive collaborative argumentation for multidisciplinary groups of learners. A control-based empirical study was conducted with 120 university students who were randomly assigned a partner based on their disciplinary backgrounds. These pairs were then randomly assigned to one of four conditions: transactive memory script, transactive discussion script, both scripts, or non-scripted (control). The effects of each respective script on various aspects of learning processes and outcomes in a multidisciplinary CSCL are

presented separately in chapters 4 and 5 of this thesis. The combined effects of these scripts on respective dependent variables are presented in detail in chapter 6 of this thesis.

Establishing a transactive memory system (TMS) is essential for learning groups, especially when they are multidisciplinary and collaborate online. The reasoning is that multidisciplinary learners suffer from having little knowledge about how expertise is distributed within a group (Rummel et al., 2009; Stasser et al., 1995) and this lack of knowledge about the collaborative partner(s) can negatively affect the exchange and distribution of unshared information and knowledge in the group (see Stasser et al., 2000). Following Wegner's (1987 & 1995) ideas, establishing a TMS in a group involves three interdependent processes: encoding, storage, and retrieval. Building on Wegner (1987), a transactive memory script was developed that spanned three interdependent processes: encoding, storage, retrieval. Chapter 4 of this thesis investigates the effects of this script on the construction of the TMS and various learning processes and outcomes in a multidisciplinary setting. Accordingly, the third research question of this thesis is: *What are the effects of a transactive memory script on the construction of the TMS, transactive knowledge sharing and transfer, as well as the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?* The results show that the transactive memory script not only facilitates the construction of various aspects of a TMS, but also improves learners' group-to-individual and shared knowledge transfer, as well as the quality of problem solution plans. Furthermore, the results indicate that specialization and coordination aspects of the TMS are mediators for the impacts of transactive memory script on only a joint but not individual problem solution plans. When learners make an appropriate estimation of the learning partner(s)' knowledge, they are able to effectively distribute the task based on specialized expertise, coordinate the distributed knowledge by assigning and accepting task/role responsibilities. When learners coordinate the learning activities, they can effectively pool and process one another's unshared information (elicitation and externalization), give feedback, ask clarifying questions, and elaborate on one another's ideas in relation to the problem case. Thus specialization and coordination help learners elaborate on the learning materials, and integrate and synthesize one another's perspectives and ideas in order to jointly make sense of the task (see Fischer et al., 2002).

Despite positive effects of various CSCL scripts on argumentative knowledge construction during the collaborative phase, these scripts have not all fostered the acquisition of domain-specific knowledge (see Jermann & Dillenbourg, 2003; Stegmann et al., 2007). Alternative instructional information in how to design CSCL scripts is needed if learners are to construct

sound arguments and engage in argumentation sequences in such a way as to also benefit from argumentative activities as an approach for enhanced domain-specific knowledge acquisition. Building on Berkowitz and Gibbs (1983), a transactive discussion script was developed that included four types of prompts (i.e. for argumentation analysis, feedback analysis, extension of the argument, and construction of argumentation sequences) to facilitate argumentative knowledge construction for enhanced domain-specific knowledge acquisition. Chapter 5 of this thesis investigates the effects of this transactive discussion script on the argumentative knowledge construction processes and outcomes in a multidisciplinary setting. Accordingly, the fourth research question of this thesis is: *What are the effects of a transactive discussion script on the processes and outcomes of argumentative knowledge construction, domain-specific knowledge, as well as the quality of joint and individual problem solution plans in a multidisciplinary CSCL setting?* With an innovative transactive discussion script designed differently than most prior scripts, this study contributes to accumulating evidence that computer-supported collaboration scripts work well to foster argumentative knowledge construction. Awareness about argument quality when analysing someone else's arguments leads to construction of better arguments and enhancement of learners' knowledge on argumentation. These continuous argument constructions and receptions followed by peer clarifications and elaborations of the learning materials enhance learners' knowledge about the topic. This might explain why this script also facilitated both individual and collaborative acquisitions of domain-specific knowledge in a multidisciplinary CSCL setting. So, scripts may be particularly efficient and effective, not when providing more structure for learners' activities, but rather when they entail knowledge about argumentation and rules for learners co-regulating each other and being transactive with each others' contributions. These results suggest that the construction of single arguments and argumentation sequences can be fostered not only by scripts for constructing one's own single arguments and exchanging them in argumentation sequences but also by scripts for analysing and evaluating learning partners' arguments and exchanging them in dialogic-sequential argumentation in a multidisciplinary CSCL setting.

Effective collaborative learning depends not only on the process by which learners gain meta-knowledge about learning partners for coordination of the distributed knowledge to pool and process unshared information, that is a TMS, but also on how they engage in transactive discussion when they elaborate, build upon, question, construct arguments, and give counter-arguments against the contributions of their learning partners. Accordingly, the fifth research

question of this thesis is: *To what extent are transactive knowledge sharing and transfer, as well as quality of problem solution plans affected by a transactive memory script, a transactive discussion script, and their combination in a multidisciplinary CSCL setting?* Chapter 6 of this thesis investigates the combined effects of transactive memory and discussion scripts on various aspects of learning processes and outcomes in a multidisciplinary CSCL setting. The results show interaction effects for the transactive memory and discussion scripts on transactive knowledge sharing and transfer, as well as the quality of the joint and individual problem solution plans in a multidisciplinary CSCL environment. This means that transactive memory and discussion scripts separately, but not in combination, positively impacted the targeted dependent variables (i.e. transactive knowledge sharing and transfer, as well as quality of problem solution plans). The interaction effects for transactive memory and discussion scripts were attributed to the notion of "over-scripting", the short study duration, and the multidisciplinary context of the study. These results suggest a need for further research in designing such scripts in relation to advancement of the research in CSCL systems.

Chapter 7 summarizes and combines the results of the studies and reflects the aims of this thesis. The results suggest that ABCSCL is an interactive process, whereby the components student, learning environment and learning process determine the component learning outcomes. In such an integrative process, effective learning takes place in a whole system when all component parts of this system support each other and are interdependent. Based on this integrative nature, explicit attention was paid to the relations between learning processes and learning outcomes to reveal the connectivity between the two. Next, crucial kinds of appropriate interactions during the learning process were explored to open the door to specific interventions aimed at improving the quality of argumentative knowledge construction outcomes. Accordingly, relevant and respective instructional interventions in the form of computer-supported collaboration scripts were designed and tested on a variety of learning outcome variables. Finally, this thesis suggests that more research needs to be done in this field on how to improve the technological settings and instructional strategies for multidisciplinary groups of learners taking into account the notion of "over-scripting" in relation to the study duration.

Dutch Summary

Het Bevorderen van Argumentatiegericht Computerondersteund Samenwerkend Leren in het Hoger Onderwijs

Met de komst van de kenniseconomie, de informatie- en communicatietechnologie en het WorldWideWeb, is het onvermijdelijk dat professionals in allerlei beroepenvelden worden geconfronteerd met snel veranderende mondiale problemen en complexe vraagstukken. Deze complexiteiten vragen om adequate specialistische domeinkennis. Gekwalificeerde beroepsbeoefenaren en deskundigen uit verschillende disciplines worden geacht samen te werken in nieuwe leer- en werkcontexten. Deze realiteit heeft ook gevolgen voor het onderwijs. Het is noodzakelijk dat studenten ruime mogelijkheden krijgen om samen te werken in multidisciplinaire groepen. Zo kunnen studenten zich ontwikkelen tot professionals die niet alleen in staat zijn om te analyseren, conceptualiseren en synthetiseren, maar ook kunnen omgaan met complexe en authentieke problemen. In leeromgevingen waarin samenwerkend leren centraal staat, dienen studenten van verschillende onderwijsniveaus te leren om hun onderbouwde standpunten helder over te brengen en redenen aan te geven voor de manier waarop zij taken uitvoeren en problemen oplossen. Het betrekken van studenten in de opbouw van argumentaties en het voeren van gezamenlijke discussies kan beschouwd worden als een onderwijskundige benadering gericht op de voorbereiding van het managen van complexe vraagstukken én op het actief deelnemen aan de kennismaatschappij. Ondanks het feit dat argumentaties worden gevormd in sociale conversaties, die in het dagelijks leven ook online worden gevoerd, dienen studenten in academische leeromgevingen onderwezen te worden in het redeneren en argumenteren op een manier die het delen van kennis, leren in domein-specifieke situaties en de gezamenlijke constructie van kennis bevordert. Online systemen ter ondersteuning van samenwerken, ofwel Computer-Supported Collaborative Learning (CSCL), waarin studenten debatteren in teams, stimuleren het uitwisselen en het construeren van argumenten en bevorderen zo te leren. Dit type leerarrangement wordt ook wel Argumentation-Based Computer-Supported Collaborative Learning (ABCSCL) genoemd. Het wordt beschouwd als een veelbelovende leeromgeving waarin het onderling debatteren en zo het leren kan worden ondersteund.

Ondanks vele empirische studies op dit terrein, is er op dit moment geen overzicht van deze studies beschikbaar. Bovendien is onduidelijk welke factoren van invloed zijn op de resultaten van ABCSCL. Daarbij ontbreekt inzicht in de relaties tussen leerprocessen en leerresultaten in termen van argumentatieve kennisconstructie in CSCL-omgevingen. Het deelnemen van studenten in multidisciplinaire groepen aan gezamenlijke discussies in CSCL-omgevingen kan als problematisch worden beschouwd, vanwege de samenkomst, integratie en coördinatie van expertise uit uiteenlopende domeinen. In deze studie is een multi-methode benadering ingezet om de beschreven problemen en kennisleemten te onderzoeken met behulp van een combinatie van literatuuronderzoek, exploratieve en experimentele studies. De eerste doelstelling van dit proefschrift is om op een systematische wijze overzicht te geven van eerdere bevindingen met betrekking tot ABCSCL en deze vervolgens te synthetiseren. De tweede doelstelling van dit proefschrift betreft het verkennen van de relaties tussen leerprocessen en leerresultaten in deze tak van wetenschapsbeoefening. De derde doelstelling van dit proefschrift is om te onderzoeken of, en zo ja hoe, de scripts voor computerondersteund samenwerken kunnen worden ontworpen om kennisdeling, kennisoverdracht tussen, kennisconstructie door en domein-specifiek leren van studenten in een multidisciplinaire setting te bevorderen. Bovendien richt dit proefschrift zich op de conceptualisering en operationalisering van deze scripts, alsook op de manier waarop deze zich manifesteren in relatie tot argumentatieve kennisconstructie en domein-specifiek leren in een multidisciplinaire, probleemoplossende setting.

Allereerst worden in hoofdstuk 1 de kernbegrippen van dit proefschrift gedefinieerd. Gezien het ontbreken van een overzicht van studies over ABCSCL en de daarmee gepaard gaande complexiteiten voor het bevorderen van onderling argumenteren, richt hoofdstuk 2 zich op de volgende vraag: *Gezien de huidige stand van kennis, welke factoren zijn van invloed op, en vormen de resultaten van ABCSCL?* Dit hoofdstuk geeft een overzicht van eerdere studies en huidige vraagstukken in dit veld. Daarin wordt een theoretisch kader geconstrueerd dat is gericht op factoren die van invloed zijn op de resultaten van ABCSCL. Daarnaast worden bevindingen gesynthetiseerd en suggesties voor nader onderzoek uiteengezet. Biggs' (2003) model over het doceren en leren in het hoger onderwijs wordt gebruikt als een raamwerk voor de ontwikkeling van een adequaat theoretisch kader, omdat ABCSCL wordt beschouwd als een interactief proces. Immers bepalen de componenten, de "student", de "leeromgeving" en het "leerproces", de component "leerresultaten". Het literatuuroverzicht is gebaseerd op specifieke inclusiecriteria en in totaal werden 108 wetenschappelijke artikelen geselecteerd

voor een systematische analyse. Afhankelijk van de doelstellingen, de tijdsdruk, de aard van de leertaak en het technologisch ontwerp etc., verschilden de empirische studies in onderzoeksfocus (leerprocessen en –resultaten), de wijze van communicatie op CSCL-platformen (synchroon of asynchroon), de onderzoeksmethode (kwalitatief en/of kwantitatief), het ontwerp van de studie (quasi-experimenteel of het gebruik van controle groepen), de groepsgrootte (diades, triades, kleine of grote groepen), het onderwijsniveau (basisonderwijs, voortgezet onderwijs of hoger onderwijs), de curricula (harde of zachte vakken) en de geografische locatie met een sterke nadruk op de westerse landen. Deze grote verscheidenheid toont het belang en de groei van dit wetenschapsdomein. De vervolgstap in dit literatuuronderzoek bestond uit het extraheren van factoren die van invloed zijn op de resultaten met betrekking tot ABCSCL en het categoriseren van deze factoren in vier onderling verbonden componenten (student, leeromgeving, leerproces en leerresultaten), gebaseerd op het model van Biggs (2003). Op basis van dit raamwerk volgden uit dit literatuuronderzoek praktische implicaties en suggesties voor vervolgonderzoek.

De tweede studie, beschreven in hoofdstuk 3, gaat in op de verbanden tussen leerprocessen en leerresultaten gelet op argumentatieve kennisconstructie. De tweede onderzoeksvraag van dit proefschrift betreft: *Wat zijn de verschillen in leerprocessen tussen succesvolle en minder succesvolle studentenkoppels op het gebied van argumentatieve kennisconstructie in CSCL-omgevingen?* In dit kader werd een experimentele studie uitgevoerd binnen een onderwijssetting met 44 studenten die een ICT-platform gebruikten, gericht op onderlinge samenwerking, in het domein van humane voeding en gezondheid. Uit de resultaten van deze exploratieve studie kwam naar voren dat leerprocessen van succesvolle en minder succesvolle studenten in een CSCL-omgeving verschilden in termen van manieren van redeneren, de omvang en diepgang van discussies. Zo construeerden succesvolle studentenkoppels redeneringen die relevanter, diepgaander, omvangrijker en overtuigender waren dan de redeneringen van minder succesvolle studentenkoppels. Met andere woorden, de bevindingen tonen aan dat individuen die deelnemen aan "vruchtbare discussies" (relevanter, diepgaander, omvangrijker en overtuigender) meer kennis opdoen dan individuen die participeren in minder vruchtbare discussies. In het verlengde hiervan suggereren deze resultaten dat, om de leerresultaten van studenten in CSCL-omgevingen te verbeteren, expliciet aandacht dient te worden besteed aan de aard van leerprocessen in dit type omgevingen in termen van relevantie, juistheid, omvang en diepgang van discussies en manieren van redeneren.

Op basis van het literatuuronderzoek en de exploratieve studie werden scripts ontworpen gericht op computerondersteund samenwerken met als doel om samenwerken in multidisciplinaire groepen te faciliteren. Voor multidisciplinaire groepen lijken er twee manieren van groepsdiscussies te zijn die het groepsleren bevorderen: het coördineren van kennis onder groepspartners én het participeren in discussies door groepspartners. Om deze groepsdiscussies in een studie te kunnen vormgeven, werden transactieve geheugenscripts ontworpen met als doel om het coördineren van kennis onder groepspartners te faciliteren. Bovendien werden transactieve discussiescripts ontworpen ter bevordering van onderlinge uitwisseling en discussie in multidisciplinaire groepen van studenten. Een gecontroleerde empirische studie werd uitgevoerd onder 120 studenten die at random een partner kregen toegewezen, gebaseerd op de betreffende disciplinaire achtergrond. Vervolgens werden deze koppels at random ingedeeld in één van de volgende vier condities: "transactieve geheugenscripts", "transactieve discussiescripts", "beide scripts" of "geen van beide scripts" (controlegroep). De effecten van elk afzonderlijk script op verschillende aspecten van de leerprocessen en de leerresultaten in multidisciplinaire CSCL worden beschreven in de hoofdstukken 4 en 5 van dit proefschrift. De gecombineerde effecten van deze scripts op de onderscheiden afhankelijke variabelen worden in hoofdstuk 6 nader behandeld.

De beschikbaarheid van een "transactief geheugensysteem" (TMS) kan als essentieel worden beschouwd om het leren binnen multidisciplinaire groepen, die online samenwerken, te bevorderen. De gedachte hierachter is dat studenten nadeel kunnen ondervinden indien de beschikbare expertise slechts beperkt wordt uitgewisseld (Rummel et al., 2009; Strasser et al., 1995) en dat dit gebrek aan gedeelde expertise onderlinge uitwisseling van informatie in een groep negatief kan beïnvloeden (Strasser et al., 2000). Uitgaande van de ideeën van Wegner (1987 & 1995), dienen de volgende onderling afhankelijke processen in ogenschouw te worden genomen bij de ontwikkeling van een TMS: het coderen, het opslaan en het opvragen van informatie. Uitgaande van het gedachtegoed van Wegner (1987), werd voor deze studie een script ontwikkeld, dat deze processen faciliteerde. Hoofdstuk 4 van dit proefschrift gaat verder in op de effecten van dit script op de constructie van de TMS én op verschillende leerprocessen en leerresultaten in een multidisciplinaire setting. Derhalve luidt de derde onderzoeksvraag van dit proefschrift: *Wat zijn de effecten van een transactief geheugenscript op de constructie van de TMS, transactieve kennisdeling en –uitwisseling, alsmede de kwaliteit van het gezamenlijk en individueel probleemoplossend vermogen in een multidisciplinaire CSCL-omgeving?* De resultaten tonen aan dat transactieve geheugenscripts

niet alleen de constructie van verschillende aspecten van een TMS faciliteren, maar ook dat onderlinge kennisuitwisseling en het probleemoplossend vermogen van studenten wordt bevorderd. Bovendien geven de resultaten aan dat aspecten van de TMS, gericht op specialisatie en coördinatie, belangrijke stimulansen zijn voor transactieve geheugenscripts om juist het probleemoplossend vermogen van de groep, in tegenstelling tot die van het individu, te bevorderen. Indien studenten een adequate inschatting kunnen maken van de aanwezige expertises in een groep, zijn zij beter in staat om taken binnen die groep te distribueren die recht doen aan de daaraan gekoppelde rollen en gevraagde expertises. Indien studenten leren om leeractiviteiten binnen een groep te coördineren, kunnen ze elkaars (ongedeelde) informatie effectief uitwisselen, feedback geven, verhelderende vragen stellen en voortborduren op elkaars ideeën in relatie tot de betreffende taak. Kortom, het coördineren en onderling uitwisselen van expertises en domein-specifieke informatie bevordert het integreren en synthetiseren van verschillende perspectieven en ideeën met als doel om de taak met succes te kunnen vervullen (Fischer et al., 2002; Nastasi & Clements, 1992).

Ondanks positieve effecten van verschillende CSCL-scripts op argumentatieve kennisconstructie tijdens bepaalde fasen in het samenwerkingsproces, bleken niet alle scripts een stimulans voor het verwerven van domein-specifieke kennis te zijn (zie Jermann & Dillenbourg, 2003; Stegmann et al., 2007). Alternatieve informatie over het ontwerp van CSCL-scripts is nodig voor het leren construeren van steekhoudende argumenten en het leren redeneren met als doel om het verwerven van domein-specifieke kennis verder te bevorderen. Voortbouwend op de ideeën van Berkowitz en Gibbs (1983), werd in deze studie een transactief discussiescript ontworpen met vier opties (gericht op analyse van het argument, analyse van feedback, uitbreiding van het argument en de sequentie van argumenten) om argumentatieve kennisconstructie voor het verwerven van domein-specifieke kennis te bevorderen. Hoofdstuk 5 van dit proefschrift beschrijft een studie waarin de effecten van dit script op argumentatieve kennisconstructie en leerresultaten in een multidisciplinaire setting worden bestudeerd. Niet verwonderlijk luidt de vierde onderzoeksvraag van dit proefschrift: *Wat zijn de effecten van een transactief discussiescript op de leerprocessen en leerresultaten van argumentatieve kennisconstructie, domein-specifieke kennis, alsmede de kwaliteit van het gezamenlijk en individueel probleemoplossend vermogen in een multidisciplinaire CSCL-omgeving?* Met behulp van een innovatief transactief discussiescript, anders ontworpen dan eerdere scripts, draagt deze studie bij aan bewijsvoering dat scripts voor computerondersteund samenwerken argumentatieve kennisconstructie wel degelijk bevorderen. Het zich bewust zijn

269

van de kwaliteiten van argumenten, wanneer argumenten van anderen worden geanalyseerd, leidt tot de constructie van betere argumenten en versterkte kennis bij studenten over argumentatie. Deze doorgaande ontwikkeling van argumentenconstructie, als gevolg van peer feedback en het voortbouwen op eerder uitgewisselde informatie, versterkt de kennis van de student over het betreffende onderwerp van de taak. Dit zou kunnen verklaren waarom dit ontworpen script zowel het individueel als het collectief verwerven van domein-specifieke kennis faciliteert binnen de context van een multidisciplinaire CSCL-omgeving. Met andere woorden, scripts zijn niet alleen efficiënt en effectief wanneer deze een platform bieden voor bepaalde leeractiviteiten, echter dienen deze scripts tevens informatie te bevatten over de opbouw van argumentaties, regels voor co-regulering en het zorgvuldig omgaan met elkaars bijdragen. Deze resultaten suggereren dat de constructie van enkelvoudige argumenten en de sequentie van argumenten niet alleen kunnen worden versterkt door scripts die gericht zijn op individuele argumenten, die worden gebruikt in sequenties van argumentaties, maar ook door het analyseren en evalueren van argumenten van groepspartners en deze uit te wisselen middels dialogen in een multidisciplinaire CSCL-omgeving.

Om studenten effectief te leren samenwerken, dienen studenten niet alleen meta-kennis te verwerven over hun groepspartners, voor wat betreft het coördineren en distribueren van informatie; het is daarnaast ook van belang hoe studenten participeren in groepsdiscussies. Hierbij kan gedacht worden aan de wijze waarop studenten argumenten construeren, elkaar vragen stellen en tegenargumenten formuleren gericht op discussiebijdragen van hun groepspartners. De vijfde onderzoeksvraag van dit proefschrift luidt daarom: *In hoeverre worden transactieve kennisdeling en –transfer, alsmede de kwaliteit van het probleemoplossend beïnvloed door een transactief geheugenscript, een transactief discussiescript en een combinatie van beide in een multidisciplinaire CSCL-setting?* Hoofdstuk 6 van dit proefschrift gaat in op de resultaten met betrekking tot de gecombineerde effecten van transactieve geheugen én discussiescripts op verschillende aspecten van leerprocessen en leerresultaten in zo'n multidisciplinaire omgeving. De resultaten bestaan uit interactie-effecten van transactieve geheugen- en discussiescripts op transactieve kennisdeling en -transfer, alsook de kwaliteit van het gezamenlijk en individueel probleemoplossend vermogen in een CSCL-setting. Hiermee wordt bedoeld dat transactieve geheugen- en discussiescripts afzonderlijk van elkaar, d.w.z. niet in combinatie, een positieve impact hebben op de geselecteerde afhankelijke variabelen, of wel transactieve kennisdeling en –transfer en de kwaliteit van het probleemoplossend vermogen. Deze interactie-effecten

werden toegeschreven aan het gegeven van "over-scripting", de beperkte tijdsduur van de studie én de multidisciplinaire context daarvan. De resultaten uit deze studie vragen om vervolgonderzoek specifiek gericht op de ontwikkeling van dit soort scripts, met als doel om onderzoek in de context van CSCL-omgevingen verder te brengen.

Hoofdstuk 7 vat de verschillende deelstudies samen en spiegelt de resultaten daarvan aan de initiële doelen van dit proefschrift. Geconcludeerd wordt dat ABCSCL gekarakteriseerd kan worden als een interactief proces, waarin de componenten, "student", "leeromgeving" en "leerproces", de component "leerresultaten" beïnvloeden. In zulke interactieve processen maakt "effectief leren" deel uit van een omvattend kader, waarin alle componenten onderling afhankelijk van elkaar zijn. Gebaseerd op dit gegeven, werd in deze studie expliciet ingegaan op de verbanden tussen leerprocessen en leerresultaten, met als doel om de onderlinge afhankelijkheid tussen deze componenten aan te tonen. Vervolgens werden essentiële kenmerken van deze leerprocessen onderzocht om specifieke interventies te realiseren voor het versterken van de kwaliteit van argumentatieve kennisconstructie. In het verlengde hiervan, werden op instructie gerichte interventies, in de vorm van scripts ter bevordering van computerondersteund samenwerken, ontworpen en in de onderwijspraktijk getoetst op een aantal onderscheiden leerresultaten. Tenslotte pleit dit proefschrift voor vervolgonderzoek met de vraagstelling op welke wijze ontwerpstrategieën voor multidisciplinaire leeromgevingen én de daaraan gekoppelde technologische platformen verbeterd kunnen worden waarbij expliciet rekening wordt gehouden met "over-scripting" in relatie tot de tijdsduur van een studie.

Wageningen School
of Social Sciences

in the context of the research school

iCO

Interuniversity Center for Educational Research

Name of the activity	Department/Institute	Year	ECTS
I. General part			
Curriculum development (ECS 50906)	WUR	2008	6
Human resource development (ECS 51306)	WUR	2008	6
Techniques for writing and presenting a scientific paper	WGS	2009	1.2
Mobilising your scientific network	WGS	2008	1
Information literacy	WGS	2010	0.6
PhD competence assessment	WGS	2009	0.3
Generalized linear models	PE&RC	2012	0.6
Writing educational research	EERA	2010	7.5
Scientific publishing	WGS	2011	0.3
II. WASS-specific part			
WASS Introduction course	WASS	2008	1.5
WASS Multidisciplinary Seminar (PhD day)	WASS	2009	1
Presentation at International conferences	-	-	10
III. Discipline-specific part			
Qualitative data analysis: procedures and strategies (YRM 60806)	WUR	2009	6
ICO introductory course	ICO	2009	7.1
ICO Toogdagen presentation	ICO	2009	1
ICO Toogdagen discussant	ICO	2009	0.4
Qualitative research methodology	ICO	2009	3.5
Multilevel analysis with SPSS	ICO	2011	3.5
Domain specific instruction in innovative learning environments	ICO	2012	3.5
Competence theory and research	ICO/WASS	2012	4
Research synthesis including meta-analysis	ICO	2012	3.5
Computer supported collaborative learning	ICO	Ongoing	3.5
Writing research proposal	WASS	2009	6
Participation in research meetings at ECS	ECS	2010	2
IV. Teaching and supervising activities (optional)			
Course Intercultural communication	ECS	2011	1
Course Argumentation skills	ECS	2012	1
TOTAL (minimum. 30 ECTS)			**82**

Publication List

Refereed ISI Journal Publictions

Noroozi, O., Biemans, H.J.A., Busstra, M.C., Mulder, M., & Chizari, M. (2011). Differences in learning processes between successful and less successful students in computer-supported collaborative learning in the field of human nutrition and health. *Computers in Human Behaviour, 27*(1), 309-318. doi:10.1016/j.chb.2010.08.009. (IF: 2.293, Q1; Ranking: 22/124 Psychology, Multidisciplinary).

Noroozi, O., Biemans, H.J.A., Weinberger, A., Mulder, M., & Chizari, M. (2013). Scripting for construction of a transactive memory system in a multidisciplinary CSCL environment. *Learning and Instruction, 25*(1), 1-12. doi:10.1016/j.learninstruc.2012.10.002. (IF: 3.732, Q1; Ranking: 2/206 Education and Educational Research).

Noroozi, O., Busstra, M.C., Mulder, M., Biemans, H.J.A., Tobi, H., Geelen, M.M.E.E., van't Veer, P., & Chizari, M. (2012). Online discussion compensates for suboptimal timing of supportive information presentation in a digitally supported learning environment. *Educational Technology Research and Development, 60*(2), 193-221. doi: 10.1007/s11423-011-9217-2. (IF: 1.085, Q2; Ranking: 51/206 Education and Educational Research).

Noroozi, O., Teasley, S.D., Biemans, H.J.A., Weinberger, A., & Mulder, M. (in press). Facilitating learning in multidisciplinary groups with transactive CSCL scripts. *International Journal of Computer-Supported Collaborative Learning.* (IF: 2.243, Q1; Ranking: 11/206 Education and Educational Research).

Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2012). Argumentation-based computer supported collaborative learning (ABCSCL). A systematic review and synthesis of fifteen years of research. *Educational Research Review, 7*(2), 79-106. doi: 10.1016/j.edurev.2011.11.006. (IF: 2.333, Q1; Ranking: 9/206 Education and Educational Research).

Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2013). Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers and Education, 61*(2), 59-76. doi: 10.1016/j.compedu.2012.08.013. (IF: 2.621, Q1; Ranking: 7/206 Education and Educational Research).

Popov, V., Brinkman, D., Biemans, H.J.A., Mulder, M., Kuznetsov A., & **Noroozi, O.** (2012). Multicultural student group work in higher education: An explorative case study on challenges as perceived by students. *International Journal of Intercultural Relations, 36*(2), 302-317. doi:10.1016/j.ijintrel.2011.09.004. (IF: 1.142, Q2; Ranking: 40/138 Sociology).

Refereed Book Chapters

Noroozi, O., Biemans, H.J.A., Busstra, M.C., Mulder, M., Popov, V., & Chizari, M. (2012). Effects of the Drewlite CSCL platform on students' learning outcomes. In A. Juan., T. Daradoumis., M. Roca., S.E. Grasman., & J. Faulin. (Eds.), *Collaborative and distributed E-research: Innovations in technologies, strategies and applications* (pp. 276-289). IGI Global. doi:10.4018/978-1-46660-125-3.

Conference Presentations and Proceedings

Busstra, M.C., Geelen, A., **Noroozi, O.,** Biemans, H.J.A., de Vries, J.H.M., & van 't Veer, P. (2010). Timing of information presentation in interactive digital learning material affects student's learning outcomes and appreciation of the material: a pilot study in the domain of nutritional research education. In J. Herrington & B. Hunter (Ed.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2010*. Chesapeake, VA: AACE, Canada (pp. 3091-3100).

Noroozi, O. (2012). Facilitation of multidisciplinary learning in a CSCL environment. *Paper presented at the Onderwijs Research Dagen (ORD) Annual Meeting.* Wageningen, the Netherlands, June 20-22, 2012.

Noroozi, O., Biemans, H.J.A., Mulder, M., & Chizari, M. (2009). Instructional support in argumentative computer supported collaborative learning (ACSCL). In N. Brouwer., B, Giesbers., B, Rienties., & L, Van Gastel (Ed.), *Proceedings of Student Mobility and ICT. Dimensions of Transition*. Amsterdam, the Netherlands (pp. 133-143).

Noroozi, O., Biemans, H.J.A., Mulder, M., & Chizari, M. (2009). Fostering quality of argumentative computer-supported collaborative learning within academic education in the agri-food sciences. In C. Lokhorst, J. Huijsmans., & R.P.M. de Louw (Ed.), *JIAC2009 Book, Joint International Agricultural Conference*. Wageningen, the Netherlands (p. 365).

Noroozi, O., Biemans, H.J.A., Mulder, M., & Chizari, M. (2010). Analyzing learning processes and outcomes in computer-supported collaborative learning in the domain of nutritional research methodology education. In J. Baralt., N, Callaos., W, Lesso., A, Tremante., & F, Welsch (Ed.), *Proceedings of the International Conference on Society and Information Technologies*. Orlando, Florida, USA (pp. 55-60).

Noroozi, O., Biemans, H.J.A., Mulder, M., & Chizari, M. (2010). Students' knowledge construction in computer-supported learning environments: A comparative study in the domain of nutritional research methodology education. In D. Gibson., & B, Dodge (Ed.), *Proceedings of the 21st International Conference on Society for Information Technology & Teacher Education (SITE)*. San Diego, California, USA (pp. 2506-2513).

Noroozi, O., Biemans, H.J.A., Mulder, M., & Teasley, S.D. (2012). Effects of the discussion script on argumentation-based computer supported collaborative learning. In M. Spada, G. Stahl, N. Miyake, N. Law, (Ed.)., *Connecting Computer-Supported Collaborative Learning to Policy and Practice: Paper presented at the European Conference On Educational Research (ECER): Seventh European Conference on Technology Enhanced Learning*. Cadiz, Spain, September 18-21, 2012.

Noroozi, O., Biemans, H.J.A., Weinberger, A., Mulder, M., & Chizari, M. (2012). Facilitating transactive memory system (TMS) through computer-supported collaboration script in multidisciplinary learning. *Paper presented at the AERA Annual Meeting.* Vancouver, Canada, April 13-17, 2012.

Noroozi, O., Biemans, H.J.A., Weinberger, A., Mulder, M., Popov, V., & Chizari, M. (2011). Supporting computer-supported argumentative knowledge construction in multidisciplinary groups of learners. In L. Gómez Chova., D. Martí Belenguer., & A. López Martínez (Ed.), *Proceedings of the 3rd International Conference on Education and New Learning Technologies*. Barcelona, Spain (1937-1945).

Noroozi, O., Mulder, M., Biemans, H.J.A., & Chizari, M. (2009). Factors influencing argumentative computer supported collaborative learning (ACSCL). In F. Salajan (Ed.), *Proceedings of the 4th international conference on e-learning*. Toronto, Canada (pp. 394-403).

Noroozi, O., Weinberger, A., Biemans, H.J.A., Teasley, S.D., & Mulder, M. (2012). Fostering multidisciplinary learning through computer-supported collaboration script: The role of a transactive memory script. In A. Ravenscroft., S. Lindstaedt., C.D. Kloos., & D. Hernández-Leo. (Eds.): *EC-TEL 2012, LNCS 7563, pp. 413-418, 2012. Proceedings of the Seventh European Conference on Technology Enhanced Learning*. Saarbrücken, Germany, September 18-21, 2012.

Popov, V., Biemans, H.J.A., Teasley, S.D., & **Noroozi, O.** (2012). Collaborative learning in culturally heterogeneous student pairs through a CSCL environment. *Paper presented at the European Conference On Educational Research (ECER): Seventh European Conference on Technology Enhanced Learning*. Cadiz, Spain, September 18-21, 2012.

Popov, V., Brinkman, D., Biemans, H.J.A., Mulder, M., **Noroozi, O.,** & Kuznetsov, A. (2011). Interactions of culturally diverse students in blackboard's discussion board: efficiency of collaborative argumentation-based learning. In L. Gómez Chova., D. Martí Belenguer., & A. López Martínez (Ed.), *Proceedings of the 3rd International Conference on Education and New Learning Technologies*. Barcelona, Spain (2805-2813).

Popov, V., **Noroozi, O.,** Biemans, H.J.A., Brinkman, D., Mulder, M., & Kuznetsov, A. (2012). Challenges in computer-supported intercultural collaborative learning in higher education: An experimental research. *Paper presented at the AERA Annual Meeting.* Vancouver, Canada, April 13-17, 2012.

Popov, V., **Noroozi, O.,** Biemans, H.J.A., & Mulder, M. (2012). Computer-supported collaborative learning in intercultural learning environment. *In A. Ravenscroft., S. Lindstaedt., C.D. Kloos., & D. Hernández-Leo. (Eds.): EC-TEL 2012, LNCS 7563, pp. 543-544, 2012. Proceedings of the Seventh European Conference on Technology Enhanced Learning.* Saarbrücken, Germany, September 18-21, 2012.

نتایج مطالعهٔ دوم نشان می دهد که یک رابطهٔ معنادار بین فرایندهای یادگیری و نتایج حاصله از آن در مطالعات مربوط به یادگیری مشارکتی بحث محور با استفاده از کامپیوتر وجود دارد. به عبارت دیگر، توجه بیشتر به فرایندهای مختلف یادگیری در این زمینه منجر به نتایج بهتر و یادگیری بیشتر فراگیران میگردد. به همین دلیل پیشنهاد میشود که مطالعات مربوط به یادگیری مشارکتی بحث محور با استفاده از کامپیوتر به صورت فرایند محور و نتیجه گرا طراحی گردند. نتایج این مطالعه و پیشنهادهای نظری و عملی مربوط به آن در فصل سوم این پایان نامه به تفسیر شرح داده شده است.

نتایج مطالعهٔ سوم حاکی از آن است که تسهیل یادگیری در محیطهای گروهی چندرشته ای نه تنها از طریق ایجاد یک سیستم مبتنی بر مدیریت حافظهٔ افراد بلکه از طریق ایجاد یک سیستم مبتنی بر بحث و استدلال گروهی در محیطهای یاد گیری الکترونیکی با همکاری سناریومحور به کمک کامپیوتر امکان پذیر است. در واقع، همکاری سناریومحور به کمک کامپیوتر منجر به بهبود فرایندها و نتایج بحث و استدلال گروهی، ایجاد، ساخت، و اشتراک دانش افراد مختلف، و همچنین افزایش کیفیت یادگیری حل مسئله در گروههای یادگیری میگردد. با این وجود، تسهیل و بهبود یادگیری در این محیطهای الکترونیکی تنها زمانی اتفاق می افتد که همکاری سناریومحور به کمک کامپیوتر باعث سرخوردگی و سلب اختیار عمل کامل فراگیران جهت خلاقیت و ایجاد ایده های نوین و جدید نگردد. نظر به اثرات تعاملی همکاری سناریومحور به کمک کامپیوتر، این مطالعه تأکید صریح بر ارائهٔ جداگانهٔ سیستم مبتنی بر مدیریت حافظهٔ افراد و سیستم مبتنی بر بحث و استدلال به جای ارائهٔ همزمان آنها در یادگیری مشارکتی با استفاده از کامپیوتر دارد. نتایج این مطالعه و پیشنهادهای نظری و عملی مربوط به آن در فصول چهارم، پنجم، و ششم این پایان نامه به تفسیر شرح داده شده است. سرانجام، در فصل هفتم خلاصه ای از مهمترین نتایج این پایان نامه همراه با کاربردها و پیشنهادهای نظری و عملی جهت بهبود نظام آموزش عالی از طریق یادگیری مشارکتی بحث محور با استفاده از کامپیوتر ارائه گردیده است.

تحقیق حاضر که از یک رهیافت مختلط (یک مطالعهٔ ادبیاتی و دو مطالعهٔ تشخیصی و آزمایشگاهی) تشکیل شده است، سعی بر ارائهٔ راه حلهای علمی برای حل مسائل و مشکلات بیان شده دارد. هدف اول این پایان نامه ارائهٔ یک مطالعهٔ جامع و سیستماتیک از یافته های اخیر درخصوص یادگیری مشارکتی بحث محور با استفاده از کامپیوتر میباشد. هدف دوم این پایان نامه تشخیص روابط بین فرایندهای یادگیری و نتایج حاصله از آن در این زمینه میباشد. هدف سوم این پایان نامه بررسی اثرات همکاری سناریومحور به کمک کامپیوتر و چگونگی تسهیل یادگیری گروهی بحث محور میباشد. مطالعهٔ سوم تلاشی برای بررسی نظریه ها و کاربردهای همکاری سناریومحور به کمک کامپیوتر در ارتباط با یادگیری بحث محور و ساخت و اشتراک گروهی دانش در محیطهای مبتنی بر حل مسئله میباشد. به طور خاص، در ابتدا اثرات همکاری سناریومحور به کمک کامپیوتر جهت تسهیل یادگیری گروهی چندرشته ای از طریق ایجاد یک سیستم مبتنی بر مدیریت حافظهٔ افراد بحث گردیده است. سپس به بررسی اثرات همکاری سناریومحور به کمک کامپیوتر جهت تسهیل یادگیری در محیطهای گروهی چندرشته ای از طریق ایجاد یک سیستم مبتنی بر بحث و استدلال پرداخته شده است. در نهایت، به بررسی روابط تعاملی بین همکاری سناریومحور به کمک کامپیوتر جهت تسهیل یادگیری گروهی چندرشته ای از طریق سیستم مبتنی بر مدیریت حافظهٔ افراد و سیستم مبتنی بر بحث و استدلال پرداخته شده است.

فصل اول این پایان نامه مقدمه ای است که شامل بیان مسئله، اهمیت موضوع، و ضرورت انجام این تحقیق میباشد. نتایج مطالعهٔ اول حاکی از آن است که یادگیری مشارکتی بحث محور با استفاده از کامپیوتر به طور فزاینده ای نه تنها در نظام آموزش عالی بلکه در تمام سطوح مختلف تحصیلی در حال گسترش است. این مطالعه خلاصه ای از جدیدترین یافته های تحقیقی مربوط به یادگیری مشارکتی بحث محور با استفاده از کامپیوتر شامل نوع تمرکز تحقیق (فرایندها و نتایج یادگیری)، کانالهای ارتباطی (متقارن و غیر متقارن)، روش تحقیق (کیفی و کمی)، طرح تحقیق (آزمایشی و نیمه آزمایشی)، تعداد افراد حاضر در گروههای یادگیری (دو، سه، چهار، و بیشتر از چهار)، سطح آموزشی (دبستان، راهنمایی، و دبیرستان)، برنامهٔ درسی (علوم اجتماعی، علوم پایه)، و محل جغرافیایی تحقیق را ارائه میکند. همچنین، در این مطالعه عوامل مؤثر در یادگیری مشارکتی بحث محور با استفاده از کامپیوتر معرفی و توضیح داده شده است. نتایج این مطالعه و پیشنهادهای نظری و عملی مربوط به آن در فصل دوم این پایان نامه به تفسیر شرح داده شده است.

چکیده فارسی

با توجه به پیشرفت سریع و حرکت پرشتاب فناوری اطلاعاتی و ارتباطاتی در دورهٔ مبتنی بر دانش و همچنین دسترسی گسترده به شبکهٔ اطلاعات جهانی، مواجههٔ افراد متخصص در رشته های مختلف با مسائل و مشکلات پیچیده در جهان در حال تغییر اجتناب ناپذیر میباشد. تطابق با اینگونه مسائل و مشکلات پیچیده، مستلزم همکاری افراد حرفه ای در علوم و رشته های مختلف در محیطهای یادگیری و کاری نوین است. این واقعیت در مورد نظام آموزش و پرورش نیز صدق میکند، بطوریکه غلبه بر مسائل و مشکلات پیچیدهٔ جهانی مستلزم همکاری فراگیران مجرب با قدرت درک و فهم و تجزیه و تحلیل بالا در علوم مختلف است. در محیطهای یادگیری گروهی، فراگیران در همهٔ رده های سنی جهت انجام تکالیف و حل مشکلات درسی خود به یادگیری بیان و توضیح عقاید و افکار خود همراه با دلایل مستند و منطقی نیاز دارند.

تشویق دانشجویان به یادگیری مشارکتی بحث محور یک رهیافت آموزشی است که منجر به آماده شدن آنها جهت مدیریت مسائل و مشکلات پیچیدهٔ دنیای امروز و مشارکت فعال آنها در جوامع مبتنی بر دانش میباشد. علیرغم آنکه استدلال و بحث در گفتگوهای اجتماعی و همچنین دنیای الکترونیکی به طور ذاتی نهفته است، نیاز به آموزش فراگیران به بیان استدلال و برهان منطقی در محیطهای دانشگاهی جهت یادگیری تخصصی، ساخت، ایجاد، و اشتراک دانش ضرورتی اجتناب ناپذیر است. محیطهای الکترونیکی یادگیری مشارکتی با استفاده از کامپیوتر که در آن فراگیران به صورت گروهی بحث و استدلال میکنند به عنوان یک رهیافت نوید بخش جهت بهبود یادگیری بحث محور شناخته شده اند. علیرغم مطالعات تجربی فراوان در این زمینه، یک تحقیق کلی و جامع در خصوص عوامل تاثیرگذار در نتایج یادگیری مشارکتی بحث محور با استفاده از کامپیوتر وجود ندارد. همچنین مطالعات تجربی جامع درخصوص روابط بین فرایندهای یادگیری و نتایج حاصله از آن در این زمینه وجود ندارد. بعلاوه وجود یک تحقیق جامع در محیطهای یادگیری که نیاز به همکاری افراد حرفه ای در علوم و رشته های مختلف دارد بیش از پیش احساس میشود زیرا هماهنگی بین دانش تخصصی این افراد به دلیل حیطه های یادگیری واگرا مشکل آفرین است.

بهبود یادگیری مشارکتی بحث محور با استفاده از کامپیوتر در آموزش عالی

امید نوروزی

رسالۀ دکترای فناوری و آموزش الکترونیکی

دانشکده علوم اجتماعی - گروه مطالعات آموزشی

دانشگاه واگنینگن

هلند

دی ماه ۱۳۹۱