Argumentation-Based Computer Supported Collaborative Learning (ABCSCL): A synthesis of 15 years of research

ARTICLE *in* EDUCATIONAL RESEARCH REVIEW · JUNE 2012

Impact Factor: 2.33 · DOI: 10.1016/j.edurev.2011.11.006

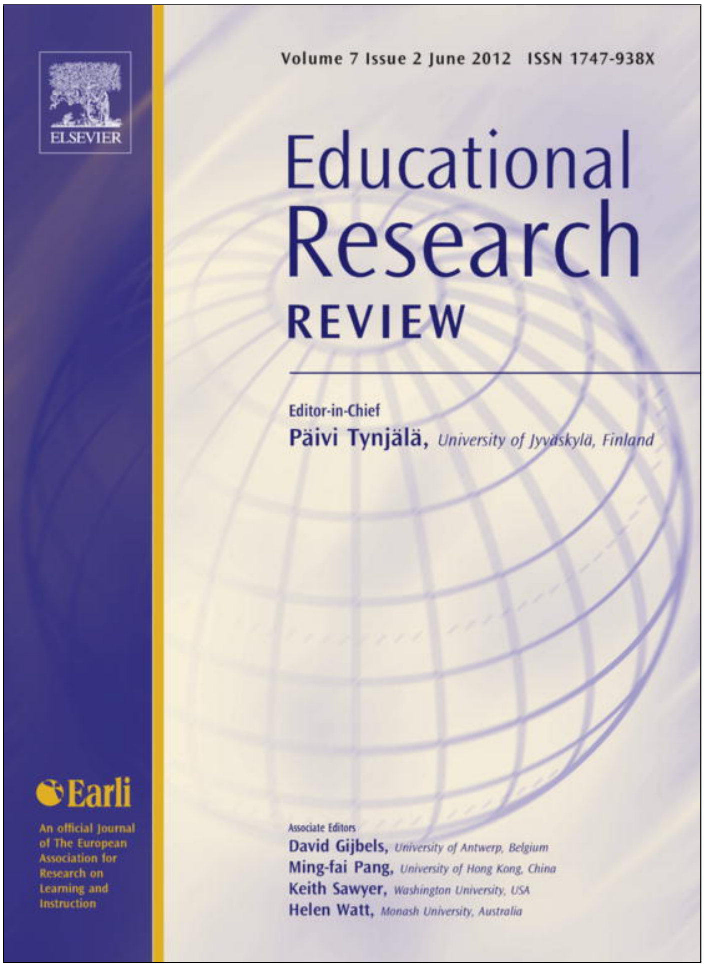
5 AUTHORS, INCLUDING:


Armin Weinberger
Universität des Saarlandes


Harm J. A. Biemans
Wageningen University


Martin Mulder
Wageningen University


Mohammad Chizari
Tarbiat Modares University


Volume 7 Issue 2 June 2012 ISSN 1747-938X
ELSEVIER
Educational
Research
REVIEW
Editor-in-Chief
Päivi Tynjälä, University of Jyväskylä, Finland
Earli
An official Journal of The European Association for Research on Learning and Instruction
Associate Editors
David Gijbels, University of Antwerp, Belgium
Ming-fai Pang, University of Hong Kong, China
Keith Sawyer, Washington University, USA
Helen Watt, Monash University, Australia

Educational Research Review 7 (2012) 79–106

Contents lists available at SciVerse ScienceDirect

Educational Research Review

journal homepage: www.elsevier.com/locate/EDUREV

Review

Argumentation-Based Computer Supported Collaborative Learning (ABCSCL): A synthesis of 15 years of research

Omid Noroozi [a,*], Armin Weinberger [b], Harm J.A. Biemans [a], Martin Mulder [a], Mohammad Chizari [c]

[a] Education and Competence Studies, Wageningen University, P.O. Box 8130, NL 6700 EW Wageningen, The Netherlands
[b] Educational Technology, Saarland University, Campus C5 4, 66123 Saarbrücken, Germany
[c] Agricultural Extension and Education, Tarbiat Modares University, P.O. Box 14115-336, Tehran, Iran

A R T I C L E   I N F O

Article history:
Received 26 January 2011
Revised 2 November 2011
Accepted 15 November 2011
Available online 7 December 2011

Keywords:
Argumentation
Argumentative knowledge construction
Collaborative argumentation
Computer-Supported Collaborative Learning
Argumentation-Based Computer Supported Collaborative Learning

A B S T R A C T

Learning to argue is an essential objective in education; and online environments have been found to support the sharing, constructing, and representing of arguments in multiple formats for what has been termed Argumentation-Based Computer Supported Collaborative Learning (ABCSCL). The purpose of this review is to give an overview of research in the field of ABCSCL and to synthesize the findings. For this review, 108 publications (89 empirical studies and 19 conceptual papers) on ABCSCL research dating from 1995 through 2011 were studied to highlight the foci of the past 15 years. Building on Biggs' (2003) model, the ABCSCL publications were systematically categorized with respect to student prerequisites, learning environment, processes, and outcomes. Based on the quantitative and qualitative findings, this paper concludes that ABCSCL environments should be designed in a systematic way that takes the variety of specific conditions for learning into account. It also offers suggestions for educational practice and future research.

Contents

* Corresponding author. Tel.: +31 317482710; fax:+31 317484573.
E-mail addresses: omid_noruzi@yahoo.com, omid.noroozi@wur.nl (O. Noroozi).

1747-938X/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.edurev.2011.11.006

1. Introduction

Arguing, critical thinking and logical reasoning are essential objectives in education. Students of all ages need to learn to clearly explain their informed opinions and give reasons for the way in which they carry out tasks and solve problems. The ability to argue is a key skill in approaching complex problems as well as in collecting observational data and applying rules of formal logic (Voss & Van Dyke, 2001).

Engaging learners in dialogic argumentation in what has been called Collaborative Argumentation-Based Learning (CABLE) is an educational approach for preparing learners to manage today's complex issues and actively participates in knowledge societies (Jeong & Frazier, 2008; Van Amelsvoort, Andriessen, & Kanselaar, 2007). CABLE demands learners to build arguments and support a position, to consider and weigh arguments and counter-arguments, to test, enlighten, and clarify their uncertainties, and thus achieve understanding about complex ill-structured problems (Aleixandre-Jimenez, 2007; Cho & Jonassen, 2002). Although literature reports positive effects of CABLE on a variety of learning mechanisms (see Van Amelsvoort et al., 2007), telling learners to argue with each other is not a sufficient way to attain CABLE's potential and hence it does not entirely guarantee successful learning (Baker, 1999; Van Amelsvoort, 2006). In the last 15 years, online support systems for collaboration or Computer-Supported Collaborative Learning (CSCL) environments in which learners argue in teams have been found to support the sharing, constructing and representing of arguments in multiple formats. This type of learning arrangement is named Argumentation-Based Computer Supported Collaborative Learning (ABCSCL) and it is seen as a promising context to facilitate CABLE (Scheuer, Loll, Pinkwart, & McLaren, 2010). Much research has been done in the field of ABCSCL (sometimes using other names for the approach e.g. Computer Supported Collaborative Argumentation, Argumentative Computer-Supported Collaborative Learning, Computer-Supported Argumentation-Based Learning, etc.), but no overview of this research is currently available. The purpose of this paper is to provide this overview and to synthesize the findings. Whereas Scheuer et al. (2010) and Clark et al. (2010) provide extensive overviews of the technological environments supporting ABCSCL, this review aims to synthesize the influential and constitutional factors of ABCSCL that have been investigated in the past 15 years.

1.1. Argumentation

Argumentation is an essential aspect of scientific thinking in education which is central to the process by which science advances (Kuhn, 1993; Kuhn, Iordanou, Pease, & Wirkala, 2008). Argumentation is not restricted to one discipline and has been the subject of study in various fields, being apparent in linguistics, philosophy, psychology, education, communication, etc. and also recently in multidisciplinary and interdisciplinary domains (Van Eemeren, Grootendorst, & Henkemans, 1996; Van Eemeren, Grootendorst, & Kruiger, 1987). Argumentation has been defined in various ways in the literature. For example, Walton (1992, 1996, 2006) defines argumentation as a goal-oriented and interactive dialog in which participants reason together to advance arguments by proving or disproving presumptions. Van Eemeren et al. (1987, 1996) view argumentation as a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of one or more propositions to justify this standpoint. Merriam-Webster's Online Dictionary defines argumentation as the act or process of forming reasons, making inductions, drawing conclusions, and applying them to the case in discussion. The common characteristic of all these definitions is the use of argumentation as a means to rationally resolve differences of opinions, questions, and issues in critical discussions (Jonassen & Kim, 2010).

1.2. Argumentation theory

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

Despite the influential role of Toulmin's model in the field of argumentation theory (e.g. in the analysis of written argumentation, line of reasoning and inquiry), the application of this model in collaborative discourse is considered to be problematic. First, one can hardly find explicit and valid inferences according to the standards of formal logic argumentation (Leitão, 2003). For example, it is difficult to distinguish warrant (which is mostly implicit) from backing (Jonassen & Kim, 2010). Second, when considering argumentation as a collaborative discourse phenomena, Toulmin's model only considers the proponent's side and ignores the role of an opponent in the process of argumentation (Andriessen, 2006). Therefore, the development of multiple perspectives, the pro and the contra, on the topic, which is the fundamental nature of argumentative discourse (Schwarz, Neuman, & Biezuner, 2000), is underestimated in Toulmin's model (Voss, Tyler, & Yengo, 1983). For this reason, the dialectical form of argument known as dialogical or multi-voiced argument has been given more attention than rhetorical argument in the learning sciences. Dialectical argument refers to the situation in which proponents of alternative claims resolve differences of opinions in critical discussions through dialog by convincing opponents (Jonassen & Kim, 2010) or compromising on multiple claims (Driver, Newton, & Osborne, 2000).

A variety of dialectical models of argumentation has been introduced in the learning sciences. Sequential-dialectics (Leitão, 2000) describe argumentation as the dynamic macro-level of argumentative dialog including arguments, counterarguments, and integrations to promote the construction of valid knowledge in a collaborative discourse. Formal-dialectics (Barth & Krabbe, 1982) view argumentation as a dialog between a proponent and an opponent around a certain topic. Pragma-dialectics (Van Eemeren & Grootendorst, 1992, 1999; Van Eemeren, Grootendorst, & Henkemans, 2008) describe argumentation as interaction between two parties to resolve differences of opinion by critically testing the acceptability of the standpoints at issue. Dialog theory (Walton, 2000) views argumentation as the necessary steps of a dialog (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. As stated by Osborne (2010, p. 463) "knowing what is wrong matters as much as knowing what is right". This is why dialogic forms of argumentation have been considered to be more applicable in the learning sciences (Jonassen & Kim, 2010) than rhetorical argumentation, which mostly covers areas such as theoretical linguistics, psycholinguistics, and computational linguistics (Taboada & Mann, 2006a, 2006).

1.3. Collaborative Argumentation-Based Learning

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

Despite the fact that argumentation is shaped in social conversation and also in learners' online exchanges in daily life (e.g. Beach & Doerr-Stevens, 2009), learners need to be taught to reason properly and generate well-established interactive argumentation that is beneficial for collaborative learning in an academic context (Kuhn, 1991, 1992, 2005, 2009; Kuhn & Udell, 2003, 2007). There could be several reasons for the need of instruction on how to argue in academic settings. First, learners may ignore or not accept the opposing views of learning partner(s) due to incompatibility with their own ideas on the issue at stake (Jonassen & Kim, 2010). Second, learners typically avoid generating counter-arguments against learning partners(s)' arguments. This could be due to a lack of knowledge about the opposing views (Leitão, 2003) or to a fear of losing face or getting into a fight with the learning partner(s) (Andriessen, 2006). Third, learners may perceive critiques and counterarguments as personal attacks rather than constructive feedback (Rourke & Kanuka, 2007). Last but not least, learners tend to support their own points of views instead of producing counter-arguments against the opposing views since they think that providing counterarguments against opponents' arguments make their own arguments less persuasive (Nussbaum & Kardash, 2005; Stein & Bernas, 1999). All these difficulties imply that when designing CABLE in educational settings consideration must be given to developing certain characteristics that will enable learners to engage in well-established and interactive argumentation which is beneficial for collaborative learning. Various approaches have been applied in educational settings to facilitate CABLE by teaching learners how to argue properly. The most prominent recent approach is the use of online support systems to support collaborative argumentation.

1.4. Argumentation-Based Computer Supported Collaborative Learning

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

Despite the variety of instructional approaches available, learners may still have difficulty arguing in rich ABCSCL environments (Van Amelsvoort, 2006; Van Bruggen & Kirschner, 2003). For several reasons, the use of ABCSCL does not necessarily lead to productive argumentation and discussion (e.g. Kirschner, 2002). Firstly, since an argument or the nature of argument is in fact complex and not linear (Toulmin, 1958), it is not a simple task to broaden and deepen the space of debate during sequential linear discussion (McCutchen, 1987). Secondly, the lack of social context cues such as physical form, accent, tone of voice, eye contact and group identity may reduce the interest and willingness of learners to discuss and argue, thereby leading to process losses in ABCSCL (Coffin & O'Halloran, 2009). Thirdly, ABCSCL may create an additional burden for learners because of complexities and demanding tasks involved in problem-solving activities (Van Bruggen, 2003). Learners rarely respond to one another's points and tend to repeat points already constructed by others (Koschmann, 2003); they may thus refuse to challenge arguments made by peers (Nussbaum, 2002), resulting in narrow discussions with low quality (Pena-Shaff, Martin, & Gay, 2001) and low consistency (Brooks & Jeong, 2006).

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

2. Conceptualizing the review

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

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

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

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

3. Method

3.1. Criteria for inclusion

For this review, we adapted a narrative analysis approach to identify current trends in ABCSCL and also to address practical implications and avenues for future research. In narrative reviews, researchers seek to systematically integrate the state of knowledge concerning the topic of interest and to highlight important issues that research has left unresolved (Van Dinther, Dochy, & Segers, 2011). Following Slavin (1986), researchers should make the search criteria and the criteria for inclusion explicit regardless of the type of review (e.g. narrative, traditional, and best-evidence synthesis). Four inclusion criteria were employed for searching and collecting relevant publications. Firstly, publications were selected for their relatedness to ABCSCL. Secondly, each had to have been published in a peer-reviewed journal to obtain scientific fidelity. Thirdly, only English publications were employed in this study, since the majority of research on ABCSCL is published in international journals in English. Finally, the time span was restricted to publications from 1995 through 2011, the period in which most ABCSCL research has been produced.

3.2. Literature search

A systematic search strategy was used based on four concepts that overlap in ABCSCL, namely learning, argumentation, collaboration and computer support. In a first step we identified synonyms or related terms using Merriam-Webster's Online Thesaurus in combination with the reviews of Scheuer et al. (2010) and Clark et al. (2010). In a second step, we combined the related terms with the Boolean operators OR and the four overlapping concept areas with AND to arrive at the following search string: *Learn** AND *Argument** AND *coll** OR *coop** OR *group** AND *CSCL* OR *online* OR *computer* OR *hypermedia* OR *technology-enhanced learning*. A wide variety of computerized databases was searched from April 2009 through April 2010, namely Educational Resources Information Center (ERIC), Scopus, the Science Citation Index Expanded (SCI-EXPANDED), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (A&HCI), the latter three of which were provided by the Web of Science®.

3.3. Identification of relevant publications

This search yielded more than 300 publications. After screening titles, abstracts and if necessary the full text of the articles, a number of publications were removed that did not: (1) *address collaborative learning*, i.e. studies focused on computer-assisted/aided/mediated/supported/based instruction and other forms of learning (e.g. digital learning module) in which individuals interacted only with the computer; (2) *address educational purposes*, i.e. studies on online argumentation or discussions with no clear educational purpose or studies on the use of computer networks for simple chatting and discussions; (3) *investigate learning processes or outcomes*, i.e. studies with a technical focus on educational platforms.

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

The identification process was carried out by two researchers independently to guarantee the inclusion of relevant and exclusion of irrelevant publications, resulting in 73 included publications at this stage. The overlap of the two researchers' decisions was sufficient (Cohen's Kappa = 0.85). The discrepancies were resolved through discussion. In a final step, we applied a snowball method and reviewed the reference lists of the selected publications, which resulted in 35 further publications in peer-reviewed journals to include in the review. We acknowledge that there are also important books, book chapters, and dissertations in this field but we do not know how the review process has been carried out with these publications. Therefore, in the actual review, we just included journal articles that guarantee a high level of quality, e.g. through the peer review process. However, we consulted books, book chapters, and dissertations (whenever needed using the snowball method) in order to further accumulate the state of knowledge and specific issues in ABCSCL without including them in the quantitative and quantitative analyzes. This review is not limited to empirical studies, since the intention was to support the results of empirical studies with conceptual literature. Focusing on only the educational empirical studies could have yielded an incomplete picture of the state of ABCSCL research. Therefore, conceptual papers in ABCSCL research were included to produce an accurate representation of this body of knowledge under a number of research paradigms. The search strategy and identification process were not limited to a single domain of interest, however, publications related to computer science and its technical aspects were excluded as they had been previously covered in other reviews.

3.4. Quantitative description of scientific research into ABCSCL

Applying the systematic search strategy, 108 publications were deemed eligible for inclusion in this review. A complete list of publications that were included in the review is distinguished by asterisks in the Reference section. Eighty-nine of the selected publications provide empirical data on ABCSCL phenomena, while 19 articles are conceptual, focusing mostly (about 90%) on fundamental theories to describe a variety of pedagogical phenomena under examination in ABCSCL. The remaining conceptual publications put forward the fundamental theories to describe methodological issues for analyzing ABCSCL processes and outcomes. The empirical publications outnumbered the conceptual papers for this review without any manipulation. Empirical articles on ABCSCL are mostly published in peer-reviewed journals, whereas most conceptual and theoretical works in this field are published as books and book chapters. Thus, more empirical articles were likely to be found than conceptual ones as we only included journal publications. A complete list of empirical publications is provided in Table 1, categorized by author(s); the year reported; participants; educational level; group size; name and functionalities of the platform; and research focus on learning processes and outcomes.

The majority of relevant publications (more than 90%) were published in peer-reviewed journals in the 21st century, largely in recent issues of the journals listed in Table 2. As expected, the International Journal of Computer Supported Collaborative Learning, Computers and Education, and Computers in Human Behavior were on top of the list due to their vast coverage of the focal point of this review. The remaining publications were found in different journals of various disciplines, e.g. Educational Psychology, Technology, Development, and Research.

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

With regard to the size of the collaborative groups studied, our review shows that researchers have been mostly investigating dyads of learners (42 empirical studies). In 14 studies, triads were formed to work in ABCSCL, while in 11 studies groups of four and in 22 studies large (more than four) or mixed groups were investigated. Fifty-two studies used synchronous modes of communication and 37 studies used asynchronous modes. The majority of ABCSCL experimental studies have been conducted in the USA (28 empirical studies) and in Europe, i.e. The Netherlands (21), Germany (11) and Finland (8 publications). ABCSCL has been studied at least once in several other countries, e.g. France, Belgium, Singapore, Norway, Taiwan, Canada, Argentina, Switzerland, Turkey and UK. Table 3 summarizes these quantitative results in a table format.

Table 1
Overview of the various characteristics of the reviewed empirical publications (alphabetically ordered).

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

(*continued on next page*)

Table 1 (*continued*)

Author(s) and year	Participant	Group size	Educational level	Platform	Functionalities of the platform for the study	Research focus	
						Learning processes	Learning outcomes
Ho et al. (2009)	45	Four/ Five	Pre-university	SL and VoR	Structured argumentation, reflection and role-play	Interaction processes	–
Janssen et al. (2010)	124	Mixed	Secondary	VCRI	Graphical/Textual Debate-tool, representational guidance	Argumentation quality and process	Knowledge performance
Jeong (2005)	32	Dyad	University	Blackboard™	Message labels/debate, linguistic qualifiers and intensifiers	Group interaction and performance	–
Jeong (2006a)	31	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Interaction and participation patterns	–
Jeong (2006b)	32	Dyad	University	Blackboard™	Conversational language, message labels, etc.	Argumentation/interaction patterns	–
Jeong (2007)	54	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Critical thinking process	–
Jeong and Davidson-Shivers (2006)	19	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Interaction patterns, participation	–
Jeong and Frazier (2008)	72	Dyad	University	Blackboard™	Discussion threads, conflict ideas, label message	Critical discourse (argument exchanges)	–
Jeong and Joung (2007)	38	Dyad	Pre-service	Blackboard™	Pre-structured threads, message constrains, message labels	Interaction & argumentation patterns	–
Jeong and Lee (2008)	33	Dyad	University	Blackboard™	Pre-structured threads, label message, sentence starters	Critical discourse process	–
Joiner and Jones (2003)	73	Four	University	Blackboard	Communication medium, conflicts of ideas, peer interaction	Argumentation quality, critical thinking	–
Kim et al. (2007)	57	Large	Primary	Web Crossing	Non-threaded discussions, peer interaction	Participation and argument stratagems	–
Kirschner et al. (2008)	99	Triad	Secondary	NTool	Scripting and coercion, Negotiation acts	Negotiation, common ground, load	–
Kollar et al. (2007)	90	Dyad	Secondary	WISE	Concept-specific/textual description, input text box	Argumentation processes	Domain general, specific knowledge
Lemus et al. (2004)	63	Large	University	Text-based	Peer interaction	Development of argument	Right or wrong decision making
Li and Lim (2008)	80	Dyad	Secondary	-	Augmentation and written prompts, questioning/modeling	Inquiry learning	–
Lin and Crawford (2007)	162	Four	University	Blackboard	Assigning roles (pro and cons), conflict schemes	Group interaction, critical thinking,	Quality of argumentative writing
Liu and Tsai (2008)	57	Four	University	WBLS	Collaborative discussion boards	Interaction patterns	Programming scores
Lu and Lajoie (2008)	14	Large	University	Whiteboard	Argumentation tools, interactive whiteboard diagrams	Quality of discourse argumentation	–
Lund et al. (2007)	36	Dyad	Secondary	JigaDREW	Argumentative diagrams/chat/graphs, multiple tools	Argumentative and debate patterns	–
Marttunen (1997)	31	Dyad	University	Email	Tutor-led and self-directed seminar modes, peer discussion	Argumentation processes	-
Marttunen (1998)	31	Dyad	University	Email	Tutor-led and self-directed seminar modes, peer discussion	Argumentation interaction	–
Marttunen and Laurinen (2001)	46	Four/ Large	University	Email	Role play, Panel Discussion boards, peer interaction	Argumentation processes	Argumentation skills
Marttunen and Laurinen (2007)	17	Dyad	Secondary	Web-tools	Collaborative chat, pre-class argumentative lessons	Argumentation processes	–
Marttunen and Laurinen (2009)	27	Dyad	Secondary	Web-tools	Collaborative chat, argumentative lessons, peer discussion	Collaborative completion, speech acts	–

Table 1 (*continued*)

Author(s) and year	Participant	Group size	Educational level	Platform	Functionalities of the platform for the study	Research focus	
						Learning processes	Learning outcomes
McAlister et al. (2004)	22	Four/ Large	University	AcademicTalk	dialog game, structured interface, sentence openers	Argumentation processes	–
Mirza et al. (2007)	9	Large	University	Digalo	Graphical tools, configurable ontology	Argumentative activities	–
Monteserin et al. (2010)	39	Triad	University	SAVER	Isolated arguments, argumentation plans	Argumentation and negotiation process	Knowledge acquisition
Munneke et al. (2003)	126	Dyad	Secondary	TC3	Representational tools, argumentative collaborative writing	Argumentation and debate patterns	–
Munneke et al. (2007)	175	Dyad	Secondary	TC3	Representational tools, argumentative collaborative writing	Argumentation and debate patterns	–
Muukkonen et al. (2005)	80	Large	University	FLE	Technology tutored and non-tutored	Progressive inquiry discourse	–
Noroozi et al. (2011)	44	Dyad	University	Drewlite	Argumentative tools, diagrams, chat	Argumentative and interactive discourse	Individual knowledge construction
Nussbaum (2005)	224	Triad	University	Web-CT	Goal instruction, question prompts	Reasoning and argumentation	–
Nussbaum (2008b)	45	Dyad	University	AVD	Diagrams/AVD training, argument templates, prompts	Argument-counter-argument integration	–
Nussbaum and Edwards (2011)	30	Dyad	Secondary	AVD	Argumentation via diagrams, critical question prompts	Critical reasoning, practical solutions	–
Nussbaum and Schraw (2007)	84	Dyad	University	AVD	Graphical organizer, criteria instruction and training	Integrating argument, counterargument	–
Nussbaum et al. (2004)	48	Dyad	University	Web-CT	Argument templates, note-starters, prompt questions	Argumentative interaction	–
Nussbaum et al. (2007)	87	Triad/ Large	University	AVD/Wiki's	Argument diagrams, templates, prompt questions	Argumentative interaction	–
Nussbaum et al. (2008)	88	Dyad	University	Web-CT	Collaborative discussion boards, peer interaction	Argumentative interaction	–
Oh and Jonassen (2006)	58	Triad	University	FLE3	Scaffolded, threaded and constraint-base discussion board	Individual problem-solving performance	–
Overdijk and Van Diggelen (2008)	21	Triad	Secondary	Computer	Graphical shared-workspace, diagrams, labeled arguments	Social construction, participation	
Prinsen et al. (2006)	120	Four	Primary	Web-Forum	Collaborative discussion boards	Quality of participation and interaction	–
Prinsen et al. (2009)	190	Four	Primary	Web-Forum	Collaborative discussion boards	Quality of participation and interaction	–
Rourke and Kanuka (2007)	12	Dyad	University	-	Collaboration and computer conferencing	Reasoned debate, critical thinking	–
Schellens and Valcke (2005)	230	Large	University	Web-tool	Collaborative threaded discussion boards, peer interaction	Cognitive processing, discussion quality	Phases of Knowledge construction
Schellens and Valcke (2006)	300	Large	University	Web-tool	Collaborative threaded discussion boards, peer interaction	Cognitive processing, discussion quality	Phases of Knowledge construction
Schellens et al. (2007)	223,286	Large	University	Web-tool	Collaborative threaded discussion, assigning roles	Process of knowledge construction	Final exam scores
Schwarz and De Groot (2007)	10	Large	Secondary	Digalo	Structured inquiry, argumentative ontology and floor control	Reasoning, argumentation components	–
Schwarz and Glassner (2007)	54	Large	Secondary	Digalo	Argumentative ontology and floor control	Argumentation and interaction quality	–
Schwarz, Neuman, Gil, et al. (2000)	120	Triad	Primary	Belvédère	Collaborative argumentative map, pro–con table	Nature of argument	Collective and Individual Knowledge

(*continued on next page*)

Table 1 (*continued*)

Author(s) and year	Participant	Group size	Educational level	Platform	Functionalities of the platform for the study	Research focus	
						Learning processes	Learning outcomes
Stegmann et al. (2007)	120	Triad	University	Text-based	Input text fields, question prompts	Single and sequential argumentation	Domain general, specific knowledge
Strijbos, Martens, Jochems, and Broers (2004)	80	Four	University	Email	Assigning functional roles	Performance in group processes	–
Strijbos et al. (2007)	49	Large	University	Email	Assigning functional roles	Group performance and collaboration	–
Suthers (2001)	12	Dyad	–	Belvédère	Text, graph, and matrix, representational guidance	Collaborative learning discourse	–
Suthers and Hundhausen (2003)	60	Dyad	University	Belvédère	Text, graph, and matrix, representational guidance	Collaborative learning processes	Individual knowledge construction
Taasoobshirazi and Hickey (2005)	15	Triad	Secondary	Village	Instructional support, peer interaction	Quality of Argumentation	Curriculum and standards tests
Van Amelsvoort et al. (2007)	195	Dyad	Secondary	TC3	Constructed and inspected diagrams, argumentative text	Argumentative patterns and processes	–
Van Amelsvoort et al. (2008)	46	Dyad	Secondary	DREW	Argumentative diagrams, chat, multiple tools	Argumentative knowledge structure	–
Van Drie, Van Boxtel, Erkens, et al. (2005)	72	Dyad	Secondary	VCRI	Graphical/Textual Debate-tool, representational guidance	Historical reasoning process	Scores on individual essays
Van Drie, Van Boxtel, Jaspers, et al. (2005)	157	Dyad	Secondary	VCRI	Graphical/Textual Debate-tool, representational guidance	Collaborative domain-specific reasoning	Scores on individual essays
Veerman, Andriessen, and Kanselaar (2000)	68	Dyad	University	NetMeetin	Reflective peer coaching, structured peer coaching	Structure and quality of the argument	–
Veerman et al. (2002)	14	Dyad	University	Belvédère	Argumentative diagrams, critical question asking	Argumentation process	–
Weinberger, Ertl, et al. (2005)	96,86	Dyad/ Triad	University	Text-based	Input text boxes, epistemic, social script, role-play	–	Individual knowledge acquisition
Weinberger et al. (2010)	72	Triad	University	Text-based	Input text windows for construction of single argument	Argumentative elaboration	Domain general, specific knowledge
Yiong-Hwee and Churchill (2007)	42	Large	University	Forum	Sentence-openers, threaded and visual representations	Quality and construction of arguments	–

Table 2
Outlet overview of the reviewed publications.

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

Table 3
Quantitative data description of the reviewed empirical publications.

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

4. Results and discussion

4.1. Exploration of research questions

This step involved extracting factors of ABCSCL that have been investigated from the reviewed publications and categorizing them into four inter-related components (student; learning environment; learning process; and learning outcomes) based on Biggs (2003) model (see Fig. 1). The component student can be divided into characteristics brought into the ABCSCL by the student including his or her traits (gender, openness to argue, learning style, willingness to argue, and internal argumentative script), prior knowledge and skills (argumentation and collaboration skills, prior knowledge, and computer skills). Each student has his/her own characteristics that are used for arguing, discussing, analyzing, conceptualizing, synthesizing and concluding along with his/her partners while solving learning tasks in ABCSCL. At the precondition level, learning environment addresses situational characteristics in ABCSCL that are set by curriculum developers, i.e. resources and settings (learning task, group composition, group size, and CSCL platform) and instructional support (knowledge representations and collaboration scripts). At the precondition level, orchestration of successful

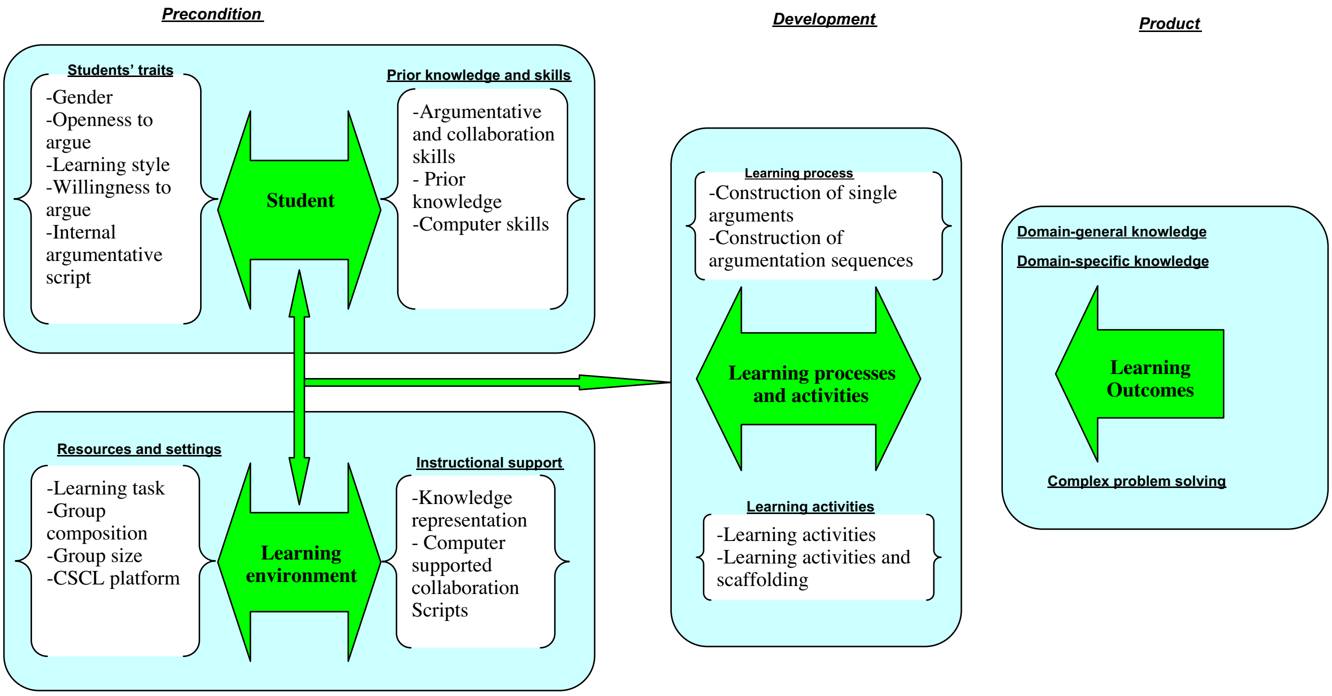


Fig. 1. ABCSCL framework based on reviewed publications (adapted from Biggs (2003)).

ABCSCL environments depends on the manipulation of multiple representations of both technological settings and instructional interventions. The development level consists of learning processes (construction of single arguments and argumentation sequences) and activities (learning activities and learning activities and scaffolding). Learners approach tasks differently depending on the technological settings and instructional interventions. At the product level, learning outcomes are based on the expected learning goals. These include knowledge construction, which can be the acquisition of both domain-specific and domain-general knowledge, e.g. knowledge on argumentation as well as complex problem-solving. Based on the research questions, components and sub-components of an ABCSCL framework (see Fig. 1) are identified in the following paragraphs.

4.2. Which student conditions that influence ABCSCL have been investigated?

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

4.2.1. Students' traits

The examined sub-components of students' traits in ABCSCL are gender, openness to argue, learning style, willingness to argue, and internal argumentative script.

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

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

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

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

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

4.2.2. Prior knowledge and skills

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

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

4.2.2.2. Prior knowledge. Many publications focus on the idea that a lack of or varying levels of prior knowledge about a topic might hinder learners from arguing effectively. Andriessen et al. (2003) contented that "confronting cognitions" (i.e. prior knowledge in peer interaction) affect learning outcomes. They claimed (cited in Schwarz & Linchevski, 2007, p. 512) that "peers may disagree on the solution to a problem as a consequence of their previous different knowledge and accommodate their divergent views to elaborate new knowledge; they may co-elaborate new knowledge through collaboration if their previous knowledge does not engender contradictions; may remain stuck if their previous knowledge is not developed enough even if they disagree, etc." To converge various learners' levels of knowledge, additional information about the given task, e.g. presentations and hand-out materials, should be given to learners (Clark, Sampson, Weinberger, & Erkens, 2007). Having adequate background knowledge of the issue could enhance the quality of collaborative argumentation (Golanics & Nussbaum, 2008). Assessing prior knowledge is important since the concept of ABCSCL is based on the assumption that individuals can take advantage of group processes and knowledge that is supposed to be distributed among partners. Learning partners are seen as additional learning resources when they contribute unshared prior knowledge to the discussion, which may eventually be shared after collaboration (Weinberger, Stegmann, & Fischer, 2010).

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

4.3. Summary and critique

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

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

4.4. Which learning environment conditions that influence ABCSCL have been investigated?

This section presents findings related to the learning environment condition in ABCSCL.

4.4.1. Resources and settings

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

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

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

Different criteria have been used for grouping students in collaborative learning environments. Kobbe et al. (2007) suggest that groups can be composed according to independent learners' characteristics (e.g. gender, age, nationality, educational background, and prior knowledge) or particular procedure for group formation mechanisms (e.g. number of students in class, size of group, and their combination). A study by Jeong and Davidson-Shivers (2006) showed that group composition in terms of gender influence argumentative activities. For example, females posted fewer rebuttals to the disagreements and challenges of females than males, and males posted more rebuttals to the challenges of females. Some scholars have categorized learning groups based on educational backgrounds, i.e. knowledge, ability and achievements (e.g. Liu & Tsai, 2008; Schellens & Valcke, 2005). Ge et al. (2000) contend that placing high-level learners together in a group may hamper their collaboration efforts because they may move quickly to the aspects of the topic that interest them most and neglect the other aspects of the topic that they are expected to elaborate on. A study by Jeong and Lee (2008) found that composing a balanced mix of active and reflective learners enhances the performance of active learners by enabling them to exchange critical messages, whereas their chance of enhancing the performance of critical discussions was not very high in groups with only or mostly active learners. In some studies, groups were composed in terms of differing opinions (a conflict schema approach known as personally seeded discussions) to ensure that multiple perspectives were present within the discussions (Clark, D'Angelo, & Menekse, 2009; Clark & Sampson, 2007, 2008). The results showed that personally seeded discussions successfully foster argumentation and therefore knowledge about the topic. In several studies (e.g. Beers et al., 2005, 2007; Rummel, Spada, & Hauser, 2009), positive learning outcomes were achieved when groups of students were composed based on divergent disciplinary backgrounds. For example, A study by Rummel and Spada (2005) showed that disciplinary heterogeneous grouping help learners acquire content-related knowledge during problem-solving activities. Here, dyads of advanced medical and psychology students were composed to jointly diagnose the patients and to develop a therapy plan making use of their complementary expertise. Students indeed benefited from one another's expertise since they could use their partner(s) as a source for clarifications and deepening of knowledge. Establishment of common ground through negotiation is crucial in such groups, however.

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

4.4.1.4. CSCL platform. Both conceptual (e.g. Arnseth & Ludvigsen, 2006; Hirsch, Saeedi, Cornillon, & Litosseliti, 2004) and empirical (e.g. De Vries, Lund, & Baker, 2002; Joiner & Jones, 2003; Lin & Crawford, 2007; Overdijk & Van Diggelen, 2008) publications focus on specific aspects of the CSCL platform and their impacts on interaction and argumentation patterns in order to justify the design principles. Strijbos, Martens, and Jochems (2004) suggested the following six design steps: (1) determine the learning objectives, (2) determine the expected interaction, (3) select the task type, (4) determine how much pre-structuring is needed, (5) determine group size, and (6) determine how affordances can be applied to support interaction. One needs to carefully consider the introduction of any new tool taking into account both the requirements of the task and the learning goals (Oh & Jonassen, 2006).

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

4.4.2. Instructional support

The sub-components of instructional support that have been investigated are external knowledge representations and collaboration scripts. These have appeared in conceptual publications (e.g. Kirschner, Beers, Boshuizen, & Gijselaers, 2008; Kirschner, Strijbos, Kreijns, & Beers, 2004) and empirical studies (e.g. Van Drie, Van Boxtel, Erkens, & Kanselaar, 2005). These instructional interventions have been manifested as stand-alone instructional tools or scaffolds to guide learners to engage in specific activities, i.e. constrained message categories with and without labels (Brooks & Jeong, 2006), conversational language (Jeong, 2006b), linguistic qualifiers (Jeong, 2005), input text fields (Baker & Lund, 1997), written prompts and argumentation template (Li & Lim, 2008), and argument map (Morgan, 2006).

4.4.2.1. Knowledge representation tools. A variety of external knowledge representation tools has been proposed to represent argumentation in ABCSCL (e.g. design-based approaches to support argumentation process by graphical representations, discussion-based tools to support dialogical argumentation of a group, and knowledge representation tools to support the construction of rhetorical argumentation). IBIS (Issue-Based Information Systems) as a design-based approach was introduced to support fundamental principles for the design processes of argumentative problem-solving, including three main nodes, namely issue, position, and argument (Conklin & Begeman, 1988). Graphical IBIS (gIBIS) is a hypertext-based environment aimed at supporting and facilitating interactions and arguments between participants for issue-based communication, critical thinking, and solving complex problems (Conklin & Begeman, 1988). Application of the gIBIS model in computer-mediated settings can be seen in study done by Liu and Tsai (2008), who employed gIBIS as an argumentation tool to support small group problem-solving activities. Discussion-based tools provide a less structured and explicit shared workspace such as discussion threads, which allow learners to exchange arguments and maintain a common focus on argumentation by tracing the discussion lines and signaling the different argumentation moves by node types (Van Bruggen et al., 2002).

Knowledge representation tools have been implemented in the same instructional elements with a different representational structure. They can be used in a more graphical implementation in the form of schemes (Schwarz & De Groot, 2007), tables (Suthers & Hundhausen, 2003) or visualizations (Ding, 2009; Munneke, Van Amelsvoort, & Andriessen, 2003) or in a more textual implementation in the form of cues or prompts (Morris et al., 2010) or scripts (Weinberger, Stegmann, Fischer, & Mandl, 2007). When graphical representation tools offer content-specific support by illustrating important aspects of the content, learners are asked to use the graphical features as a cognitive tool to modify the representational context for accomplishing the task (Ertl, Kopp, & Mandl, 2008). The other form of knowledge representation that has been called "computer-supported collaboration script" offers collaboration-specific support.

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

In a study by Fischer and Mandl (2005), learners benefited more from content-specific than content-unspecific representation regarding both the process of collaborative knowledge construction and the quality of the collaborative solution by using more appropriate knowledge resources without sharing more knowledge after collaboration. Nevertheless, for both groups a low range of knowledge convergence in terms of outcomes was achieved. The obtained knowledge convergence was lower for factual than application-oriented knowledge. In another study by Fischer, Bruhn, Gräsel, and Mandl (2002), no difference was found in terms of knowledge gain under the two visualization conditions. In several studies by Nussbaum and colleagues (e.g. Nussbaum, 2008b; Nussbaum & Edwards, 2011; Nussbaum & Schraw, 2007; Nussbaum, Winsor, Aqui, & Poliquin, 2007), the effects of Argumentation Vee Diagrams (AVDs) on the quality of students' argumentation, critical discussion and reasoning were investigated. Compared to a control group, the AVDs not only enhanced the integration of arguments and counterarguments i.e. compromises but also fostered critical discussions and reasoning. They argue that the strength of an argument is a function of how well a counterargument is approached by refuting, discounting, or accepting, or by proposing a creative solution that eliminates possible objections (see also Nussbaum, 2005, 2008a; Nussbaum et al., 2008). Well-designed graphical tools for argumentation include evaluating and integrating both sides of an issue resulting in more elaboration of the possible arguments for and against a topic at stake.

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

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

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

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

4.4.2.3. Conflict schema approaches. A particular class of script known as "conflict scheme" or personally seeded discussions (whereby groups of students with varied conflict perspectives describe the data using their own explanations as the seed comments for the ensuing discussion) successfully fostered argumentation structure, which in turn improved the students' knowledge gain (Clark & Sampson, 2007, 2008; Clark et al., 2009). Furthermore, in a study by Clark et al. (2009), students in an augmented-preset script condition (seed-comments by researchers) outperformed students in a personally-seeded script condition (students' own explanations as seed-comments) in terms of argumentation structure. The reason was that the optimal diversity of ideas as sets of preset seed-comments were provided by an expert-wise approach in the augmented preset groups and non-optimal diversity sets of seed-comments were provided by students' own explanations.

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

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

4.5. Summary and critique

Orchestration of argumentation in ABCSCL builds on multiple representations and instructional interventions. The consensus among researchers is that learning tasks should be neither too simple and artificial, especially for professionals, nor too difficult and complicated, especially for novice learners, to prevent frustration and unintended side effects. The topic of discussion should be arguable and debatable if learners are to delve deeply and broadly into a topic or solve ill-defined problems. As far as group composition is concerned, researchers unanimously favor heterogeneous groups. The plausible explanation is that each learner encounters a wider range of perspectives and resources in heterogeneous groups than in homogenous groups and this could likely maximize the likelihood of beneficial interactions for learning. There is no agreement, however, among scholars about criteria for grouping learners into heterogeneous teams. While many have grouped learners on the basis of learners' characteristics, recent studies have tended to group learners based on their differing opinions to ensure that multiple perspectives are present and to thus facilitate deeper and wider argumentation and discussion. Grouping learners based on their divergent disciplinary backgrounds to ensure complimentary expertise in multidisciplinary teams is a new and under-investigated trend in ABCSCL. Future ABCSCL research needs to focus on the quality of group work and peer interaction patterns in multidisciplinary groups versus in groups of learners within the same discipline. Quantitative analysis shows that small group size, i.e. dyads and triads, have been prioritized in ABCSCL research. This is because of the ever-present danger of free-riding and sucker influence in large groups compared to the more active participation, more turn taking, and faster establishment of common ground that is likely in small groups. A relatively large number of publications studied CSCL platforms with different functionalities and modes of communication. To synthesize, ABCSCL demands well-designed, well-scaffolded and user-friendly platforms that take into account the type of learning task, the level of technology affordances, users' experiences, domain issues, learning goals, etc.

This review shows that most publications of the past 15 years have been devoted to instructional support as a sub-component of ABCSCL. A synthesis of reviewed publications regarding knowledge representation tools indicated that when the purpose of ABCSCL is to deepen learners' knowledge or produce productive arguments, writing tasks and argumentative texts could be the most useful (Suthers & Hundhausen, 2003). Diagrams are shown to have the most added value when the intention is to support the argumentative sequence and belief change (Nussbaum, 2008b), to maintain focus and also to broaden and deepen the discussion (Van Amelsvoort et al., 2007, 2008). When the intention is to include relations to a topic for patterns of evidence, a matrix is considered to be a suitable tool (Baker, Andriessen, Lund, Van Amelsvoort, & Quignard, 2007), whereas graphs are useful for gathering and relating information to elaborate on a topic while keeping learners focused on the relevant aspect of the debate (Baker et al., 2007). In spite of the advantages of various forms of scripts, overconcentration on one specific process-oriented dimension of argumentative knowledge construction was shown to cause unintended side effects related to other process-oriented dimensions. Researchers still need to address when, under what conditions, and which external scripts foster argumentative knowledge construction in all its dimensions.

4.6. Which learning process conditions that constitute ABCSCL have been investigated?

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

4.6.1. Learning process

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

4.6.1.1. Construction of single arguments. Construction of a single argument was proposed against Toulmin's (1958) model of argumentation (see Stegmann, Wecker, Weinberger, & Fischer, in press). From Toulmin's point of view, an argument consists of six interconnected parts: claim, data, warrant, backing, rebuttal, and qualifier, respectively. Several researchers concurred that the complexity of the model should be reduced for use as a basis for instructional support (e.g. Stegmann et al., 2007, in press; Voss & Van Dyke, 2001). Hence, a simplified version of Toulmin's model was proposed comprising the components claim, grounds, and qualifications. The claim is an expression of the position that is advanced in the argument. The elements datum, warrant, and backing from Toulmin's model all fall within the term grounds. Datum is the factual information that is expressed to support the acceptance of the claim, e.g. observations. Warrant is a rule of inference that justifies the transition from the datum to the claim and reveals the relevance of the data for the claim, e.g. definitions, theories, and rules. Backing is factual information, e.g. reasonable evidence, statistics or expert ideas that provide a rationale for a warrant. Qualifiers and their interrelated rebuttals have to do with qualifying the relationship between claim and warrant. They both might be used in an argumentative process to limit the validity of a claim. More explicitly, qualifier has to do with expressing a potential limitation and rebuttal has to do with further explanation when the claim is not valid (Stegmann et al., 2007). Hence, based on the formal quality of argumentation, learners' knowledge construction in ABCSCL comprises five argumentative moves: (1) simple claim that refers to statements that advance a position without limitation of its validity or provision of grounds that warrant the claim; (2) qualified claim that refers to the claim without provision of grounds, but with limitation of the validity of the claim (with qualifier); (3) grounded claim that refers to the claim without limitation of its validity, but with the provision of grounds that warrant the claim; (4) grounded and qualified claim that refers to the claim with grounds that warrant the claim and a limitation of its validity; and non-argumentative moves that refer to questions, coordinating moves and meta-statements on argumentation. Therefore, in ideal situations, a completely explicit argument would comprise a claim supported by grounds and limited by qualifications.

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

4.6.2. Learning activities

The most frequently examined sub-components of learning activities are learning activities as well as learning activities and scaffolding. In ABCSCL, learners approach their tasks in different ways depending on various previously mentioned factors at the level of pre-condition, namely student and learning environment. Erkens and Janssen (2008) divided learners' communicative functions into five activities: argumentative (a line of argumentation or reasoning), responsive (confirmations, denials, and answers), informative (transfer of information), elicitative (questions or proposals requiring a response) and imperative (commands). Baker et al. (2007) and Van Amelsvoort et al. (2007, 2008) divided students' activities into seven categories: outside activity, social relations, interaction management, task management, opinions, arguments, and exploration and deepening of activities. This framework points out that students not only engage in discussion and argument but also in off-task activities as well as social, interaction and management activities. In a framework constructed by Weinberger and Fischer (2006), students' activities were divided into four independent dimensions for knowledge construction including participation, epistemic, argumentative and social modes of co-construction. The participation dimension refers to the extent to which learners participate and interact, as well as to the heterogeneity of participation, i.e. the (un-)equal participation of learners in the same group. The degree to which learners participate in discussions (number of words) and also the quality of interaction (elaboration of the responses) are positively associated with the learning (Prinsen et al., 2009; Schellens et al., 2007). In the epistemic dimension, students' activities have to do with construction of both problem case and conceptual space that support the understanding of the problem and the theory through relating theoretical concepts with case information and prior knowledge. In the formal argumentative dimension, micro-level activities (construction of single arguments) and macro-level activities (construction of sequences of argumentation) can be identified. In the social dimension, the extent to which learners base their reasoning on the reasoning of their partners can be analyzed through different social modes (Weinberger & Fischer, 2006). Nevertheless, according to Kobbe et al. (2007), in every independent dimension, more coarse-grained or greater activities (discussion) can be decomposed to more fine-grained or lesser activities (elaborations, explanations, question asking, etc.). More fine-grained activities (asking specific questions or checking a report for mistakes, etc.) can be subsumed in more coarse-grained activities (help seeking).

4.6.3. Learning activities and scaffolding

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

Depending on the degree of scaffolding, students' activities in ABCSCL might be different. For example, students with the Universanté Script (see Dillenbourg & Jermann, 2006) are supposed to follow activities such as (a) analyzing and elaborating the case; (b) summarizing and explaining; (c) analyzing, comparing and relating new information to prior knowledge; (d) giving feedback and critiquing; and (e) problem solving. ABCSCL prompted with the ArgueGraph Script (Dillenbourg & Jermann, 2006) demands activities such as (a) justifying opinions and constructing arguments; (b) comparing, evaluating, and elaborating; (c) negotiating and constructing arguments; (d) explaining and justifying opinions; and (e) summarizing and making connections. ABCSCL scaffolded with a peer-review script (see Weinberger, Ertl, et al., 2005) encourages students to engage in activities such as (a) applying theoretical concepts to cases and constructing arguments; (b) critiquing, initially scaffolded with prompts for eliciting clarification, identifying conflicting views, and constructing counter-arguments. ABCSCL scaffolded with epistemic scripts encourages learners to focus on a specific task for applying theoretical concepts and knowledge to the problem case (Clark, Sampson, et al., 2007). ABCSCL scaffolded with argumentative scripts encourages learners to engage in activities that broaden and deepen their arguments (Weinberger et al., 2007) by warranting, qualifying, or arguing against proposed solutions with reasonable evidence and logical examples.

4.7. Summary and critique

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

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

4.8. Which evidence is available on the relationship between ABCSCL and learning outcomes?

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

4.8.1. Acquisition of domain-general and domain-specific knowledge

Knowledge acquisition is one of the most important learning outcomes of ABCSCL. Both conceptual (e.g. Weinberger & Fischer, 2006) and empirical (e.g. Gerber, Scott, Clements, & Sarama, 2005; Muukkonen, Lakkala, & Hakkarainen, 2005; Taasoobshirazi & Hickey, 2005) publications indicate that participation and interactions in ABCSCL can lead to knowledge construction. In ABCSCL, learners engage in specific discourse activities to elaborate on the available learning materials, to express their viewpoints and also to react to learning partner(s)' perspectives, resulting in an interactive argumentation which is beneficial for acquiring both domain-specific and domain-general knowledge (see Weinberger, Ertl, et al., 2005; Weinberger, Stegmann, et al., 2005; Weinberger et al., 2007). ABCSCL has been used by a considerable number of scholars to acquire domain-general knowledge, i.e. knowledge on argumentation (e.g. Baker et al., 2007; Clark & Sampson, 2007, 2008). ABCSCL research has also shown positive impacts on domain-specific knowledge construction as well as declarative, procedural, conceptual, cognitive and meta-cognitive knowledge construction (e.g. Cho & Jonassen, 2002; Ho, Rappa, & Chee, 2009). Some researchers (e.g. Stegmann et al., 2007, in press) found positive relationships between the construction of sound (micro-level) and complete (macro-level) arguments with cognitive elaboration processes and hence knowledge acquisition. As assumed by Baker (2003), argumentation-related cognitive processing in argumentative discourse is positively related to formal quality of argumentation and acquisition of knowledge on argumentation (Stegmann et al., in press).

4.8.2. Complex problem-solving

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

4.9. Summary and critique

Scholars in the field of ABCSCL research concur that engaging in various forms of argumentative activities can facilitate acquisition of knowledge on argumentation and domain-specific knowledge that could be applied for complex and ill-defined problem solving. Moreover, ABCSCL can promote higher-order thinking and problem solving and, thus, can lead to deeper understanding of the topic (e.g. Van Bruggen & Kirschner, 2003). The results of this review's quantitative analysis, however, indicate that only one-third of reviewed publications investigated the learning outcomes in ABCSCL as such. Studies that do not report on outcomes seem to be based on the assumption that learning processes and activities determine the quality of learning outcomes in ABCSCL. In this view, facilitating ABCSCL processes will improve the quality of learning outcomes as well (see Noroozi et al., 2011). This review study seems to confirm such a relationship. For example, studies by Jeong and Davidson-Shivers (2006) and Jeong (2007) showed that gender (student level) could play a key role in mediating the effects of openness (student level) while posting rebuttals in reply to critique (learning process), which in turn were shown to lead to higher quality of knowledge construction as can be seen in the learning outcomes (Weinberger, Stegmann, & Fischer, 2005; Weinberger et al., 2007). Furthermore, less open and curious learners (student level) showed a higher quality of knowledge (learning outcome) by showing more disagreement (learning process) when note starters were prompted (learning environment) compared to students who were more curious, anxious and assertive (Nussbaum et al., 2004). To develop a more prescriptive model, future research would have to be organized not by factor but by factor–factor pairings (e.g. student-learning outcome, learning environment-learning process, learning environment-learning outcome, student-learning process, etc.). Such research would not only help us understand the nature of these relationships, the optimal combination of conditions, the influence of one factor on another and the stability of such an influence, but also lead to a further understanding of what and how ABCSCL can be designed more effectively.

5. Conclusion and directions for future work

This paper demonstrates that the design of ABCSCL environments requires a systematic approach that takes the variety of specific conditions for learning into account. Biggs' model provided a way to categorize similarities in reported studies despite their different foci. A framework was proposed here by clustering various influencing and constituting factors in ABCSCL that have been investigated over the last 15 years. This framework consists of the four interconnected components student, learning environment, learning process and learning outcomes, each of which is divided into sub-components for pedagogic and design decisions related to teaching and learning in ABCSCL (see Fig. 1).

The quantitative analysis of 15 years of research into ABCSCL revealed that empirical publications outnumber conceptual ones, since scholars have been mostly interested in testing instructional interventions for ABCSCL. This is what we expected since conceptual publications with theoretical backgrounds can be mostly found in books and book chapters rather than journal publications. Our analysis showed that ABCSCL has not only been designed for controlled laboratory studies but also for quasi-experimental field settings that require argumentative skills in science education. Quantitative studies outnumber qualitative studies, which indicates further need for qualitative analysis methods in ABCSCL. The educational context of the reported empirical studies varied in terms of educational level (primary and secondary schools and universities), curricula (both hard and soft subjects) and geographic location; however, there was a strong emphasis on Western countries. These figures show the importance and growing nature of this body of scholarship in the 21st century. A limited number of reviewed publications reported on both learning processes and outcomes, whereas most publications in ABCSCL reported on learning processes and activities. The reason is that differences in learning outcomes result from differences in learning processes (see Noroozi et al., 2011). Therefore, in order to improve student learning outcomes in ABCSCL, explicit attention needs to be paid to the nature of the students' learning processes. Nevertheless, since direct practical relevance would only be achieved by looking at the learning outcomes in relation to learning processes and activities, we advise that future research in ABCSCL be aimed at revealing the differences in the learning processes and activities between successful and less-successful learners in terms of learning outcomes. So far, small group sizes (dyads and triads) have been prioritized in ABCSCL studies, and the selection of group size has depended on the learning goals, time constraint, complexity of the learning task and the technological design. Almost equal attention was paid to synchronous and asynchronous modes of communication since each has advantages and disadvantages.

One focus of ABCSCL research in the last 15 years has been on the role of external knowledge representations and various collaboration scripts. The structure of scripts for collaborative learning differs. While some researchers provide rather rough guidelines for specific activities, sequences and roles, others may provide highly structured scripts, including detailed instructions for learners regarding what activities should be carried out, when and by whom (Kollar et al., 2007). There is a need for more empirical research to investigate the interplay between internal and external scripts. The ongoing research aims to find the optimal balance between students' external and internal scripts, in order to avoid the disadvantages of over-scripting (Carmien et al., 2007). Some evidence shows that highly structured scripts have resulted in better learning outcomes than less-structured scripts (Beers et al., 2005, 2007). Nonetheless, overly detailed scripts or "over-scripting" has also been questioned (Dillenbourg, 2002; Tchounikine, 2008). Based on lessons learned from ABCSCL research, scripts could be faded out to avoid cognitive overload in overly scripted collaborative tasks (Dillenbourg, 2002; Jermann & Dillenbourg, 2003; Kester & Paas, 2005). One under-investigated question is how detailed and specific external scripts need to be in order to prevent frustration among students through over-scripting. Also how, when and under what conditions should external scripts be faded out to avoid over-scripting, prevent frustration, and foster internalization of external scripts in ABCSCL. Overly rigid scripts would inhibit and spoil the richness of natural interaction, whereas overly flexible scripts would fail to illicit the intended interaction (Dillenbourg & Tchounikine, 2007). The ongoing research focus is to determine the extent to which learners can internalize and stabilize external scripts over time taking into account their internal scripts. For how long, in what way, and under what conditions do learners need to interact using external scripts to internalize them without becoming over-scripted?

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

Our review revealed that over the last 15 years considerable attention has been paid to the nature of instructional interventions in mono-disciplinary teams, but only few studies have dealt with multi-disciplinary teams. More research needs to be done to compare the effectiveness of various instructional interventions in groups made up of members from the same discipline and in groups made up of member from differing disciplines. Interdisciplinary thinking is gradually becoming a major research theme in ABCSCL since grouping of learners based on different disciplinary backgrounds could help them integrate knowledge of two or more disciplines and thereby help them acquire content-related knowledge. Although considering a problem from various viewpoints in multidisciplinary groups can be productive, it is not always an advantage (e.g. Barron, 2003). First, group members need to establish a common ground, which is vital to team performance but difficult to achieve (e.g. Beers et al., 2005; Courtney, 2001). This implies that they might need to engage in a non-productive discussion of pieces of information that may already be known to all group members from the start (Stasser & Titus, 1985). As a consequence, only after extended periods of working together they can start efficiently pooling their unshared knowledge resources. Speeding up this process can be best achieved when they have meta-knowledge about the domain expertise and knowledge of their learning partners (Rummel et al., 2009), that is, a transactive memory system (Wegner, 1987, 1995). Second, due to divergent domains of expertise, group members may have some difficulties in building arguments for and against the arguments being put forward by their learning partner(s) and thus they may avoid engaging in critical and transactive discussions. To make decisions for joint solutions and to take full advantage of one another's complementary expertise, learning partners need to engage in transactive discussion and critically evaluate the given information from different perspectives on the basis of their domain expertise (Rummel & Spada, 2005). It would be a worthwhile endeavor to develop and introduce a set of scripts that could help learners promptly pool and process their unshared information through establishment of a transactive memory system, and then help them engage in critical and transactive discussions aimed at reaching consensus for their joint solutions. This would also help researchers improve the technological settings and instructional strategies in multidisciplinary groups in ABCSCL environments, and thereby make the best use of learners' complementary expertise.

This literature review built on a renowned conceptual framework involving essential aspects of teaching and learning (Biggs, 2003). It is intended to contribute to a growing body of knowledge on designing ABCSCL environments. This review covered a selected time span, language, variety of relevant databases, and adopted a search strategy that provided a sufficient representation of research carried out in this field in the last 15 years. In our review study, however, we did not report the effects of various forms of instructional support and interventions on the various components of the learning outcomes in ABCSCL. It would be insightful if another literature review focus on the empirical evidence to report the (intra) relationships between instructional interventions and learning outcomes in order to demonstrate the interactive nature of components within teaching and learning in ABCSCL. Future research therefore could focus on in-depth quantitative meta-analysis on the topic to examine how, under which condition, and which instructional interventions in ABCSCL directly determine various components of learning outcomes within the proposed framework. This would enable researchers to draw conclusive conclusions on whether and how a particular type of intervention has a real effect on the intended dependent variable. Furthermore, future research studies could aim at answering specific questions with respect to each particular dimension of argumentation-based learning. For example, future review studies should categorize and then analyze ABCSCL publications on the basis of their argumentation focus (e.g. quality of single argument, argumentation sequence, reasoning, argumentative discourse and interactions, etc.) to draw conclusions on the effects of collaborative argumentation on various types of learning achievements: problem solving, knowledge construction, learning of subject contents, etc.

Acknowledgments

This research was supported by the Ministry of Science, Research, and Technology (MSRT) of the Islamic Republic of Iran through a grant awarded to Omid Noroozi. The authors want to express their gratitude for this support.

References

References marked with one asterisk indicate empirical publications included in the review. References marked with two asterisks indicate conceptual publications included in the review.

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

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

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

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

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

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

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

Baker, M. (1999). Argumentation and constructive interaction. In G. Rijlaarsdam, & E. Esperet (series Eds.) & J. Andriessen, & P. Coirier (Eds.). Studies in writing: (Vol. 5). Foundations of argumentative text processing (pp. 179–202) Amsterdam: Amsterdam University Press.

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

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

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

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

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

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

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

*Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Gijselaers, W. H. (2005). Computer support for knowledge construction in collaborative learning environments. *Computers in Human Behavior, 21*(4), 623–643.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*Crossa, D., Taasoobshirazib, G., Hendricksc, C., & Hickeya, D. T. (2008). Argumentation: A strategy for improving achievement and revealing scientific identities. *International Journal of Science Education, 30*(6), 837–861.
*De Vries, E., Lund, K., & Baker, M. (2002). Computer-mediated epistemic dialogue: Explanation and argumentation as vehicles for understanding scientific notions. *Journal of the Learning Sciences, 11*(1), 63–103.
*De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2007). Applying multilevel modelling on content analysis data: Methodological issues in the study of the impact of role assignment in asynchronous discussion groups. *Learning and Instruction, 17*(4), 436–447.
Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL. Can we support CSCL* (pp. 61–91). Heerlen: Open Universiteit Nederland.
**Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. *International Journal of Computer-Supported Collaborative Learning, 3*(1), 5–23.
Dillenbourg, P., & Jermann, P. (2006). Designing integrative scripts. In F. Fischer, I. Kollar, H. Mandl, & J. Haake (Eds.), *Scripting computer-supported collaborative learning: Cognitive, computational and educational perspectives*. New York: Springer.
**Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for CSCL. *Journal of Computer Assisted Learning, 23*(1), 1–13.
*Ding, N. (2009). Visualizing the sequential process of knowledge elaboration in computer-supported collaborative problem solving. *Computers and Education, 52*(2), 509–519.
Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287–312.
*Erkens, G., & Janssen, J. (2008). Automatic coding of dialogue acts in collaboration protocols. *International Journal of Computer-Supported Collaborative Learning, 3*(4), 447–470.
*Erkens, G., Jaspers, J., Prangsma, M., & Kanselaar, G. (2005). Coordination processes in computer supported collaborative writing. *Computers in Human Behavior, 21*(3), 463–486.
*Ertl, B., Fischer, F., & Mandl, H. (2006). Conceptual and socio-cognitive support for collaborative learning in videoconferencing environments. *Computers and Education, 47*(3), 298–315.
*Ertl, B., Kopp, B., & Mandl, H. (2006). Fostering collaborative knowledge construction in case-based learning scenarios in videoconferencing. *Educational Computing Research, 35*(4), 377–397.
*Ertl, B., Kopp, B., & Mandl, H. (2008). Supporting learning using external representations. *Computers and Education, 51*(4), 1599–1608.
*Ertl, B., Reiserer, M., & Mandl, H. (2005). Fostering collaborative learning in videoconferencing: The influence of content schemes and collaboration scripts on collaboration outcomes and individual learning outcomes. *Education Communication & Information, 5*(2), 147–166.
Felton, M., & Kuhn, D. (2001). The development of argumentative discourse skill. *Discourse Processes, 32*(2), 135–153.
*Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction, 12*(2), 213–232.
*Fischer, F., & Mandl, H. (2005). Knowledge convergence in computer-supported collaborative learning: The role of external representation tools. *The Journal of the Learning Sciences, 14*(3), 405–441.
**Ge, X., & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development, 52*(2), 5–22.
Ge, X., Yamashiro, K., & Lee, J. (2000). Pre-class planning to scaffold students for online collaborative learning activities. *Educational Technology and Society, 3*(3), 1–16.
*Gerber, S., Scott, L., Clements, D. H., & Sarama, J. (2005). Instructor Influence on Reasoned Argument in Discussion Boards. *Educational Technology Research & Development, 53*(2), 25–39.
*Golanics, J. D., & Nussbaum, E. M. (2008). Enhancing online collaborative argumentation through question elaboration and goal instructions. *Journal of Computer Assisted Learning, 24*(3), 167–180.
Gress, L. Z. C., Fior, M., Hadwin, F. A., & Winne, H. P. (2010). Measurement and assessment in computer-supported collaborative learning. *Computers in Human Behavior, 26*(5), 806–814.
**Hirsch, L., Saeedi, M., Cornillon, J., & Litosseliti, L. (2004). A structured dialogue tool for argumentative learning. *Journal of Computer Assisted Learning, 20*(1), 72–80.
*Ho, M. L. C., Rappa, N. A., & Chee, Y. S. (2009). Designing and implementing virtual enactive role-play and structured argumentation: Promises and pitfalls. *Computer Assisted Language Learning, 22*(5), 381–408.
Infante, D. A., & Rancer, A. S. (1982). A conceptualization and measure of argumentativeness. *Journal of Personality Assessment, 46*(1), 72–80.
Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007). Visualization of participation: Does it contribute to successful computer-supported collaborative learning? *Computers and Education, 49*(4), 1037–1065.
*Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science, 38*(1), 59–88.
*Jeong, A. C. (2005). The effects of linguistic qualifiers and intensifiers on group interaction and performance in computer-supported collaborative argumentation. *International Review of Research in Open and Distance Learning, 6*(3), 100–110.
*Jeong, A. C. (2006a). Gender interaction patterns and gender participation in computer-supported collaborative argumentation. *American Journal of Distance Education, 20*(4), 195–210.
*Jeong, A. C. (2006b). The effects of conversational language on group interaction and group performance in computer-supported collaborative argumentation. *Instructional Science, 34*(5), 367–397.
*Jeong, A. C. (2007). The effects of intellectual openness and gender on critical thinking processes in computer-supported collaborative argumentation. *Distance Education, 22*(1), 1–18.
*Jeong, A. C., & Davidson-Shivers, G. (2006). The effects of gender interaction patterns on student participation in computer-supported collaborative argumentation. *Educational Technology Development and Research, 54*(6), 543–568.
*Jeong, A. C., & Frazier, S. (2008). How day of posting affects level of critical discourse in asynchronous discussions and computer-supported collaborative argumentation. *British Journal of Educational Technology, 39*(5), 875–887.
*Jeong, A. C., & Joung, S. (2007). Scaffolding collaborative argumentation in asynchronous discussions with message constraints and message labels. *Computers and Education, 48*(3), 427–445.
*Jeong, A. C., & Lee, J. (2008). The effects of active versus reflective learning style on the processes of critical discourse in computer-supported collaborative argumentation. *British Journal of Educational Technology, 39*(4), 651–665.
Jermann, P., & Dillenbourg, P. (2003). Elaborating new arguments through a CSCL script. In P. Dillenbourg (Ed.), *Learning to argue* (pp. 205–226). Dordrecht, the Netherlands: Kluwer.
*Joiner, R., & Jones, S. (2003). The effects of communication medium on argumentation and the development of critical thinking. *International Journal of Educational Research, 39*(8), 861–971.
**Jonassen, D. H., & Kim, B. (2010). Arguing to learn and learning to argue: Design justifications and guidelines. *Educational Technology Research and Development, 58*(4), 439–457.
Keefe, J. W. (1979). Learning style: An overview. In *NASSP's Student learning styles: Diagnosing and proscribing programs* (pp. 1-17). Reston, VA. National Association of Secondary School Principles.
Kester, L., & Paas, F. (2005). Instructional interventions to enhance collaboration in powerful learning environments. *Computers in Human Behaviour, 21*(4), 689–696.
*Kim, I., Anderson, R. C., Nguyen-Jahiel, K., & Archodidou, A. (2007). Discourse patterns during children's collaborative online discussions. *Journal of the Learning Sciences, 16*(3), 333–370.

Kirschner, P. A. (2002). Cognitive load theory: Implications of cognitive load theory on the design of learning. *Learning and Instruction, 12*(1), 1–10.
*Kirschner, P. A., Beers, P. J., Boshuizen, H. P. A., & Gijselaers, W. H. (2008). Coercing shared knowledge in collaborative learning environments. *Computers in Human Behavior, 24*(2), 403–420.
Kirschner, P. A., Buckingham Shum, S. J., & Carr, C.S. (Eds.). (2003). *Visualizing argumentation:* Software tools for collaborative and educational sense-making. london:springer.
Kirschner, P. A., Strijbos, J. W., Kreijns, K., & Beers, P. J. (2004). Designing electronic collaborative learning environments. *Education Technology Research & Development, 52*(3), 47–66.
**Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning, 2*(2–3), 211–224.
*Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration scripts-a conceptual analysis. *Educational Psychology Review, 18*(2), 159–185.
*Kollar, I., Fischer, F., & Slotta, D. J. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction, 17*(6), 708–721.
Koschmann, T. (2003). CSCL, argumentation, and deweyan inquiry: Argumentation is learning. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to learn. Confronting cognitions in computer-supported collaborative learning environments*. Dordrecht: Kluwer.
Kuhn, D. (1991). *The skills of argument*. Cambridge University Press.
Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review, 62*(2), 155–178.
Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*(3), 319–337.
Kuhn, D. (2005). *Education for thinking*. Harvard University Press.
Kuhn, D. (2009). Do students need to be taught how to reason? *Educational Research Review, 4*(1), 1–6.
Kuhn, D., & Goh, W. W. L. (2005). Arguing on the computer. In T. Koschmann, D. Suthers, & T. W. Chan (Eds.), *Computer supported collaborative learning 2005: The next 10 years!* (pp 125–134). Mahwah, NJ: Lawrence Erlbaum.
Kuhn, D., Iordanou, K., Pease, M., & Wirkala, C. (2008). Beyond control of variables: What needs to develop to achieve skilled scientific thinking? *Cognitive Development, 23*(4), 435–451.
Kuhn, D., Shaw, V., & Felton, M. (1997). Effects of dyadic interaction on argumentative reasoning. *Cognition and Instruction, 15*(3), 287–315.
Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), 1245–1260.
Kuhn, D., & Udell, W. (2007). Coordinating own and other perspectives in argument. *Thinking and Reasoning, 13*(2), 90–104.
Leitão, S. (2000). The potential of argument in knowledge building. *Human Development, 43*(6), 332–360.
Leitão, S. (2003). Evaluating and selecting counterarguments. *Written Communication, 20*(3), 269–306.
*Lemus, D., Seibold, D., Flanagin, A., & Metzger, M. (2004). Argument and decision making in computer-mediated groups. *Journal of Communication, 54*(2), 302–320.
*Li, D. D., & Lim, P. C. (2008). Scaffolding online historical inquiry tasks: A case study of two secondary school classrooms. *Computers and Education, 50*(4), 1394–1410.
*Lin, S. J., & Crawford, Y. (2007). Innovations in teaching: An online debate series for first-year pharmacy students. *American Journal of Pharmaceutical Education, 71*(1), 1–8.
*Liu, C. C., & Tsai, C. C. (2008). An analysis of peer interaction patterns as discoursed by on-line small group problem-solving activity. *Computers and Education, 50*(3), 627–639.
*Lu, J., & Lajoie, S. P. (2008). Supporting medical decision making with argumentation tools. *Contemporary Educational Psychology, 33*(3), 425–442.
*Lund, K., Molinari, J., Sejourne, A., & Baker, M. (2007). How do argumentation diagrams compare when student pairs use them as a means for debate or as a tool for representing debate? *International Journal of Computer-Supported Collaborative Learning, 2*(2–3), 273–295.
*Marttunen, M. (1997). Electronic mail as a pedagogical delivery system: An analysis of the learning of argumentation. *Research in Higher Education, 38*(3), 345–363.
*Marttunen, M. (1998). Electronic mail as a forum for argumentative interaction in higher education studies. *Journal of Educational Computing Research, 18*(4), 387–405.
*Marttunen, M., & Laurinen, L. (2001). Learning of argumentation skills in networked and face-to-face environments. *Instructional Science, 29*(2), 127–153.
*Marttunen, M., & Laurinen, L. (2007). Collaborative learning through chat discussions and argument diagrams in secondary school. *Journal of Research on Technology in Education, 40*(1), 109–126.
*Marttunen, M., & Laurinen, L. (2009). Secondary school students' collaboration during dyadic debates face-to-face and through computer chat. *Computers in Human Behavior, 25*(4), 961–969.
*McAlister, S., Ravenscroftw, A., & Scanlon, E. (2004). Combining interaction and context design to support collaborative argumentation using a tool for synchronous CMC. *Journal of Computer Assisted learning, 20*(3), 194–204.
McCutchen, D. (1987). Children's discourse skill: Form and modality requirements of schooled writing. *Discourse Processes, 10*(3), 267–289.
*Mirza, N. M., Tartas, V., Perret-Clermont, A. P., & De Pietro, J. (2007). Using graphical tools in a phased activity for enhancing dialogical skills: An example with Digalo. *International Journal of Computer-Supported Collaborative Learning, 2*(2–3), 247–272.
*Monteserin, A., Schiaffino, S., & Amandi, A. (2010). Assisting students with argumentation plans when solving problems in CSCL. *Computers and Education, 54*(2), 416–426.
**Morgan, A. (2006). Argumentation, geography education and ICT. *Geography, 91*(2), 11–19.
Morris, R., Hadwin, A. F., Gress, C. L. Z., Miller, M., Fior, M., Church, H., & Winne, P. H. (2010). Designing roles, scripts, and prompts to support CSCL in gstudy. *Computers in Human Behavior, 26*(5), 815–824.
*Munneke, L., Andriessen, J., Kanselaar, G., & Kirschner, P. (2007). Supporting interactive argumentation: Influence of representational tools on discussing a wicked problem. *Computers in Human Behavior, 23*(3), 1072–1088.
*Munneke, L., Van Amelsvoort, M., & Andriessen, J. (2003). The role of diagrams in collaborative argumentation-based learning. *International Journal of Educational Research, 39*(1–2), 113–131.
*Muukkonen, H., Lakkala, M., & Hakkarainen, K. (2005). Technology-mediation and tutoring: How do they shape progressive inquiry discourse? *Journal of the Learning Sciences, 14*(4), 527–565.
Nastasi, B. K., & Clements, D. H. (1992). Social-cognitive behaviours and higher-order thinking in educational computer environments. *Learning and Instruction, 2*(3), 215–238.
*Noroozi, O., Biemans, H. J. A., Busstra, M. C., Mulder, M., & Chizari, M. (2011). Differences in learning processes between successful and less successful students in computer-supported collaborative learning in the field of human nutrition and health. *Computers in Human Behavior, 27*(1), 309–318.
Noroozi, O., Biemans, H. J. A., Busstra, M. C., Mulder, M., Popov, V., & Chizari, M. (in press). Effects of the Drewlite CSCL platform on students' learning outcomes. In A. Juan, T. Daradoumis, M. Roca, S. E. Grasman, & J. Faulin (Eds.), *Collaborative and distributed e-research: Innovations in technologies, strategies and applications* (pp. 0–386). IGI Global. doi:10.4018/978-1-46660-125-3.
Noroozi, O., Busstra, M. C., Mulder, M., Biemans, H. J. A., Geelen, M. M. E. E., van't Veer, P., et al. (in press). Online discussion compensates for suboptimal timing of supportive information presentation in a digitally supported learning environment. *Educational Technology Research & Development*. doi:10.1007/s11423-011-9217-2.
Nussbaum, E. M. (2002). How introverts versus extroverts approach small-group argumentative discussions? *The Elementary School Journal, 10*(3), 183–197.
*Nussbaum, E. M. (2005). The effect of goal instructions and need for cognition on interactive argumentation. *Contemporary Educational Psychology, 30*(3), 286–313.
Nussbaum, E. M. (2008a). Collaborative discourse, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology, 33*(3), 345–359.

⁎Nussbaum, E. M. (2008b). Using argumentation vee diagrams (AVDs) for promoting argument/counterargument integration in reflective writing. *Journal of Educational Psychology, 100*(3), 549–565.

Nussbaum, E. M., & Bendixen, L. D. (2003). Approaching and avoiding arguments: The role of epistemological beliefs, need for cognition, and extraverted personality traits. *Contemporary Educational Psychology, 28*(4), 573–595.

⁎Nussbaum, E. M., & Edwards, O. V. (2011). Critical questions and argument stratagems: A framework for enhancing and analyzing students' reasoning practices. *Journal of the Learning Sciences, 20*(3), 443–488.

⁎Nussbaum, E. M., & Schraw, G. (2007). Promoting argument-counterargument integration in students' writing. *Journal of Experimental Education, 76*(1), 59–92.

⁎Nussbaum, E. M., Hartley, K., Sinatra, G. M., Reynolds, R. E., & Bendixen, L. D. (2004). Personality interactions and scaffolding in on-line discussions. *Journal of Educational Computing Research, 30*(1–2), 113–137.

Nussbaum, E. M., & Kardash, C. M. (2005). The effects of goal instructions and text on the generation of counterarguments during writing. *Journal of Educational Psychology, 97*(2), 157–169.

⁎Nussbaum, E. M., Sinatra, M. G., & Poliquin, A. (2008). Role of epistemic beliefs and scientific argumentation in science learning. *International Journal of Science Education, 30*(15), 1977–1999.

⁎Nussbaum, E. M., Winsor, D. L., Aqui, Y. M., & Poliquin, A. M. (2007). Putting the pieces together: Online argumentation vee diagrams enhance thinking during discussions. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 479–500.

O'Donnell, A. M., & Dansereau, D. F. (1992). Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interactions in cooperative groups. The theoretical anatomy of group learning* (pp. 120–141). Cambridge, MA: University Press.

⁎Oh, S., & Jonassen, D. H. (2006). Scaffolding online argumentation during problem solving. *Journal of Computer Assisted Learning, 23*(2), 95–110.

Osborne, J. (2010). Arguing to learn in science. The role of collaborative, critical discourse. *Science, 328*(5977), 463–466.

⁎Overdijk, M., & Van Diggelen, W. (2008). Appropriation of a graphical shared workspace. Organizing principles and their application. *International Journal of Computer-Supported Collaborative Learning, 3*(2), 165–192.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The Journal of the Learning Sciences, 13*(3), 423–451.

Pena-Shaff, J., Martin, W., & Gay, G. (2001). An epistemological framework for analyzing student interactions in computer mediated communication environments. *Journal of Interaction Learning Research, 12*(1), 41–68.

⁎Prinsen, F. R., Volman, M. L. L., & Terwel, J. (2006). The influence of learner characteristics on degree and type of participation in a CSCL environment. *British Journal of Educational Technology, 38*(6), 1037–1055.

⁎Prinsen, F. R., Volman, M. L. L., Terwel, J., & Van den Eeden, P. (2009). Effects on participation of an experimental CSCL-programme to support elaboration: Do all students benefit? *Computers and Education, 52*(1), 113–125.

Reznitskya, A., Anderson, R. C., McNurlin, B., Nguyen-Jahiel, K., Archodidou, A., & Kim, S. Y. (2001). Influence of oral discussion on written argumentation. *Discourse Processes, 32*(2–3), 155–175.

⁎Rourke, L., & Kanuka, H. (2007). Barriers to online critical discourse. *International Journal of Computer-Supported Collaborative Learning, 2*(1), 105–126.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences, 14*(2), 201–241.

Rummel, N., Spada, H., & Hauser, S. (2009). Learning to collaborate from being scripted or from observing a model. *International Journal of Computer-Supported Collaborative Learning, 26*(4), 69–92.

⁎Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior, 21*(6), 957–975.

⁎Schellens, T., & Valcke, M. (2006). Fostering knowledge construction in university students through asynchronous discussion groups. *Computers and Education, 46*(4), 349–370.

⁎Schellens, T., Van Keer, H., De Wever, B., & Valcke, M. (2007). Scripting by assigning roles: Does it improve knowledge Construction in asynchronous discussion groups? *International Journal of Computer-Supported Collaborative Learning, 2*(2–3), 225–246.

⁎⁎Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. M. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning, 5*(1), 43–102.

⁎Schwarz, B. B., & De Groot, R. (2007). Argumentation in a changing world. *International Journal of Computer-Supported Collaborative Learning, 2*(2–3), 297–313.

⁎Schwarz, B. B., & Glassner, A. (2007). The role of floor control and of ontology in argumentative activities with discussion-based tools. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 449–478.

Schwarz, B. B., & Linchevski, L. (2007). The role of task design and argumentation in cognitive development during peer interaction. The case of proportional reasoning. *Learning and Instruction, 17*(5), 510–531.

Schwarz, B. B., Neuman, Y., & Biezuner, S. (2000). Two wrongs may make a right. If they argue together! *Cognition and Instruction, 18*(4), 461–494.

⁎Schwarz, B., Neuman, Y., Gil, J., & Ilya, M. (2000b). Construction of collective and individual knowledge in argumentative activity: An empirical study. *The Journal of the Learning Sciences, 12*(2), 219–256.

Slavin, R. E. (1986). Best-evidence synthesis: An alternative to meta-analysis and traditional reviews. *Educational Researcher, 15*(9), 5–11.

⁎⁎Spatariu, A., Linda, F. Q., & Hartley, K. (2007). A review of research on factors that impact aspects of online discussions quality. *TechTrends: Linking Research and Practice to Improve Learning, 51*(3), 44–48.

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review, 21*(4), 365–378.

Spiro, R. J., & Jehng, J. C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and muli-dimensional traversal of complex subject matter. In D. Nix & R. J. Spiro (Eds.), *Cognition education, and multimedia: Exploring ideas in high technology* (pp. 163–205). Hillsdale: Erlbaum.

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology, 48*(6), 1467–1478.

Stegmann, K., Wecker, C., Weinberger, A., & Fischer, F. (in press). Collaborative argumentation and cognitive processing in computer-supported collaborative learning environment. *Instructional Science*. doi:10.1007/s11251-011-9174-5.

⁎Stegmann, K., Weinberger, A., & Fischer, F. (2007). Facilitating argumentative knowledge construction with computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning, 2*(4), 421–447.

Stein, N. L., & Bernas, R. (1999). The early emergence of argumentative knowledge and skill. In J. Andriessen & P. Corrier (Eds.), *Foundations of argumentative text processing* (pp. 97–116). Amsterdam: Amsterdam University Press.

Strijbos, J. W., Martens, R. L., & Jochems, W. M. G. (2004). Designing for interaction: Six steps to designing computer-supported group-based learning. *Computers and Education, 42*(4), 403–424.

⁎Strijbos, J. W., Martens, R. L., Jochems, W. M. G., & Broers, N. J. (2004). The effect of functional roles on group efficiency: Using multilevel modeling and content analysis to investigate computer-supported collaboration in small groups. *Small Group Research, 35*(2), 195–229.

⁎Strijbos, J. W., Martens, R. L., Jochems, W. M. G., & Broers, N. J. (2007). The effect of functional roles on perceived group efficiency during computer-supported collaborative learning: A matter of triangulation. *Computers in Human Behavior, 23*(1), 353–380.

⁎Suthers, D. (2001). Towards a systematic study of representational guidance for collaborative learning discourse. *Journal of Universal Computer Science, 7*(3), 254–277.

⁎Suthers, D., & Hundhausen, C. (2003). An empirical study of the effects of representational guidance on collaborative learning. *Journal of the Learning Sciences, 12*(2), 183–219.
⁎Taasoobshirazi, G., & Hickey, D. T. (2005). Promoting argumentative discourse: A design-based implementation and refinement of an astronomy multimedia curriculum, assessment model, and learning environment. *Astronomy Education Review, 4*(1), 53–70.
Taboada, M., & Mann, W. (2006a). Applications of rhetorical structure theory. *Discourse Studies, 8*(4), 567–588.
Taboada, M., & Mann, W. (2006b). Rhetorical structure theory: Looking back and moving ahead. *Discourse Studies, 8*(3), 423–459.
⁎⁎Tchounikine, P. (2008). Operationalizing macro-scripts in CSCL technological settings. *International Journal Computer-Supported Collaborative Learning, 3*(2), 193–233.
Teasley, S. (1997). Talking about reasoning: How important is the peer in peer collaboration? In L. B. Resnick, R. Saljo, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools and reasoning: Essays on situated cognition* (pp. 361–384). Berlin: Springer.
Toulmin, S. (1958). *The Uses of Argument*. Cambridge, UK: Cambridge University Press.
Van Amelsvoort, M. (2006). *A space for debate. How diagrams support collaborative argumentation-based learning*. PhD dissertation, Utrecht University, The Netherlands.
⁎Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2007). Representational tools in computer-supported collaborative argumentation-based learning: How dyads work with constructed and inspected argumentative diagrams. *Journal of the Learning Sciences, 16*(4), 485–521.
⁎Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2008). How students structure and relate argumentative knowledge when learning together with diagrams. *Computers in Human Behavior, 24*(3), 1293–1313.
Van Bruggen, J. M. (2003). *Explorations in graphical argumentation: The use of external representations in collaborative problem solving*. PhD dissertation, Open University, The Netherlands.
Van Bruggen, J. M., Boshuizen, H. P., & Kirschner, P. A. (2003). A cognitive framework for cooperative problem solving with argument visualization. In P. A. Kirschner, S. J. Buckingham-Shum, & C. S. Carr (Eds.), *Visualizing argumentation: Software tools for collaborative and educational sense-making* (pp. 25–49). London: Springer.
Van Bruggen, J. M., & Kirschner, P. A. (2003). Designing external representations to support solving wicked problems. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 177–204). Dordrecht, The Netherlands: Kluwer Academic Publishers.
⁎⁎Van Bruggen, J., Kirschner, P., & Jochems, W. (2002). External representation of argumentation in CSCL and the management of cognitive load. *Learning and Instruction, 12*(1), 121–138.
Van Dinther, M., Dochy, F., & Segers, M. (2011). Factors affecting students' self-efficacy in higher education. *Educational Research Review, 6*(2), 95–108.
⁎Van Drie, J., Van Boxtel, C., Erkens, G., & Kanselaar, G. (2005). Using representational tools to support historical reasoning in computer-supported collaborative learning. *Technology. Pedagogy and Education, 14*(1), 25–41.
⁎Van Drie, J., Van Boxtel, C., Jaspers, J., & Kanselaar, G. (2005b). Effects of representational guidance on domain specific reasoning in CSCL. *Computers in Human Behaviour, 21*(4), 575–602.
Van Eemeren, F. H., & Grootendorst, R. (1992). *Argumentation, communication, and fallacies: A pragma-dialectical perspective*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Van Eemeren, F. H., & Grootendorst, R. (1999). Strategic manoeuvring in argumentative discourse. *Discourse Studies, 1*(4), 479–497.
Van Eemeren, F. H., Grootendorst, R., & Henkemans, F. S. (1996). *Fundamentals of argumentation theory: A handbook of historical backgrounds and contemporary developments*. Mahwah, NJ: Erlbaum.
Van Eemeren, F. H., Grootendorst, R., & Henkemans, F. S. (2008). Dialectical profiles and indicators of argumentative moves. *Journal of Pragmatics, 40*(3), 475–493.
Van Eemeren, F. H., Grootendorst, R., & Kruiger, T. (1987). *Handbook of argumentation theory: A critical survey of classical backgrounds and modern studies*. Foris Publications: Dordrecht.
Veerman, A. L. (2003). Constructive discussions through electronic dialogue. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (pp. 117–143). Amsterdam: Kluwer.
⁎Veerman, A. L., Andriessen, J. E. B., & Kanselaar, G. (2000). Learning through synchronous electronic discussion. *Computers and Education, 34*(3–4), 269–290.
⁎Veerman, A. L., Andriessen, J. E. B., & Kanselaar, G. (2002). Collaborative argumentation in academic education. *Instructional Science, 30*(3), 155–186.
Voss, J. F., Tyler, S. W., & Yengo, L. A. (1983). Individual differences in the solving of social science problems. In R. F. Dillon & R. R. Schmeck (Eds.), *Individual differences in cognition* (pp. 204–232). Academic Press: New York.
Voss, J. F., & Van Dyke, J. A. (2001). Argumentation in psychology: Background comments. *Discourse Processes, 32*(2–3), 89–111.
Walton, D. N. (1992). *Plausible argument in everyday conversation*. Albany, NY: State University of New York Press.
Walton, D. N. (1996). *Argumentation schemes for presumptive reasoning*. Mahwah, NJ: Lawrence Erlbaum Associates.
Walton, D. N. (2000). The place of dialogue theory in logic, computer science and communication studies. *Synthese, 123*(3), 327–346.
Walton, D. N. (2006). Examination dialogue: An argumentation framework for critically questioning an expert opinion. *Journal of Pragmatics, 38*(5), 745–777.
Wegner, D. M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), *Theories of group behavior* (pp. 185–208). New York: Springer-Verlag.
Wegner, D. M. (1995). A computer network model of human transactive memory. *Social Cognition, 13*(3), 1–21.
⁎Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science, 33*(1), 1–30.
⁎⁎Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers and Education, 46*(1), 71–95.
Weinberger, A., Stegmann, K., & Fischer, F. (2005b). Computer-supported collaborative learning in higher education: Scripts for argumentative knowledge construction in distributed groups. In T. Koschmann, D. D. Suthers, & T. K. Chan (Eds.), *Computer supported collaborative learning: The next 10 years!* (pp 717–726). Mahwah, NJ: Erlbaum.
⁎Weinberger, A., Stegmann, K., & Fischer, F. (2010). Learning to argue online. Scripted groups surpass individuals (unscripted groups do not). *Computers in Human behavior, 28*(4), 506–515.
Weinberger, A., Stegmann, K., Fischer, F., & Mandl, H. (2007). Scripting argumentative knowledge construction in computer-supported learning environments. In F. Fischer, H. Mandl, J. Haake, & I. Kollar (Eds.), *Scripting computer-supported communication of knowledge – cognitive, computational and educational perspectives* (pp. 191–211). New York: Springer.
⁎Yiong-Hwee, T., & Churchill, D. (2007). Using sentence openers to support students' argumentation in an online learning environment. *Educational Media International, 44*(3), 207–218.