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Facilitating argumentative knowledge construction through a transactive discussion script in CSCL

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A B S T R A C T

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 counterarguments, 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 CSCL scripts and argumentative knowledge construction.

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1. 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 (see Coffin & O'Halloran, 2008). 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, Biemens, Mulder, & Chizari, 2012; Van Eemeren, Grootendorst, & Henkemans, 1996; Van Eemeren, Grootendorst, & Kruiger, 1987). 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 focussing 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, counterargument, integration) (see Stegmann, Weinberger, & Fischer, 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, Fischer, & Slotta, 2007; Stegmann et al., 2007). Stegmann,

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Wecker, Weinberger, and Fischer (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, Weinberger, & Fischer, 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 fostering elaboration of the learning materials for enhanced domain-specific knowledge acquisition. This study thus investigates how scripts can facilitate argumentative discourse activities and knowledge on argumentation as well as domain-specific knowledge acquisition in a multidisciplinary CSCL setting.

1.1. 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, Wegerif, and Hartley (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 (see also Voss & Van Dyke, 2001). 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, Baker, & Suthers, 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 (Andriessen, 2006; Jeong & Frazier, 2008; Ravenscroft & McAlister, 2008; Van Amelsvoort, Andriessen, & Kanselaar, 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, Aleven, Ashley, & Lynch, 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 counterarguments, 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).

1.1.1. 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, 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, e.g. 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. 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 (Noroozi, Weinberger et al., 2012; Kollar et al., 2007; Stegmann et al., 2007; 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, Simon, & Osborne, 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 (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, Neuman, & Biezuner, 2000), is underestimated in Toulmin's model (Voss, Tyler, & Yengo, 1983). For these reasons, we further analyse argumentative knowledge construction based on sequential collaborative argumentation.

1.1.2. 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 (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 counterarguments 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, counterarguments, 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 counterargument (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 in the learning sciences.

1.2. 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, Scheuer, and Mikšátko (2010), Scheuer, Loll, Pinkwart, and McLaren (2010), as well as Noroozi, 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 (McAllister, Ravenscroft, & Scanlon, 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 modelling 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. McAllister et al., 2004) and InterLoc (e.g. Ravenscroft & McAlister, 2006). Ravenscroft (2007, 2011) provide extensive overviews 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, Newton, & Osborne, 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 in a problem-solving setting.

1.3. 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, Stegmann, & Fischer, 2007). 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, Fischer, & Hesse, 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 (Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2004; McAllister 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; Weinberger, Ertl, Fischer, & Mandl, 2005).

1.4. 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 counterarguments (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 process (Jeong, 2006). 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, Van Keer, De Wever, & Valcke, 2007; Weinberger et al., 2005, 2007). Communication-oriented scripts facilitated interaction and social modes of co-construction (Rummel & Spada, 2005; Rummel, Spada, & Hauser, 2009; Schellens et al., 2007; Weinberger et al., 2005, 2007).

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., 2005, 2007). For example, despite the positive effects of epistemic scripts on the reduction of cognitive effort (Weinberger et al., 2005, 2007) 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., 2005, 2007). In studies by Ertl, Kopp, and Mandl (2006) and Ertl, Reiserer, and Mandl (2005), 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 learning materials and additional resources for enhanced domain-specific knowledge acquisition (Baker & Lund, 1997; Stegmann et al., 2007; Weinberger et al., 2005, 2007).

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.

1.5. 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, i.e. claim, grounds, and qualifications) 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 hypothesis 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.

2. Method

2.1. 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 MSc students from two different disciplinary backgrounds, i.e. 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 (54%) 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.

2.2. 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. More 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 focused on removing barriers to an activity while simultaneously enhancing the activity's benefits. 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 ($M = 3.96$; $SD = 1.57$). 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 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.

2.3. 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, 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 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 Figs. 1, 2, and 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.

2.3.1. 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.

2.3.2. 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 Figs. 1, 2, and 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. Table 1 shows a full list of prompts for the transactive discussion script in this study. On the basis of four types of question

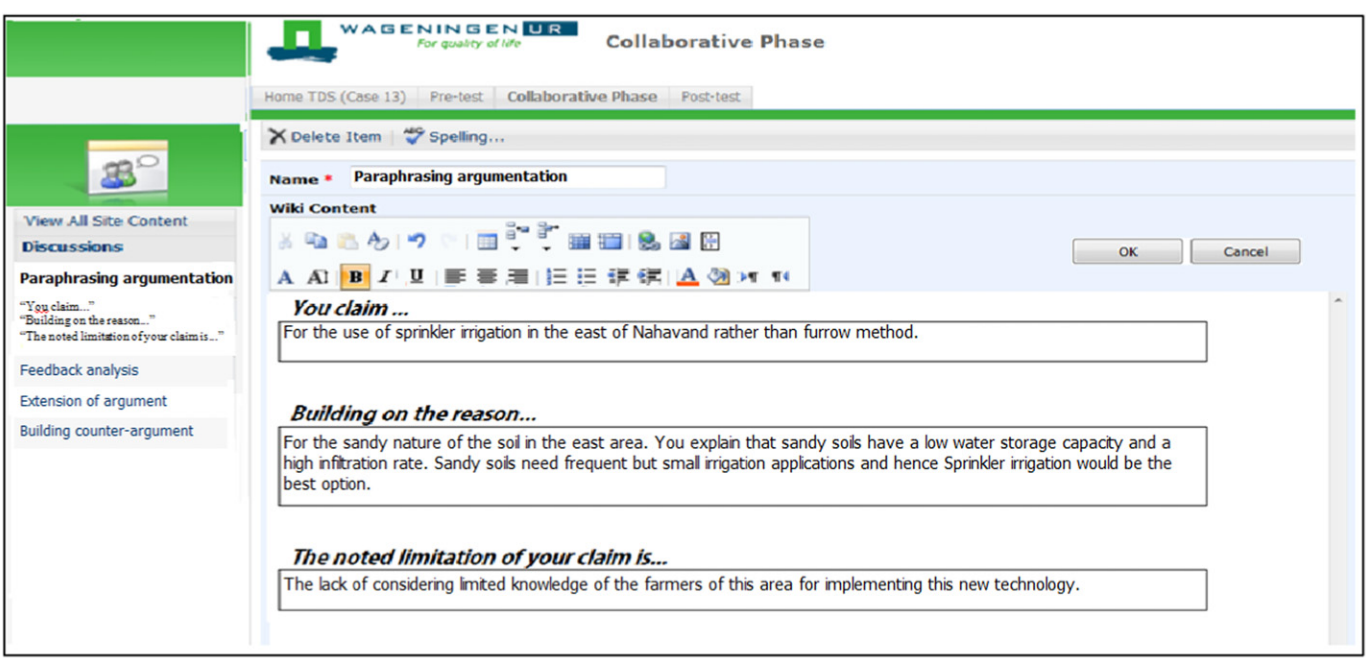

Fig. 1. Screenshot of the transactive discussion script initiated by prompts for argumentation analysis and paraphrasing.

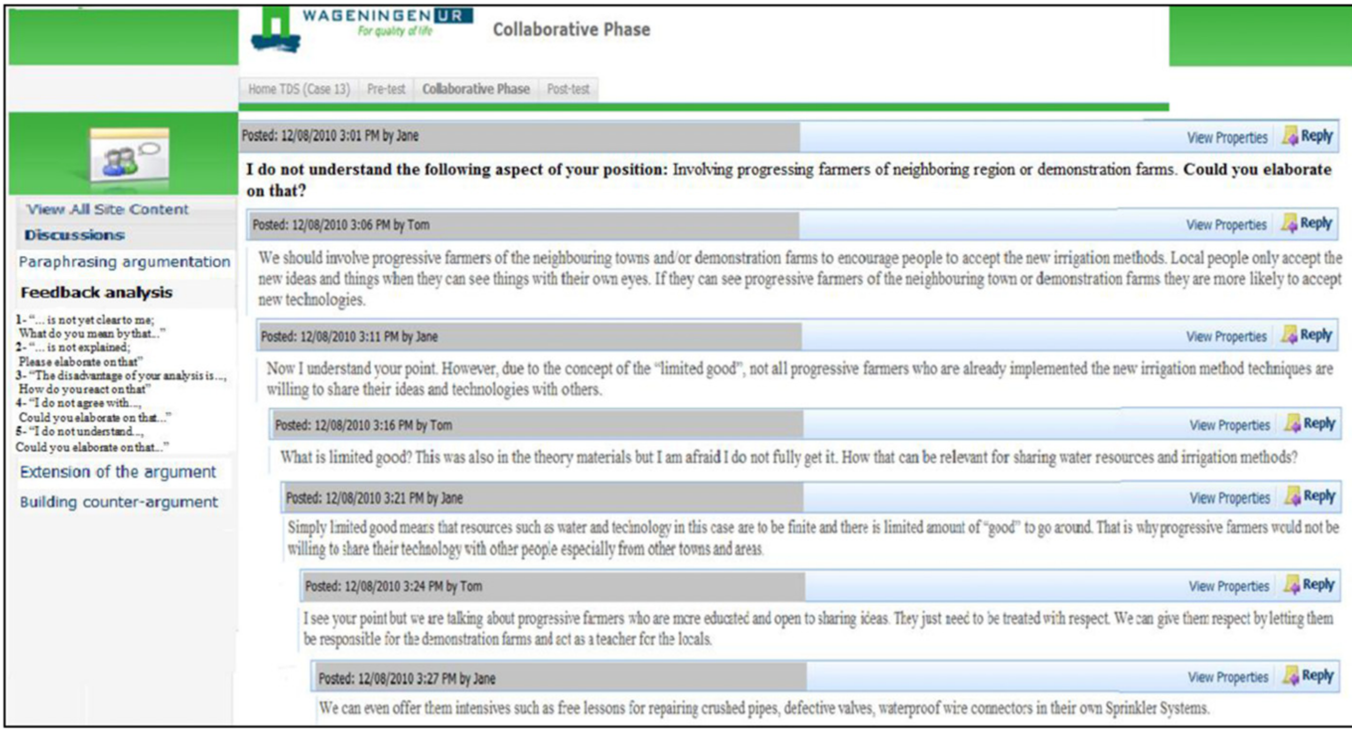

Fig. 2. Screenshot of the transactive discussion script initiated by a prompt for feedback analysis.

prompts for facilitation of transactive argumentative discourse, each participant was asked to paraphrase, criticize, ask clarifying/extension questions, give counterarguments, 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 (Kollar et al., 2007; Stegmann et al., 2007, 2012), 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

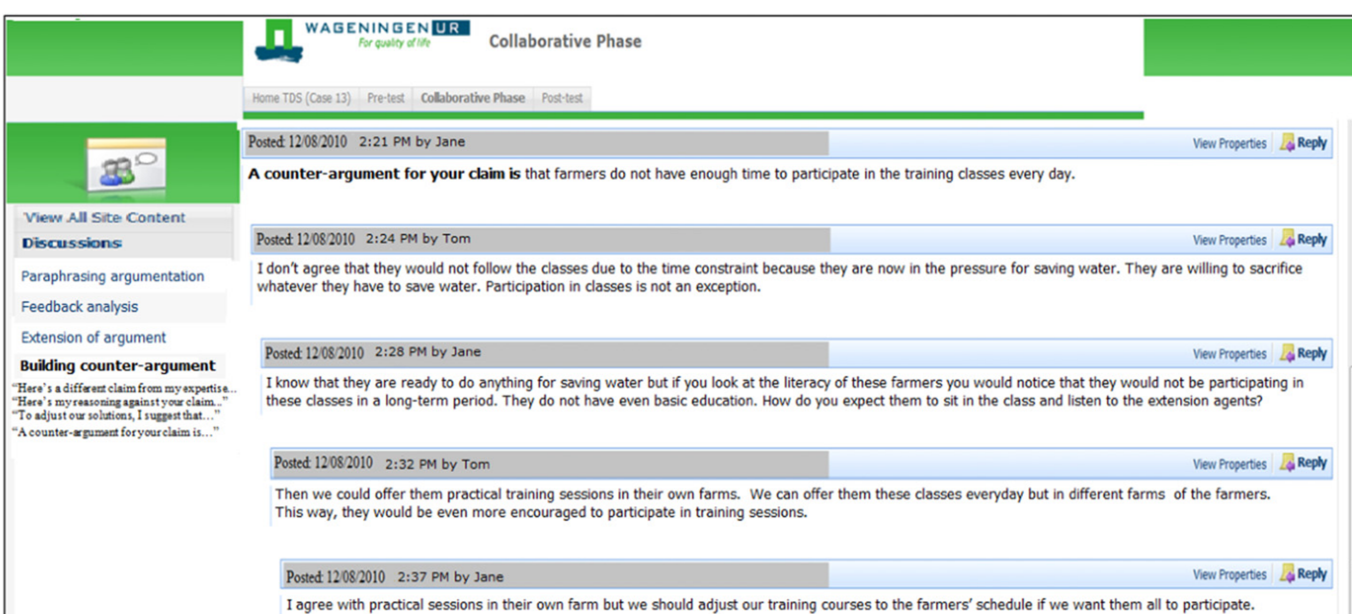

Fig. 3. Screenshot of the transactive discussion script initiated by a prompt for building counterarguments and interactive arguments.

Table 1
Examples of prompts for the transactive discussion script based on Berkowitz and Gibbs (1983).

Argumentation analysis and paraphrasing	➢ "You claim..."
	➢ "Building on the reason..."
	➢ "The noted limitation of your claim is..."
Feedback analysis	➢ "... is not yet clear to me; What do you mean by that..."
	➢ "... is not explained; Please elaborate on that..."
	➢ "The disadvantage of your analysis is..., How do you react on that..."
	➢ "I do not agree with the following aspect of your position..., Could you please elaborate on that..."
	➢ "I do not understand the following aspect of your position..., Could you please elaborate on that..."
Extension of the argument	➢ "Here's a further thought offered in the spirit of your position in terms of the social aspect of the case …"
	➢ "Here's an elaboration of your position in terms of the technical aspect of the case..."
	➢ "Here's a further thought offered in the spirit of your position in terms of the social aspect of the case …"
	➢ "Here's an elaboration of your position in terms of technical aspect of the case..."
Building counter-arguments and interactive arguments	➢ "Here's a different claim from my expertise..."
	➢ "Here's my reasoning against your claim..."
	➢ "To adjust/combine our solutions, I suggest that…"
	➢ "A counter-argument for your claim is…"

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. Fig. 1 shows an example 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.). Fig. 2 shows an example 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 counterarguments 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 in our study, 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. Fig. 3 shows an example of the transactive discussion script initiated by a prompt for building counterarguments and interactive arguments.

2.4. Procedure

In a pilot study with eight learners we first ensured adequate levels of task difficulty, comprehensibility of the learning material, applicability of the tests and the technical functioning of the script and the learning environment.

Overall, the experimental session took about 3.5 h and consisted of four main phases with a 10-min break between phases two and three. During the (1) introduction and pre-test phase, which took 35 min, individual learners received introductory explanations for 5 min. They were then asked to complete several questionnaires (15 min) on demographic variables, computer literacy, prior experience with and attitude towards collaboration. Next, the learners' knowledge on argumentation was tested (15 min). 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 min). They were then given 5 min to read the problem case and 10 min 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 min) for fostering sustainable behaviour on the basis of their own domain of expertise. More 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 and 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-min break, the (3) collaborative learning phase (90 min) began. First, learners were oriented to the CSCL platform and acquainted with the procedure of the collaboration phase (10 min). Subsequently, learners were asked to discuss their analyses and design plans in pairs (80 min). More 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 min), learners were first asked to work on a comparable case-based assignment individually (20 min) based on what they had learnt in the collaboration phase. More 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 experience and its outcomes (20 min). Finally, the participants got a short debriefing for about 5 min (see Table 2 for the procedure of the study).

2.5. 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.

2.5.1. 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.

2.5.1.1. 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 that support claims 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, e.g. "Did we cover all relevant aspects?", coordinating moves, e.g. "Could you check this sentence?", and meta-statements on argumentation, e.g. " We are doing quite well, aren't we?" (see Weinberger & Fischer, 2006). 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 $\kappa = .91$). 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).

Table 2
Overview of the procedure of the experimental study.

(1) Introduction and pre-test phase	Duration
Introductory explanations	5 min
Assessment of personal data (questionnaires)	10 min
Pre-test of knowledge on argumentation	20 min
(2) Individual learning phase	
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	
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	
Individual analysis of the problem case	20 min
Post-test of knowledge on argumentation	15 min
Assessment of satisfaction with the learning outcomes	5 min
Debriefing	5 min
Total time	**About 3.5 h**

2.5.1.2. 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, counterarguments, integrations, and non-argumentative moves (see also Kollar et al., 2007; Leitão, 2000; Stegmann et al., 2007; Weinberger & Fischer, 2006; Weinberger et al., 2005, 2007). An argument is a statement put forward in favour of a specific proposition that comprises claims that have not been discussed before. Counterargument 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 counterargument. An integration is a statement that aims to balance, integrate, and advance a preceding argument and counterargument. Integrations thus resolve the conflict or tension between arguments and counterarguments on a higher level. However, learners are not limited to writing counterarguments and integrations that address the arguments of their learning partners; they may also construct counterarguments 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, counterargument, or integration. Subsequently, the number of transitions between the message types (argument, counterargument, 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 $\kappa = .83$). 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 counterargument, counterargument to integration, and integration to counterargument as an indicator of quality of argumentation sequences for each dyad. In addition, we analysed the proportion of non-argumentative messages, arguments, counterarguments, and integrations. The reliability coefficient was sufficiently high (Cronbach $\alpha = .72$).

2.5.2. Measuring individual acquisition of knowledge on argumentation

The argumentation knowledge test measures (pre-test and post-test) 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.

2.5.2.1. 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 sufficiently high both for the pre-test (Cronbach $\alpha = .78$) and post-test (Cronbach $\alpha = .82$). The gain of knowledge from pre-test to post-test was calculated and served as an indicator for the acquisition of knowledge on formal quality of single arguments.

2.5.2.2. 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, counterargument, 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 $\alpha = .79$) and post-test (Cronbach $\alpha = .88$). The gain of knowledge from pre-test to post-test was calculated and served as an indicator for the acquisition of knowledge on formal quality of argumentation sequences.

2.5.3. 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 $\alpha = .84$) and post-test (Cronbach $\alpha = .89$). 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.

2.5.4. 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 (Weinberger & Fischer, 2006). 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 $\kappa = .88$). 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 $\kappa = .91$) and intra-coder test–retest reliability for each coder for 10% of the data (90% of identical scores) were high.

2.5.5. 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 $\kappa = .93$).

2.6. 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 Beers, Kirschner, Boshuizen, & Gijselaers, 2007; Noroozi, Biemans, Busstra, Mulder, & Chizari, 2011; Noroozi, Biemans et al., 2012; Noroozi, Busstra et al., 2012; Rummel & Spada, 2005; Rummel et al., 2009). We therefore controlled for uneven distribution of these measures over the two conditions.

2.6.1. 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 programs), (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 $\alpha = .87$).

2.6.2. 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 $\alpha = .83$) and attitudes towards collaboration (Cronbach $\alpha = .88$).

2.7. 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 group values) was used to determine the individual transfer from argumentative knowledge construction according to research questions 2 and 3. The statistical analysis was performed with SPSS. We used ANOVA analysis (see Cohen, 1988) to compare formal quality of single arguments and argumentation sequences during discourse corpora. 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 examine the effects of the transactive discussion script across several similar sets of dependent variables. Specifically, MANOVA analysis 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, counterargument, 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.

3. Results

3.1. 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, $F(1, 26) = .35$, $p > .2$ ($M = 10.78$, $SD = 2.53$, $Max = 16$, $Min = 7$) 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 studies 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, $F(1, 26) = .48$, $p > .2$. These results show that the distribution of learners based on their prior knowledge and background requirements was successful.

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 the learners' attitudes towards collaboration, $F(1, 54) = .26$, $p > .2$. These results show that the randomization in terms of learners' individual prerequisites in the two conditions was also successful.

3.2. 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.

3.2.1. 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 formal quality of single arguments were higher for scripted ($M = 18.14$, $SD = 5.26$, $Max = 30$, $Min = 10$) than unscripted learners ($M = 10.93$, $SD = 3.79$, $Max = 18$, $Min = 4$). More 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'* $\lambda = .30$, $F(1, 26) = 13.10$, $p < .01$, $\eta^2 = .69$. More 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 significant 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 3).

3.2.2. Construction of argumentation sequences during discourse

Learners in the two conditions showed significant difference with respect to formal quality of argumentation sequences during discourse, $F(1, 26) = 7.25$, $p < .05$, $\eta^2 = .22$. The average scores for the number of transitions from argument to counterargument, counterargument to integration, and integration to counterargument 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'* $\lambda = .27$, $F(1, 26) = 15.56$, $p < .01$, $\eta^2 = .73$. More 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 counterarguments, $F(1, 26) = .04$, $p = .84$ between scripted and unscripted learners (see Table 4).

3.3. Results for research question 2

In this section we will first present our findings on individual 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.

3.3.1. 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'* $\lambda = .36$, $F(1, 26) = 45.56$, $p < .01$, $\eta^2 = .64$ from pre-test to post-test ($M_{T1} = 4.11$; $M_{T2} = 4.98$; $SD_{T1} = .64$; $SD_{T2} = .65$).

Table 3
Share of arguments in discourse for scripted and unscripted learners by degree of formal structure of single arguments.

Items	Labels	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.

Table 4
Share of arguments in discourse for scripted and unscripted learners by degree of formal structure of argumentation sequences.

Items	Labels	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			
Counterarguments	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.

Furthermore, scripted and unscripted learners differed significantly with respect to their acquisition of knowledge on formal quality of single arguments, *Wilks'* $\lambda = .69$, $F(1, 26) = 11.86$, $p < .01$, $\eta^2 = .31$. 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).

3.3.2. 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'* $\lambda = .34$, $F(1, 26) = 49.46$, $p < .01$, $\eta^2 = .65$ 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'* $\lambda = .66$, $F(1, 26) = 13.65$, $p < .01$, $\eta^2 = .34$. 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).

3.3.3. 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'* $\lambda = .43$, $F(1, 26) = 33.92$, $p < .01$, $\eta^2 = .56$ 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'* $\lambda = .99$, $F(1, 26) = .01$, $p = .92$. 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).

3.4. Results for research question 3

In this section we will present our findings on individual domain-specific 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. More 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.

3.5. Results for research question 4

In this section we will present 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

Table 5
Mean scores of knowledge acquisition for scripted and unscripted learners by degree of formal structure of single arguments and argumentation sequences.

Dependent variables	Conditions	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

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. More 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.

4. 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. More 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, i.e. claim, grounds, and qualifications. 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 clearly 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 min. The learning partners may have felt more need for analysing learning 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 counterarguments 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, counterargument, and integration. Kollar et al. (2007) provided learners with pre-structured text boxes (e.g. argument, counterargument, 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 question prompts in the interface of the CSCL 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 mono-disciplinary context of the Kollar et al. (2007) and Stegmann et al. (2007, 2012), 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 focussing 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) as well as Kollar et al. (2007), who reported a positive effect of argumentation scripts on individual knowledge acquisition on argumentation sequences. More specifically, during the collaborative phase, scripted learners were prompted to build counterarguments 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 (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 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 counterarguments 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; Weinberger, 2011). When learners engage in more transactive discussions and argumentations, they benefit to a greater extent from the external memories available, e.g. contributions of their learning partners (e.g. Teasley, 1997; Weinberger et al., 2005, 2007). That is why scripted 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, counterarguments, 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; 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; Weinberger & Fischer, 2006).

5. Implications, limitations, and suggestions for future research

This study shows that the construction of single arguments and argumentation sequences (see Kollar et al., 2007; Stegmann et al., 2007, 2012) 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 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 CSCL multidisciplinary 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 others' contributions.

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 experiment and the learning task, we assume that these effects could be replicated in standard curricular educational settings. This is not certain, however, and thus we suggest that the specific conditions and learner perceptions of such a scripted environment in a real multidisciplinary course in an authentic educational setting be further investigated.

This study used a content analysis approach to assess various aspects of learning processes and outcomes in terms of argumentative knowledge construction. The inter-rater reliability values of these instruments have been satisfactory in prior studies (see Kollar et al., 2007; Leitão, 2000; Stegmann et al., 2007, 2011; Weinberger & Fischer, 2006; Weinberger et al., 2005, 2007) and were even higher in the present study. The method used in the current study 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, Jones, & Doherty, 2008; North, Coffin, & Hewings, 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 (like the one we used in this study) 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 (see Wegerif et al., 2010).

In this study we only administrated short-term individual measurement to account for the domain-specific knowledge acquisition in a multidisciplinary setting. 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 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. Therefore we suggest that follow up research be aimed at this question. This could have consequences not only for the design principles of a transactive discussion script, but also for the transfer of learning from group to individuals in a long-term study.

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 counterarguments 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 i.e. 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.

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