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Contemporary intellectual structure of CSCL research (2006–2013): a co-citation network analysis with an education focus

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Abstract This present study endeavors to discover the scholarly communication structure in the CSCL knowledge domain. To explore the intellectual structure of contemporary literature of CSCL research from 2006 to 2013, over a thousand research papers indexed in the leading journal publications and conference proceedings were retrieved from WOS. Accordingly, this paper adopted a series of methods to analyze these research articles from macro to micro level, including document co-citation analysis (DCA), exploratory factor analysis (EFA), and social network analysis (SNA). As a result, a total of 7,552 and 2,180 co-citation ties were obtained from 403 to 66 source papers, respectively. In addition, six intellectual subfields within the CSCL literature were extracted, namely: (1) representation, discourse & pattern, (2) factors influencing CSCL, (3) intervention and comparison, (4) critical reasoning, (5) process of social construction, and (6) design and modeling of CSCL. Central documents and publications within contemporary CSCL research were identified and presented in the undirected co-citation networks from both macro and micro perspectives. Furthermore, the dissemination of underlying subfields and pivotal documents serving as a boundary-spanning role were discussed. This is the very first attempt to integrate the bibliographical method, statistical analysis, and visualization techniques in relation to contemporary CSCL research. Further discussion and research directions for future CSCL study are provided.

Keywords Computer supported collaborative learning (CSCL) · Document co-citation analysis (DCA) · Exploratory factor analysis (EFA) · Social network analysis (SNA) · Literature review

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Introduction

The philosophy of collaborative learning has had a long-standing history since 1940 (Sharan 2010). The development of computer supported collaborative learning (CSCL) is relatively new, and CSCL has been considered as one of the contemporary research trends and an emerging branch of the learning sciences because of great supports from the rapid development of learning technologies (Lonchamp 2012; Long et al. 2013; Scheuer et al. 2010; Stahl et al. 2006). Taking advantage of these supports, such as graphical representational tools and technology-mediated interaction (Janssen et al. 2007; Suthers et al. 2008; Van Amelsvoort et al. 2007), CSCL facilitates users' collaborative inquiry and learning together with social interactions (Stahl et al. 2006).

First appearing in the 1990s, the development of CSCL research has continued for over 20 years (Stahl et al. 2006). According to the investigation in the Web of Science, there were 31 pioneering research papers published during the 1990s, and the trend continued to develop until the early 2000s. To date (retrieved, January 16th, 2013), over 1,000 CSCL studies (appeared in the journal publications and conference proceedings) have been published, successfully generating a significant impact with 5,000 citations.

The existing fruitful literature provides appropriate material for the analysis of the research trajectory in the CSCL community. Based on the literature development, researchers may turn their attention towards performing a systematic literature review when an academic discipline has reached a certain degree of maturity (Lee et al. 2009; Lin et al. 2014; Tsai and Wen 2005). By means of experienced experts' opinions, some prestigious review works have provided insightful overviews for field researchers in this manner (Kirschner and Erkens; 2013; Stahl et al. 2006; Suthers 2006). While qualitative review research based on experts' opinions can provide valuable insights for understanding the development of CSCL research, a review from a quantitative perspective based on longitudinal data analyses is also necessary. Through longitudinal data retrieval, a quantitative review can provide a large-scale platform for further scholarly discussion. Therefore, it is worthwhile in a field of growing CSCL literature to use different but complementary methods to provide insights into the ways of scholarly communication (Lonchamp 2012).

Document co-citation analysis, one of the best-known structuring methods of bibliometrics (Small 1973; Small and Griffith 1974), is useful to identify authors or documents belonging to the same discipline (or field) by analyzing the references. Accordingly, the current paper employed document co-citation with additional analyses of factor analysis to assess the contributions of documents and delineate the distinct subfields within the realm of CSCL.

Social network analysis was also adopted to profile the centrality features of the co-citation network of the selected documents (Freeman 1979). This method permits the exploration of existing linkages between the most central and prominent works within the focal discipline (Wasserman and Faust 1994; Scott 1991). The advantage of a social network is that it can propose a complementary viewpoint from the citation side and provide a visualizing map of interdisciplinary scholarly communications (White 2003), especially in recent educational research (Chen and Lien 2011; Lonchamp; 2012; Tight 2008).

Taking them together, the present study undertook an exploratory analysis using these three approaches to reach the following objectives: (1) identify the core documents, publications and underlying subfields which constitute the intellectual structure of CSCL; (2) identify boundary spanning documents which play a pivotal role in bridging two or more conceptual domains of research; and (3) graphically map the intellectual structure of contemporary CSCL research that emerge from the relationships generated by the co-citation base.

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Literature review

Review studies on CSCL

Prior CSCL studies and many of its applications have covered diverse research topics, methodologies, and representatives of various research communities during the past two decades. Stahl and his colleagues (2006) proposed a general review of CSCL from a historical perspective to illustrate the changes in trends, for example, from artificial intelligence to collaboration support, from individuals to interacting groups, from mental representations to meaning making by interaction, and from quantitative comparisons to micro-case studies. Stahl et al. (2006) suggested that the current focus of learning within CSCL is through collaboration with other learners rather than directly from the instructors, or even computers. They also pointed out that the future research direction is to integrate new theories, methodologies, and technologies in the support of collaborative learning. Suthers (2006) proposed an integrated research agenda for CSCL from the viewpoint of technology affordances for intersubjective meaning making. A working definition of intersubjective meaning making is close to joint interpretations. Suthers (2006) suggested that intersubjective epistemologies of learning are a simultaneous process of interaction within CSCL; therefore, CSCL research should identify how collaborators appropriately perceive the affordances of technology.

More recently, Kirschner and Erkens (2013) proposed a multidimensional research framework, including level of learning (e.g., cognitive, social, and motivational), unit of learning (e.g., individual, group/team, and community), and pedagogical measures (e.g., interactive, representational, and guiding). This framework provides an insightful classification of existing publications and directions for future research.

In sum, previous work illuminated core ideas underlying the CSCL research from the viewpoints of experienced researchers by providing qualitative review. This current study, however, introduces a bibliometric analysis to provide a complementary approach to capture the ongoing developments of CSCL literature with all of its expanding and diverse subjects.

Document co-citation analysis

Document co-citation analysis (DCA), a bibliographic method, is a computational analysis based on citation frequency (Small 1973). DCA is often used to evaluate the network or the degree of relationships between documents according to their joint citations (Small 1973). Ramos-Rodríguez and Ruíz-Navarro (2004) suggested that periodical papers with peer review have shown their reliability after rough evaluation, which further confirms the value of document co-citation.

Small (1973) defined document co-citation analysis as a measure of the relationship degree between papers as perceived by the population of citing authors. Small and Griffith (1974) further explained that each document expresses its concepts, methods, or concepts which are commonly found by the citing documents. These co-citation analyses are therefore suggested as a representation of "the field's view" (White and Griffith 1981). By definition, a document co-citation pair is counted when two papers are jointly cited in the same citing document (Small 1973). Accordingly, the more counts of co-citation that two documents receive, the higher their co-citation strength, and the more likely they are to be bibliographically related. In other words, these two cited papers are assumed to have a higher degree of similarity.

Numerous studies have demonstrated that the document co-citation method is a valid approach to exploring the intellectual structure of various scientific disciplines (Acedo et al. 2006a; Borgman and Furner 2002; Di Stefano et al. 2010; Hsiao and Yang 2011; Peteraf et al. 2013; Small 1973; White and McCain 1998). Recently, related co-citation analysis has also been gradually adopted in education and educational research (Carolan and Natriello 2005; Chen and Lien 2011; Lonchamp 2012; Tight 2008; Tuire and Erno 2001).

To conclude, document co-citation analysis is an effective method to identify the intellectual structure of documents that belong to the same discipline within the CSCL literature. Furthermore, the use of document co-citation analysis is helpful in understanding how CSCL studies relate to each other, representing the CSCL field's view of itself.

Social network analysis

Originating from modern sociology, social network analysis (SNA) is designated to express the complex sets of relationships between members of social systems of all scales from interpersonal, inter-organizational to international relationships (Wasserman and Faust 1994). Therefore, the technique of SNA is considered as a broad strategy of structural analysis for investigating the social structure of scholarly communication (Wellman and Berkowitz 1988; White 2003).

SNA views individual actors within a network and their relationships as nodes and ties, which are usually denoted as circles and lines in a social network diagram (Borgatti et al. 2002). Embedded in graph layout algorithms, SNA is advantageous when performing a visual network diagram of bibliographic analysis to demonstrate nodes and ties in the directed or even undirected graphs (Everton 2004; Otte and Rousseau 2002).

In addition, the layout of each node presented in the undirected co-citation graph is visualized by spring embedding algorithm which is built in NetDraw module of UCINET version 6.499 (Borgatti et al. 2002). The spring embedding algorithm is a graph-drawing algorithm which seeks the optimal location with minimal stress to position nodes in the network (Everton 2004). Detailed information about the algorithm for drawing undirected graphs behind UCINET can be found in the research of Fruchterman and Reingold (1991) as well as Kamada and Kawai (1989).

Recently, the technique of visualization has been recognized as a useful tool for realizing and mapping the interdisciplinary scholarly communications in education research (Chen and Lien 2011; Desmedt and Valcke 2004; Lonchamp 2012; Tight 2008). Accordingly, the results of co-citation analysis are visualized through combining the SNA technique to express the complex sets of relationships among CSCL research documents. In the meantime, the co-citation patterns can be used to map out in great detailed relationships between these key ideas.

Methodology

To explore the literature structure of contemporary CSCL empirical studies, document co-citation analysis is used as an initial approach to matching the bibliographic data into co-citation pairs. Adapted from McCain's (1990) research process, the current study started with paper selection, bibliographic data retrieval, and the computation and compilation of a co-citation matrix. After the bibliographic analysis, exploratory factor analysis and social network analysis were utilized to present a co-citation network. Finally, interpretations and future

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research directions based on the above analysis are provided at the end of this paper. The detailed research flow chart is presented as Fig. 1.

Document co-citation analysis

Selection of CSCL research

The most critical step for co-citation analysis is to select the source papers; therefore, the set of source documents must be as large as possible to cover all the evolution within the theory (McCain 1990). To meet this research goal, a systematic data querying procedure is adopted to ensure that the set of CSCL research was relevant and representative for constructing the initial paper set.

First, a multi-keywords searching strategy is used to query the initial data in WOS. The set of keyword combinations used to construct initial dataset was consulted with a renowned professor and an experienced postdoctoral researcher in science education. In this study, several core concepts of CSCL were used to collect all relevant CSCL research, including: "collaborative learning" and "educational technology", "computer-supported collaborative learning*", and "computer supported collaborative learning*". The star sign (*) is to enlarge the dataset with different naming conventions "Computer Supported Collaborative Learning" and "Computer-Supported Collaborative Learning" in its topic terms. Note that top three research categories of keyword searches from WOS are listed as "Education & Educational Research (EER)", "Computer Science", and "Psychology". However, the research domain of EER is closer to the research paradigm of CSCL community suggested by Stahl (2002) than the other two, and thus it is the main interest of this study. In this manner, the category of "Education & Educational Research" in the Web of Science is used to refine the searching results to align with the research interest of this study.

In addition to journal papers, research presented on the conferences have been gradually emphasized and viewed as the contemporary research within the CSCL community (Hoadley 2005; Kienle and Wessner 2005, 2006; Wessner and Kienle 2007; Stahl 2002). In this manner, two additional databases for conference proceedings (i.e., Conference Proceedings Citation Index- Science (CPCI-S) and Conference Proceedings Citation Index- Social Sciences & Humanities (CPCI-SSH)) are used to enlarge the initial dataset. As a result, all related papers are retrieved using the above keywords in these databases.

Last, in order to exhaust important CSCL papers which may not be found from the above selected keywords, the current study further included papers published in the *International Journal of Computer-Supported Collaborative Learning* (ijCSCL) into the initial dataset. The aim of ijCSCL is to facilitate the development of the international CSCL research, and ijCSCL is ranked as one of the first tier journals in the field of education. This procedure can increase the research quality and avoid the gap by keyword searches. Additionally, in line with the publication period of ijCSCL and two prominent CSCL review articles (Suthers 2006; Stahl et al. 2006), the research period of this current study is set from 2006 to 2013.

After applying the search criteria mentioned above, a total of 1,438 papers were obtained, among which 692 were cited at least twice to satisfy the minimum requirement of co-citation analysis. After removing replicated papers and incomplete records, 403 documents were obtained and nominated as the initial dataset for the following investigation. This set of source documents was considered as a collection of representative papers related to CSCL research that appeared in the journals and conference proceedings. This great number of documents can

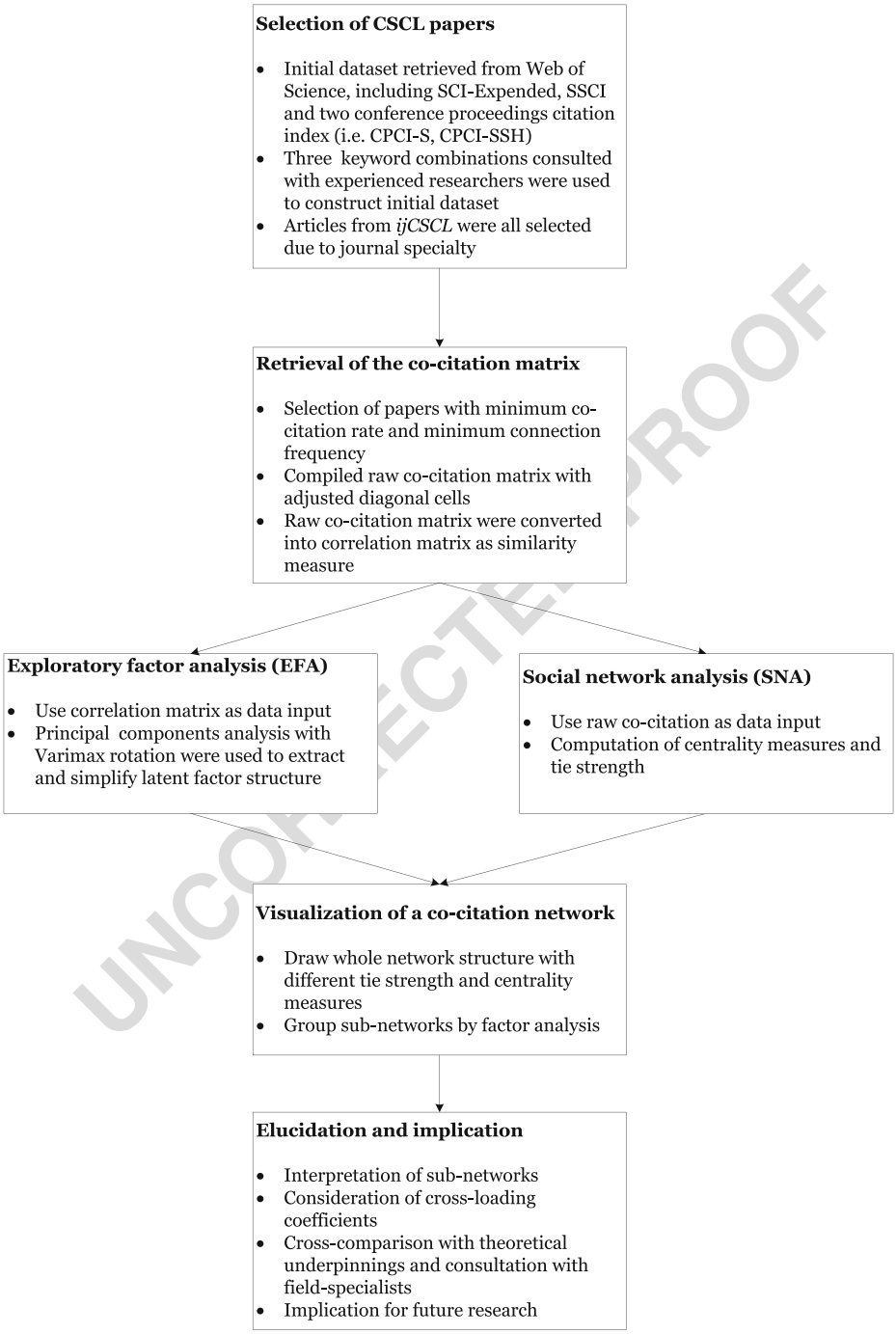

Fig. 1 Research flow chart (adapted from McCain 1990)

be treated as a well-theoretical foundation for investigating a broad expansion of CSCL literature. The research process is shown as Table 1.

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t1.1 **Table 1** Keywords search results from the Web of Science (2006–2013)

t1.2 Search history[a]	Results	
t1.3	Number of articles which in the EER[b] category	Number of articles which listed in the EER category and have been cited at least twice times[c]
t1.4 In SCI/SSCI/A&HCI database (for journal papers)		
t1.5 TS = (Collaborative learning & educational technology)	132	81
Q3 t1.6 TS = (Computer-supported collaborative learning*)	253	177
t1.7 TS = (Computer supported collaborative learning*)	363	249
t1.8 In CPCI-S/CPCI-SSH database (for conference papers)		
t1.9 TS = (Collaborative Learning & Educational Technology)	196	19
t1.10 TS = (Computer-Supported Collaborative Learning*)	113	13
t1.11 TS = Computer Supported Collaborative Learning*)	185	21
t1.12 For articles published in the ijCSCL		
t1.13 SO = (International Journal of Computer-Supported Collaborative Learning)	196	132
t1.14 Subtotal	1,438	692

[a] Databases: database for searching journal articles: *SCI* sciences citation index, *SSCI* social sciences citation index; database for searching conference articles: *CPCI-S* conference proceedings citation index- science, *CPCI-SSH* conference proceedings citation index- social sciences & humanities

[b] EER represents the research domain of "Education & Educational Research", which is categorized in the Web of Science. In the latest edition of journal citation reports 2012, the EER category consists of 219 journal publications. The research scope of EER covers major issues in educational research. In this manner, the EER category is used to refine searching results from both SCI/SSCI and CPCI-S/CPCI-SSH to align with the research interest in this study

[c] Citation counts were accumulated until the access date: December 13, 2013

Retrieval of the co-citation matrix

Overall, the pool of 403 source documents received a total of 5,351 times cited. It takes two weeks until December 26, 2013 to finish the documents collection process in which 5,351 citing articles were retrieved document by document. Then, each of the 403 documents was paired with every other document for computing co-citation frequency. As a result, a symmetric matrix of 403 by 403 was created and computed (i.e., raw co-citation matrix). Each cell in the matrix represents the counts of a co-citation pair by matching every other source document within the 5,351 citing articles. It is assumed that cited papers are considered to be important by citing authors in their research domain. Through analyzing the highly cited papers inside the field, these papers' core concepts, theories, and methods can be extracted out to provide researchers clues to understand the interrelationships between invisible colleges in the field (de Solla Price 1965; Small 1973). In this study, the co-citation analysis of 403 source documents (endorsed by 5,351 citing papers) can represent "the field's view" of itself (White and Griffith 1981), then inspiring the self-reflection of the CSCL research.

Exploratory factor analysis

Exploratory factor analysis (EFA) is a multivariate statistical method used to reduce the number of dimensions. Accompanying the bibliometric purposes, EFA played an intermediate role of analysis to extract latent common factors and derive the subfields from the co-citation matrix in this study (McCain 1990; White and Griffith 1981). In this manner, the raw co-citation matrix is transformed into Pearson's correlation matrix to satisfy the statistical requirements of EFA. White (2003) concluded that Pearson's r performs well enough for the purposes of co-citation research, mainly because the standardized scale in the correlation matrix can avoid the scale effect of raw count.

Documents in specialized areas tended to cite some researchers' concepts or be co-cited by others within the field (Small 1973). Therefore, those documents are prone to be loaded on the same factor. According to Small and Griffith (1974), each subfield corresponding to the extracted factors represented an intellectual theme defined by authors who were loaded highly on that subfield/factor. In this sense, a factor is interpreted or defined by those documents with loadings greater than ±0.7 in document citation analysis (McCain 1990). Moreover, the amount of variance explained by a factor can be viewed as its contribution to the conceptual foundation of the field. By the use of EFA, the salient subgroups of documents, which show the positional trends within the CSCL area, can be clearly identified.

Social network analysis

Network researchers suggested that the major contribution of SNA is to provide a relative novel approach of visualizing the most prominent documents in a network (Scott 1991; Wasserman and Faust 1994). In this sense, the use of SNA is helpful to present a "full picture" toward understanding the CSCL literature, shedding lights on scholarly communications within the CSCL community. However, it is necessary to differentiate between directed and undirected networks. In bibliographic study, directed graph usually refers to a citation analysis, which is based on publication time. Thus a "direction" here indicated the citation relationship from citing author(s) to cited author(s). Instead, an undirected graph used in the co-citation research is to present a measure of the co-citation relationships among paired documents (or authors) which were perceived by the population of citing authors (Small 1973). Through analyzing these relationships from the population of citing authors, researchers have opportunities to access to other researchers whom previously may have been unknown to them (Acedo et al. 2006b). These interactions performed in the bibliographical contexts are as the network of invisible colleagues. Therefore, an undirected graph is more appropriate to express the overall structure of co-citation patterns (Acedo et al. 2006b; Otte and Rousseau 2002). In other words, there is no arrow head in the co-citation network studied here.

Characteristics of network: centrality measures

Another interesting issue by using SNA to present a bibliographic structure is to analyze how central position a CSCL research holds within a research network. In this manner, three measures of centrality (i.e., degree, closeness, and betweenness), reflecting how central position of a particular node plays, are used to capture the roles of actors in the relational networks (Freeman 1979; Scott 1991). According to Freeman (1979), "degree" of points is to measure the connectedness among actors. While "closeness" is the index of nodes' independence, "betweenness" of nodes is the index of potential for controlling communications.

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Degree centrality, by definition, is the number of immediate connected ties that a node has. As the most straightforward centrality, degree centrality is usually used to reflect the extent of a research paper's connectedness with other nodes (i.e., co-citation) in the networks. Closeness centrality measures the geodesic distance of a node from other nodes in a network. Here, geodesic distance means the shortest path between two nodes. The higher value of the closeness centrality, the larger size of a node presented in the network, and the less central role of information diffuser it will be. Finally, betweenness centrality, reflecting the documents' bridging location, quantifies the extent of a node that acts as a bridge along the shortest path between two nodes (Acedo et al. 2006a). In other words, a high betweenness centrality indicates that a document plays a bridging role among different documents (Otte and Rousseau 2002). While the degree centrality is straightly presented as the number of linked ties, the closeness and betweenness centralities are normalized measures based on Freeman's (1979) approach.

The complementary viewpoints: the EFA and SNA

One more issue in terms of the relationship between the results of the EFA and SNA is noted here. Overall, the intellectual structure of CSCL research visualized by two data inputs is the same. Therefore, researchers have adopted SNA as a complementary approach to further augment and cross-validate the results of factor analysis in terms of center–periphery configurations and specialties (Acedo et al. 2006b; Nerur et al. 2008; Pilkington and Meredith 2009; Uysal 2010; Weigel et al. 2013). In this sense, the results of the EFA and the SNA can be viewed as complementary approaches to study the document co-cited phenomenon within the CSCL literature. This study provided the very first attempt to integrate the bibliometrics, statistical analysis, and visualization technique to examine the underlying academic relationships within CSCL community.

Results

Results of the co-citation analysis

After bibliographic data for the whole sample of CSCL research were retrieved (including 403 source articles and 5,351 citing papers), co-citation frequency of each pair is counted using 5,351 citing data and complied into a co-citation matrix. In this matrix, the rows and columns are the source documents and each cell represents the frequency of co-citation pairs. It should be noted that the results of upper and lower matrices cross diagonal line are identical. The larger amounts of jointly cited in the cell, the more likely two documents are bibliographically similar. The results of top ten co-cited CSCL papers are demonstrated as shown in Table 2.

Overall, a total of 15,104 co-citation pairs are found in the current study, indicating the existence of 7,552 ties in each triangle matrix. Among these, the highest co-cited works appeared in the circled pair of De Wever et al.'s work (2006) and Weinberger and Fischer's work (2006). This pair has been counted over 32 times, suggesting a tight connection and a high similarity of two seminal papers.

Previous co-citation studies usually employed citation count as a single threshold for the selection of core papers (Acedo et al. 2006a; Hsiao and Yang 2011; Nerur et al. 2008). In this paper, however, two aspects from co-citation and citation counts have been taken into consideration. The thresholds for citation counts and co-citation counts were 5 and 50, respectively. As a result, 66 cores were obtained from 403 source documents (Table 3). This

t2.1 **Table 2** A raw co-citation matrix of top ten co-cited CSCL papers

t2.2 Label	a	b	c	d	e	f	g	h	i
t2.3 KobbeWDHHHF2007(76)	7	5	17	3	7	6	6	4	24
t2.4 WeinbergerF2006(130)		32	16	19	7	10	0	9	5
t2.5 DeWeverSVV2006(130)			4	29	3	11	3	11	4
t2.6 StegmannWF2007(46)				2	2	5	2	3	11
t2.7 StrijbosMPJ2006(107)					7	10	2	8	2
t2.8 Suthers2006(84)						5	2	1	5
t2.9 DeWeverVSV2007(46)							1	6	4
t2.10 CressK2008(67)								1	3
t2.11 SchellensV2006(64)									4

a = WeinbergerF2006(130); b = DeWeverSVV2006(130); c = StegmannWF2007(46); d = StrijbosMPJ2006(107); e = Suthers2006(84); f = DeWeverVSV2007(46); g = CressK2008(67); h = SchellensV2006(64); i = DillenbourgT2007(92)

The label is for the use of presentation in the following analyses, and contains the first author's last name and abbreviations of all co-authors of the publication. Full details of the core papers are listed in the references preceded by an asterisk

suggested that the core papers selected here have an exalted reputation in the CSCL community.

Among 403 documents, 339 (84 %) were selected from journal publications. Top three sources are: *International Journal of Computer-Supported Collaborative Learning* (n=128), *Computers & Education* (n=117), and *Educational Technology & Society* (n=26). In addition, 38 (9 %) were selected from conference proceedings and top three sources are: *8th International Conference on Computer Supported Collaborative Learning* (n=10), *8th IEEE International Conference on Advanced Learning Technologies* (n=3), *Biennial Conference on Computer Assisted Learning* (n=3), and *Symposium on Learning in Digital Worlds* (n=3). Furthermore, fifteen documents are review articles (4 %), and 11 are editorial materials (3 %).

Finally, to standardize the measurement scale and avoid discrepancy, the 66 by 66 co-citation matrix deriving from the set of source documents was converted into a Pearson's correlation matrix as a measure of similarity for further data analysis.

Results of the exploratory factor analysis

In order to discover the underlying structure of CSCL research, exploratory factor analysis (EFA) was employed. Since EFA is based on the correlation matrix, the raw co-citation matrix needs to be transformed into a Pearson's correlation matrix (White 2003). In this manner, the Bartlett's test of Sphericity statistics was used to examine the adequacy of the transformed dataset. The result of the test was significant (p<0.000), indicating that the transformed dataset was appropriate for the use of factor analysis (Kaiser 1974).

Then, a principal component analysis adopting the Varimax rotation procedure was used to extract latent common factors. As a whole, there were 44 latent common factors extracted from the all sample of 403 CSCL source documents. Although these factors have indeed reduced the dimensionality (strictly speaking, there are 403 latent factors in total), the variability explained by these 44 components is not as high as expected (81 % in total). Practically, it is too complex to describe and demonstrate the results.

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t3.1 **Table 3** Set of source documents of 66 core papers

t3.2	Label	Publication	Co-citations	Citations	Citations per year
t3.3	KobbeWDHHHF2007(76)	Kobbe et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	375	76	12.7
t3.4	WeinbergerF2006(130)	Weinberger and Fischer (2006), *Computers & Education*.	367	130	18.6
t3.5	DeWeverSVV2006(130)	De Wever et al. (2006), *Computers & Education*.	353	130	18.6
t3.6	StegmannWF2007(46)	Stegmann et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	323	46	7.7
t3.7	StrijbosMPJ2006(107)	Strijbos et al. (2006), *Computers & Education*.	264	107	15.3
t3.8	Suthers2006(84)	Suthers (2006), *International Journal of Computer-Supported Collaborative Learning*.	227	84	12
t3.9	DeWeverVSV2007(46)	De Wever et al. (2007), *Learning and Instruction*.	223	46	7.7
t3.10	CressK2008(67)	Cress and Kimmerle (2008), *International Journal of Computer-Supported Collaborative Learning*.	198	67	13.4
t3.11	SchellensV2006(64)	Schellens and Valcke (2006), *Computers & Education*.	194	64	9.1
t3.12	DillenbourgT2007(92)	Dillenbourg and Tchounikine (2007), *Journal of Computer Assisted Learning*.	183	92	15.3
t3.13	Schrire2006(91)	Schrire (2006), *Computers & Education*.	174	91	13
t3.14	WeinbergerSF2007(44)	Weinberger et al. (2007), *Learning and Instruction*.	158	44	7.3
t3.15	KollarFS2007(39)	Kollar et al. (2007), *Learning and Instruction*.	157	39	6.5
t3.16	RoseWCASWF2008(50)	Rose et al. (2008), *International Journal of Computer-Supported Collaborative Learning*.	151	50	10
t3.17	ArnsethL2006(34)	Arnseth and Ludvigsen (2006), *International Journal of Computer-Supported Collaborative Learning*.	130	34	4.9
t3.18	ErkensJ2008(24)	Erkens and Janssen (2008), *International Journal of Computer-Supported Collaborative Learning*. (draft is presented on International Conference on Computer Support for Collaborative Learning)	129	24	4.8
t3.19	Tchounikine2008(23)	Tchounikine (2008), *International Journal of Computer-Supported Collaborative Learning*.	125	23	4.6
t3.20	JanssenEKJ2007(54)	Janssen et al. (2007), *Computers & Education*.	123	54	9
t3.21	SchellensVDV2007(25)	Schellens et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	121	25	4.2
t3.22	CakirZS2009(20)	Cakir et al. (2009), *International Journal of Computer-Supported Collaborative Learning*.	121	20	5

t3.23 **Table 3** (continued)

	Label	Publication	Co-citations	Citations	Citations per year
t3.24	DillenbourgH2008(40)	Dillenbourg and Hong (2008), *International Journal of Computer-Supported Collaborative Learning.*	110	40	8
t3.25	JonesDL2006(32)	Jones et al. (2006), *International Journal of Computer-Supported Collaborative Learning.*	108	32	4.6
t3.26	ScheuerLPM2010(30)	Scheuer et al. (2010), *International Journal of Computer-Supported Collaborative Learning.*	108	30	10
t3.27	Cress2008(29)	Cress (2008), *International Journal of Computer-Supported Collaborative Learning.*	107	29	5.8
t3.28	StrijbosF2007(33)	Strijbos and Fischer (2007), *Learning and Instruction.*	102	33	5.5
t3.29	BuderB2008(18)	Buder and Bodemer (2008), *International Journal of Computer-Supported Collaborative Learning.*	96	18	3.6
t3.30	KapurK2009(24)	Kapur and Kinzer (2009), *International Journal of Computer-Supported Collaborative Learning.*	93	24	6
t3.31	DeLaatLLS2007a(31)	De Laat et al. (2007b), *Instructional Science.*	92	31	5.2
t3.32	VanderpolAS2006(19)	van der Pol et al. (2006), *International Journal of Computer-Supported Collaborative Learning.*	92	19	2.7
t3.33	JeongJ2007(34)	Jeong and Joung (2007), *Computers & Education.*	91	34	5.7
t3.34	JanssenEKK2010(13)	Janssen et al. (2010), *Instructional Science.*	90	13	4.3
t3.35	SchwarzG2007(15)	Schwarz and Glassner (2007), *International Journal of Computer-Supported Collaborative Learning.*	88	15	2.5
t3.36	VanAmelsvoortAK2007(24)	Van Amelsvoort et al. (2007), *Journal of the Learning Sciences.*	86	24	4
t3.37	SuthersDMV2010(14)	Suthers et al. (2010), *International Journal of Computer-Supported Collaborative Learning.*	84	14	4.7
t3.38	BaghaeiMI2007(26)	Baghaei et al. (2007), *International Journal of Computer-Supported Collaborative Learning.*	82	26	4.3
t3.39	LundMSB2007(16)	Lund et al. (2007), *International Journal of Computer-Supported Collaborative Learning.*	82	16	2.7
t3.40	SuthersVMJD2008(37)	Suthers et al. (2008), *Computers & Education.*	81	37	7.4
t3.41	VanaalstC2007(34)	van Aalst and Chan (2007), *Journal of the Learning Sciences.*	81	34	5.7
t3.42	RourkeK2007(17)	Rourke and Kanuka (2007), *International Journal of Computer-Supported Collaborative Learning.*	76	17	2.8
t3.43	JermannD2008(24)	Jermann and Dillenbourg (2008), *Computers & Education.*	74	24	4.8
t3.44	NorooziBMBTGVC2012(6)	Noroozi et al. (2012), *Educational Technology Research and Development.*	73	6	6

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t3.45 **Table 3** (continued)

	Label	Publication	Co-citations	Citations	Citations per year
t3.46	MeierSR2007(37)	Meier et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	71	37	6.2
t3.47	Reimann2009(22)	Reimann (2009), *International Journal of Computer-Supported Collaborative Learning*.	70	22	5.5
t3.48	SchwarzD2007(19)	Schwarz and De Groot (2007), *International Journal of Computer-Supported Collaborative Learning*.	68	19	3.2
t3.49	IsotaniIIM2009(10)	Isotani et al. (2009), *International Journal of Computer-Supported Collaborative Learning*.	68	10	2.5
t3.50	HernandezLeoVADJRR2006(63)	Hernandez-Leo et al. (2006), *Educational Technology & Society*.	66	63	9
t3.51	Ding2009(10)	Ding (2009), Computers & Education.	65	10	2.5
t3.52	MirzaTPD2007(7)	Mirza et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	65	7	1.2
t3.53	Jeong2006(9)	Jeong (2006), *Instructional Science*.	64	9	1.3
t3.54	NaiduJ2006(22)	Naidu and Jarvela (2006), *Computers & Education*.	62	22	3.1
t3.55	HämäläinenH2010(8)	Hämäläinen and Häkkinen (2010), *Teaching and Teacher Education*.	62	8	2.7
t3.56	BakerALVQ2007(18)	Baker et al. (2007), *International Journal of Computer-Supported Collaborative Learning*.	61	18	3
t3.57	AsterhanS2010(11)	Asterhan and Schwarz (2010), *International Journal of Computer-Supported Collaborative Learning*.	61	11	3.7
t3.58	ErtlKM2008(13)	Ertl et al. (2008), *Computers & Education*.	59	13	2.6
t3.59	StegmannWWF2012(8)	Stegmann et al. (2012), *Instructional Science*.	59	8	8
t3.60	DeweverVSV2010(7)	De Wever et al. (2010), *Learning and Instruction*.	59	7	2.3
t3.61	OnrubiaE2012(5)	Onrubia and Engel (2012), *International Journal of Computer-Supported Collaborative Learning*.	58	5	5
t3.62	StahlH2009(8)	Stahl and Hesse (2009), *International Journal of Computer-Supported Collaborative Learning*.	57	8	2
t3.63	DeSmetVV2008(20)	De Smet et al. (2008), *Computers & Education*.	56	20	4
t3.64	Arvaja2007(15)	Arvaja (2007), *International Journal of Computer-Supported Collaborative Learning*.	55	15	2.5
t3.65	DeLaatLLS2007b(19)	De Laat et al. (2007a), *International Journal of Computer-Supported Collaborative Learning*.	54	19	3.2
t3.66	DeWeverVSV2009(17)	De Wever et al. (2009), *Journal of Computer Assisted Learning*.	53	17	4.3
t3.67	PrinsenVTV2009(8)	Prinsen et al. (2009), *Computers & Education*.	53	8	2

t3.68 **Table 3** (continued)

Label	Publication	Co-citations	Citations	Citations per year
t3.69 JonassenK2010(12)	Jonassen and Kim (2010), *Educational Technology Research and Development*.	52	12	4
t3.70 Lonchamp2006(16)	Lonchamp (2006), *International Journal of Computer-Supported Collaborative Learning*.	50	16	2.3
t3.71 VanAalst2009(15)	van Aalst (2009), *International Journal of Computer-Supported Collaborative Learning*.	50	15	3.8
t3.72 Subtotal		7,490	2,161	6

The collection process of all times cited references for each core had continued for two weeks until December 26, 2013

Instead, co-citation patterns of 66 core papers, which were screened out from whole sample with two thresholds of citation and co-citation counts, can be considered as representative for conveying the intellectual structure of CSCL research in a relative simple structure. As shown in Table 4, six factors were extracted with 83 % of the explained variance. All factor loadings greater than ±0.4 was revealed in the results (McCain 1990). Most CSCL articles were loaded on one specific factor with high loadings, and each factor revealed the underlying subject matter (loading greater than ±0.7). This is useful in elucidating a latent factor and also provides evidence for the validity of the latent structure. As a result, each factor was named based on a general assessment of the research areas represented by documents with leading factor loadings as well as the terminology used in the CSCL literature.

The first emerging factor was named as "representation, discourse, and pattern", accounting for almost one third of the total variance (27.43 %). This main stream containing 23 research findings mainly discusses the methodological issues in CSCL studies (e.g., Cress 2008; De Wever et al. 2007; Schrire 2006; Strijbos and Fischer 2007; Strijbos et al. 2006; Suthers 2006), as well as the effects of representational tools on learning, such as text or diagrams, visualization of participation, and knowledge maps. Factor 1 also consists of some issues regarding critical discourse and the patterns of CSCL, such as communication patterns, interaction, and teaching assistance. Note that this first research stream has been cited over thousand times and been co-cited over 3,000 times in total. Most of the leading works are mainly from *Computers & Education, International Journal of Computer-Supported Collaborative Learning,* and *Learning and Instruction*.

Led by a position research paper (Jonassen and Kim 2010), factor 2 exhibits the research of "factors influencing CSCL", accounting for 21.86 % variance explained. This second popular community of CSCL deals with the issues of certain factors affecting CSCL, such as the skills of critical thinking and argumentation (e.g. Jeong and Joung 2007; Lund et al. 2007; Scheuer et al. 2010; Stegmann et al. 2012; Van Amelsvoort et al. 2007), technological guidance, and theory-driven characteristics. Factor 3 represents "intervention and comparison", accounting for 16.48 % of variance explained. It examines themes of CSCL through varying treatments, such as technological settings, contextual settings, and scripting activities (Dillenbourg and Hong 2008; Dillenbourg and Tchounikine 2007; Tchounikine 2008). Two areas have attracted a number of 350 citations and 1,500 co-citations during the period of investigation. Research

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t4.1 **Table 4** Results of the exploratory factor analysis

t4.2 Core paper	Representation, pattern & discourse(F1)	Factors influencing CSCL (F2)	Intervention & comparison (F3)	Critical reasoning (F4)	Process of social construction (F5)	Design & modeling of CSCL (F6)
t4.3 DeWeverVSV2007(46)	0.96					
t4.4 NaiduJ2006(22)	0.95					
t4.5 Schrire2006(91)	0.95					
t4.6 StrijbosMPJ2006(107)	0.95					
t4.7 DeLaatLLS2007a(31)	0.94					
t4.8 WeinbergerF2006(130)	0.92					
t4.9 DeWeverSVV2006(130)	0.92					
t4.10 DeSmetVV2008(20)	0.91					
t4.11 SchellensV2006(64)	0.91					
t4.12 StrijbosF2007(33)	0.85					
t4.13 JanssenEKJ2007(54)	0.84					
t4.14 SuthersVMJD2008(37)	0.81					
t4.15 Cress2008(29)	0.81					
t4.16 DeLaatLLS2007b(19)	0.75					
t4.17 RoseWCASWF2008(50)	0.72					
t4.18 JermannD2008(24)	0.67					
t4.19 WeinbergerSF2007(44)	0.66					
t4.20 ArnsethL2006(34)	0.66					
t4.21 ErkensJ2008(24)	0.63					
t4.22 OnrubiaE2012(5)	0.61					
t4.23 VanderpolAS2006(19)	0.57					
t4.24 Suthers2006(84)	0.54					
t4.25 VanAalstC2007(34)	0.51					
t4.26 JonassenK2010(12)		0.93				
t4.27 VanAmelsvoortAK2007(24)		0.92				

Table 4 (continued)

Core paper	Representation, pattern & discourse(F1)	Factors influencing CSCL (F2)	Intervention & comparison (F3)	Critical reasoning (F4)	Process of social construction (F5)	Design & modeling of CSCL (F6)
Jeong2006(9)		0.92				
NorooziBMBTGVC2012(6)		0.88				
ErtlKM2008(13)		0.87				
PrinsenVTV2009(8)		0.85				
JanssenEKK2010(13)		0.84				
ScheuerLPM2010(30)		0.81				
LundMSB2007(16)		0.78				
JeongJ2007(34)		0.76				
Reimann2009(22)		−0.74				
IsotaniIIM2009(10)		−0.72				
BuderB2008(18)		0.68				
MirzaTPD2007(7)		0.66				
Ding2009(10)		0.66				
StegmannWWF2012(8)		0.64				
CressK2008(67)		−0.63				
MeierSR2007(37)		−0.57				
CakirZS2009(20)		−0.54				
DillenbourgT2007(92)			0.95			
Arvaja2007(15)			0.94			
HernandezLeoVADJRR2006(63)			0.90			
DeweverVSV2010(7)			0.87			
HämäläinenH2010(8)			0.84			
DillenbourgH2008(40)			0.82			
StahlH2009(8)			0.77			
SchellensVDV2007(25)			0.76			

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t4.54 **Table 4** (continued)

Core paper	Representation, pattern & discourse(F1)	Factors influencing CSCL (F2)	Intervention & comparison (F3)	Critical reasoning (F4)	Process of social construction (F5)	Design & modeling of CSCL (F6)
RourkeK2007(17)			0.73			
Tchounikine2008(23)			0.73			
KollarFS2007(39)		0.50	0.71			
DeWeverVSV2009(17)	0.53		0.58			
StegmannWF2007(46)		0.52	0.55			
BaghaeiMI2007(26)			0.42			
SchwarzD2007(19)				0.74		
AsterhanS2010(11)				0.74		
SchwarzG2007(15)				0.65		
BakerALVQ2007(18)				0.64		
VanAalst2009(15)					0.73	
KapurK2009(24)					0.63	
SuthersDMV2010(14)		−0.52			0.59	
Lonchamp2006(16)						0.75
KobbeWDHHHF2007(76)						0.74
JonesDL2006(32)		−0.54				0.63
Eigen value	18.11	14.43	10.88	4.21	3.80	3.46
Total variance explained (%)	27.43	21.86	16.48	6.37	5.76	5.25

papers in these two sub-areas are mainly published in *International Journal of Computer-Supported Collaborative Learning, Computers & Education, Learning and Instruction*, and *Journal of Computer Assisted Learning*.

Factor 4 is labeled as "critical reasoning" in CSCL, primarily focusing on the dialogic approach and argumentative activity in synchronous e-discussions, (e.g., Asterhan and Schwarz 2010; Schwarz and De Groot 2007; Schwarz and Glassner 2007). In contrast to synchronous CSCL studies, factor 5 focuses on the social aspects of group learning, and was named as "process of social construction". Finally, factor 6 represents "design and modeling of CSCL", providing interdisciplinary viewpoints (e.g., computer science, cognitive psychology). Research in factor 6 addresses key design and modeling topics in various CSCL environments, for example, generic model for increasing feasibility of CSCL system, frameworks for the specification of collaboration scripts and meso-level approach to CSCL design (Jones et al. 2006; Kobbe et al. 2007; Lonchamp 2006).

Although citations and co-citation counts received from factor 6 were less than those of the first three streams, an interesting result can be found when looking inside the field of design and modeling of CSCL. On the average, the citation and co-citation counts are both ranked at the first tier among the other five streams. The research papers in these topics are highly and often cross-referenced. Note that the last three communities presented in this current study are all listed in the *International Journal of Computer-Supported Collaborative Learning*. A summary of factor analysis is presented in Table 5.

Cross-boundaries phenomenon

More inferences can be drawn from cross factor loading, which helps researchers to identify papers loaded on more than one factor. In Table 4, most cross loading works loaded positively on two factors, but only two loaded negatively on cross-factor 2 (Suthers et al. 2010; Jones et al. 2006). In a co-citation study, a paper with positive cross-loading could indicate that it serves as a bridge between two or more factors (Acedo et al. 2006a; McCain 1990). In this study, most bridging papers with positive cross loading appeared in factor 3. For example, some studies attributed to both factors 3 and 2 (i.e., Kollar et al. 2007; Stegmann et al. 2007), factors 3 and 1 (De Wever et al. 2009).

Comparing with positive loading, papers with negative factor loadings may have different meanings, and thus it is hard to interpret in the co-citation contexts (Leydesdorff and Rafols 2009). Some bibliometry researchers suggested that the negative load of co-citation pattern shared the "reverse co-citation profiles" with each other across or within the group (Acedo et al. 2006a; Di Stefano et al. 2010). It may result from the variation of the approaches they adopted or even research topics they discussed are unlikely. Thus, these works are not to be cited together. In the current study, this profile mainly occurs in the documents inside the factor 2.

Results of the social network analysis

The global structure of CSCL: a macro view

Network analysts have suggested that the SNA, based on graph-theoretic layout, is able to provide researchers with a whole picture toward understanding the social structure of a given research area. In this study, the SNA was therefore used to profile the center–periphery configurations of all source papers, providing a "full picture" of the whole sample of CSCL research. In a giant network, some interesting issues using SNA to present a bibliographic

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t5.1 **Table 5** summary of factor analysis

t5.2 Factor	Article	Major publication	Co-citation	Average co-citation (per article)	Citation	Average citation (per article)	Average citation (per year)
t5.3 Representation, pattern & discourse (F1)	23	*C&E* (10) *ijCSCL* (8) *L&I* (3)	3352	145.74	1131	49.17	7.94
t5.4 Factors influencing CSCL (F2)	19	*ijCSCL* (9) *C&E* (4) *L&I* (3)	1571	82.68	364	19.16	4.76
t5.5 Intervention & comparison (F3)	14	*ijCSCL* (8) *L&I* (2) *JCAL* (2)	1529	109.21	426	30.43	5.44
t5.6 Critical reasoning (F4)	4	*ijCSCL* (4)	278	69.50	63	15.75	3.08
t5.7 Process of social construction (F5)	3	*ijCSCL* (3)	227	75.67	53	17.67	4.81
t5.8 Design & modeling of CSCL (F6)	3	*ijCSCL* (3)	533	177.67	124	41.33	6.51

C&E=Computers & Education; *ijCSCL*=International Journal of Computer-Supported Collaborative Learning; *L&I*=Learning and Instruction; *JCAL*=Journal of Computer Assisted Learning.

While the amount of co-citation counts is aggregated by each latent factor, the average co-citation is divided by the number of articles within each factor. Similarly, the last two average citation numbers are divided by the number of articles, and by the average publication year within each factor, respectively

structure can help reveal how central position a CSCL research hold within a CSCL research network (Scott 1991). Several centrality measures, including degree, closeness, and betweenness, were used to capture the characteristics of the whole network structure and to examine the roles of actors in the relational networks (Freeman 1979). In this study, the intellectual structure of undirected co-citation network of 403 CSCL research, using raw co-citation frequency as input, was performed with NetDraw module of UCINET (Borgatti et al. 2002).

As a result, the whole co-citation networks of 403 CSCL documents with overall 7,552 co-citation ties were mapped, as shown in Fig. 2. In the diagram, all core papers were denoted as 403 nodes and every possible co-citation links as edges. From a macro perspective, the largest component of whole co-citation network, consisting of 99 % components apart from two isolated structures, had a clustering coefficient of 0.78. Clustering coefficient is similar to the average density ranging from 0 to 1. Compared with the coefficient of same sized random network (0.57), the network of CSCL community shows a high density community.

Next, three centralities were facilitated to identify the central nodes within the network: degree, closeness, and betweenness (see Fig. 2a, b and c). In general, the more central position a node located, the larger a node will be presented, and more important it is. In this sense, the most central cores among three properties of centrality in the network studied here were made up by Cress and Kimmerle (2008), De Wever et al. (2006), Kobbe et al. (2007), Schellens and Valcke (2006), Stegmann et al. (2007), Strijbos et al. (2006), Suthers (2006), and Weinberger and Fischer (2006) (presented as boldface in Table 6). These works are considered as the seminal research in the field of CSCL.

Fig. 2 Co-citation networks of whole sample of 403 CSCL research from 2006 to 2013. Among these, the size of node (i.e. research work) is measured by degree centrality (presented as **a**), closeness centrality (presented as **b**), and betweenness centrality (presented as **c**)

A close look at CSCL: a micro view

For a close look toward CSCL research, a further network analysis based on centering 66 core documents was presented as a micro view of CSCL. This 66 highly co-cited CSCL studies can be regarded as a representative of the central intellectual structure of CSCL literature. Accompanying with the result of EFA, the undirected graph of 66 documents by adopting SNA is presented in Fig. 3. Overall, the network above is composed of 66 nodes and 2,180 co-citation ties, resulting a density of 50.8 % of all possible linkages. Compared with the Finnish educational research community of 13 % (Tuire and Erno 2001), this core CSCL community network provides further evidence for a relatively high number of connections and active knowledge diffusion toward scholarly communication. In addition, all nodes were grouped into each research stream respectively according to the EFA results. It will be helpful for researchers to identify each study in this relational map.

t6.1 **Table 6** The most central papers according to three measures of centrality

t6.2 Centralities	Degree centrality	Closeness centrality	Betweenness centrality
t6.3 The most central papers (top ten of each measures)	KobbeWDHHHF2007	DeweverSVV2006	DeweverSVV2006
	WeinbergerF2006	KobbeWDHHHF2007	CressK2008
	DeweverSVV2006	WeinbergerF2006	WeinbergerF2006
	StegmannWF2007	CressK2008	Suthers2006
	StrijbosMPJ2006	StegmannWF2007	KobbeWDHHHF2007
	Suthers2006	Suthers2006	StrijbosMPJ2006
	DeweverVSV2007	StrijbosMPJ2006	Cole2009
	CressK2008	SchellensV2006	SchellensV2006
	SchellensV2006	DeweverVSV2007	StegmannWF2007
	DillenbourgT2007	RoseWCASWF2008	Hernandez-leoVADJRR2006

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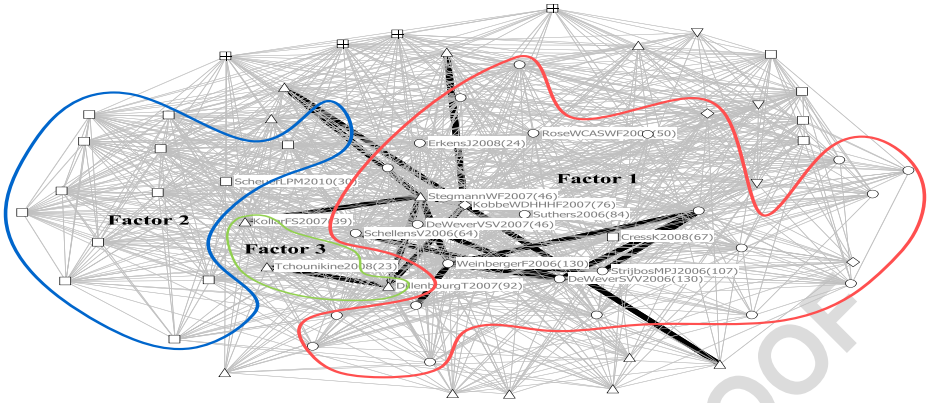

Fig. 3 The co-citation network of 66 core CSCL research from 2006 to 2013. Note: 66 papers are denoted as 66 nodes and every possible co-citation links as lines. The *thickness* of the lines represents the weights of the different links. While the *gray lines* represent a minimal co-citation linkage, the *solid and thicker lines* indicate heavy co-citation in which the counts of co-cited documents are more than eleven times. The *red circle* indicates factor 1; the blue and green one are factor 2 and 3, respectively. Six factors are denoted by different sharp as below. (*Circle*)- Factor 1; (*square*)- Factor 2; (*up triangle*)- Factor 3; (*box*)- Factor 4; (*down triangle*)- Factor 5; (*diamond*)- Factor 6

The nodes located in the most central position and the most thickness links constituted the main research of interests in the network studied here. In this manner, the close look of the CSCL co-citation network can be interpreted from the two aspects. From the network perspective, core actors found in the most center of map were Kobbe et al. (2007), Stegmann et al. (2007), De Wever et al. (2007), Weinberger and Fischer (2006), Schellens and Valcke (2006), De Wever et al. (2006), Strijbos et al. (2006) and Suthers (2006) as shown in Fig. 3. It is also interesting to note that the lists of central cores in Table 6 (from 403 papers) and 7 (from 66 papers) are almost identical, providing further evidence to confirm their importance toward CSCL literature.

Another analyses focused on the bibliographical characteristics by the thickness of the lines representing the weights of different links, calculated by the counts of paired articles jointly cited. While the gray lines represent a minimal co-citation linkage, the solid and thicker lines indicate heavy co-citation in which the counts of co-cited documents are more than eleven times. In this paper, most of the thicker lines were also found in this central and dense area. Among these, the highest co-linked node has 375 co-citation counts (i.e., Kobbe et al. 2007), which is also a dominant node among all centrality measures in the network. Note that the strongest tie has been co-cited as 32 times high (i.e., Weinberger and Fischer 2006; De Wever et al. 2006). These two papers are also considered as the most popular CSCL studies in terms of their highest times cited and average counts of 130 and 18.6 times, respectively. The most central CSCL papers in terms of three centralities and their bibliographic characteristics are listed in Table 7 as well.

Further investigations went beyond article level to issue level. As labeled, results shown in Fig. 3, factors 1 as the main issue of current CSCL research located in the very center of the whole network, where part of factor 3 and 6 were also included inside. Looking inside, these dense ties can divide into two clusters. One faction cohered with four most highly cited papers (i.e., De Wever et al. 2006; Schellens and Valcke 2006; Strijbos et al. 2006; Weinberger and Fischer 2006), which are all classified as factor 1 and

Table 7 The most central CSCL research according to normalized centrality indices and co-citation measures: A close view

Label	Authors	Source	Attributed factor	Betwe-enness	Close-ness	Degree	Total Co-citations	Highest co-cited times	Average times cited
KobbeWDHHHF2007(76)	Kobbe, L; Weinberger, A; Dillenbourg, P; Harrer, A; Hämäläinen, R; Häkkinen, P; Fischer, F	*ijCSCL*	Factor 6	72.8	94.2	61	375	24	12.7
StegmannWF2007(46)	Stegmann, K; Weinberger, A; Fischer, F	*ijCSCL*	Factor 3	67.0	92.9	60	323	17	7.7
DeWeverVSV2007(46)	De Wever, B; Van Keer, H; Schellens, T; Valcke, M	*L&I*	Factor 1	52.0	86.7	55	223	11	7.7
WeinbergerF2006(130)	Weinberger, A; Fischer, F	*C&E*	Factor 1	51.3	82.3	51	367	32	18.6
SchellensV2006(64)	Schellens, T; Valcke, M	*C&E*	Factor 1	46.7	83.3	52	194	11	9.1
DeWeverSVV2006(130)	De Wever, B; Schellens, T; Valcke, M; Van Keer, H	*C&E*	Factor 1	41.7	78.3	47	353	32	18.6
StrijbosMPJ2006(107)	Strijbos, JW; Martens, RL; Prins, FJ; Jochems, WMG	*C&E*	Factor 1	37.5	76.5	45	264	29	15.3
Suthers2006(84)	Suthers, DD	*ijCSCL*	Factor 1	34.3	79.3	48	227	7	12.0
CressK2008(67)	Cress, U; Kimmerle, J	*ijCSCL*	Factor 2	33.7	75.6	44	198	9	13.4
Tchounikine2008(23)	Tchounikine, P	*ijCSCL*	Factor 3	29.4	74.7	43	125	14	4.6
ErkensJ2008(24)	Erkens, G; Janssen, J	*ijCSCL*	Factor 1	29.2	80.3	49	129	6	4.8
KollarFS2007(39)	Kollar, I; Fischer, F; Slotta, JD	*L&I*	Factor 3	20.4	72.2	40	157	13	6.5
ScheuerLPM2010(30)	Scheuer, O; Loll, F; Pinkwart, N; McLaren, BM	*ijCSCL*	Factor 2	19.9	73.0	41	108	6	10.0
DillenbourgT2007(92)	Dillenbourg, P; Tchounikine, P	*JCAL*	Factor 3	19.9	71.4	39	183	24	15.3
RoseWCASWF2008(50)	Rose, C; Wang, YC; Cui, Y; Arguello, J; Stegmann, K; Weinberger, A; Fischer, F	*ijCSCL*	Factor 1	19.1	73.0	41	151	9	10.0

While the degree centrality is straightly presented as the number of linked ties, the closeness and betweenness centralities are normalized measures based on Freeman's (1979) approach. Total co-citation is a summated co-cited times of documents. The number of highest co-cited times is the highest co-cited counts among co-citation pairs. The average times cited calculates the times cited per year on average

Factor 1: representation, discourse & pattern, Factor 2: factors influencing CSCL, Factor 3: intervention and comparison, Factor 6: design and modeling of CSCL

C&E Computers & Education, *ijCSCL* International Journal of Computer-Supported Collaborative Learning, *L&I* Learning and Instruction, *JCAL* Journal of Computer Assisted Learning

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published by *Computers & Education (C&E)*. Among these studies related to the issue of learners' discourse practices, the methodology used in this circle mainly focused on content analysis schemes for transcripts. Another faction has two main studies published in *ijCSCL*, including the research of Kobbe et al. (2007) and Stegmann et al. (2007). These two works focused on the use of collaboration scripts in CSCL environment. Compared with the former *C&E* circle, this *ijCSCL* faction played more like as a role of "broker", which linked three main factors (i.e., factor 1, 3 and 6).

While factor 4 was grouped in the upper side, factor 5 is located in the right side between factor 1 and part of factor 2. Note that some documents of factor 2 located on the two opposite sides, where one main group gathered at on the left side of the network. Some documents of factor 2 positioned on the right side of the map. Those documents also can be found to have negative loadings in factor 2 from the result of EFA (see Table 4. such as the works of Reimann (2009), Isotani et al. (2009), Meier et al. (2007) and Cakir et al. (2009)).

Discussion

The purposes of the current paper were to reveal the underlying subfields, to identify the central documents and publications within contemporary CSCL research, and to present the intellectual structure map of the contemporary CSCL research by using the methods of co-citation analysis, factor analysis, and social network analysis. Based on the results of the analyses, the following discussions are provided.

Underlying subfields, central documents and publications within contemporary CSCL research

The results of the co-citation analysis, factor analysis and social network analysis have yielded some insights into the underlying subfields within contemporary CSCL research by uncovering latent co-citation structure. In this paper, six research streams in current CSCL literature were identified as: (1) representation, discourse & pattern, (2) factors influencing CSCL, (3) intervention and comparison, (4) critical reasoning, (5) process of social construction, and (6) design and modeling of CSCL. The intellectual structure of six research subfields was an important framework to access contemporary CSCL literature. Among these, the top three emerging areas (i.e., factor 1, 2, and 3) constituted 56 out of 66 core papers and about 70 % of the variance explained. This suggests that "representation, discourse and pattern", "factors influencing CSCL", and the issues of "intervention and comparison" can be regarded as the most focal research streams of CSCL research.

In addition, the most influential documents and research streams were further identified through various centrality measurements by SNA. This study cross accessed all three centralities on both macro (403 papers) and micro (66 cores) level to identify the most central core papers. As a result, certain seminal research works were identified, including Kobbe et al. (2007), Stegmann et al. (2007), De Wever et al. (2007), Weinberger and Fischer (2006), Schellens and Valcke (2006), De Wever et al. (2006), Strijbos et al. (2006) and Suthers (2006). While six of them have been grouped into factor 1, the rest attributed to factor 3 and 6. It is interesting to note that these works were issued by two major publications, *C&E* (four papers and all focused on factor 1) and *ijCSCL* (three papers scattered into factor 1, 3 and 6). These key works and source publications served as an important foundation and scholarly communication platform in the whole CSCL research community.

Dissemination and research trend of CSCL

The co-citation network shows the dissemination of CSCL studies graphically. While estimating the distance away from the central area (i.e., factor 1 and part of factor 3 and 6), factor 2 (factors influencing CSCL) appeared at two opposite sides (mainly on the left circle, the rest on the right side). Then comes factor 4 (critical reasoning) and factor 5 (process of social construction), located in the very upper and right corner, respectively. This conceptual map posted the relational location of six research subfields.

Among the network, research of "representation, discourse and pattern", "intervention and comparison" and "design and modeling of CSCL" were identified as most close connected areas in current CSCL research. Note that "design and modeling school" included in this central position played as a boundary spanner between factor 1 and 3. The most tied bridging node in the network is the work of Kobbe et al. (2007). This research provided a generic framework to design collaboration scripts, shedding lights on implications for learners' interactions.

While most documents of factor 2 (representing factors influencing CSCL) were concentrated on the left side of the network, some documents with negative factor loadings were on the very right side. These works shared the reverse co-citation profiles. Specifically, they adopt more conceptual/theoretical perspectives, rather than empirically-based research, to seek influencing factors toward knowledge construction via CSCL, for example, event-centred view, ontology engineering, rating scheme, and some systemic approaches from Piaget's theory.

Compared with central structure mentioned above, two research groups structured as the periphery of network (i.e., factors 4 and 5). The result indicates that these nodes within both factor 4 and factor 5 were less path-dependent on other nodes in terms of closeness centrality. Inside this subfield, the issue such as "productive failure" is considered as one of the relative independent research interest in CSCL.

The intellectual structure of the co-citation network served as a roadmap of theory development to access CSCL literature, especially referring to those focal cornerstones of highly cited and co-cited works. In addition to the EFA results, some research trends accessing those latest documents within each CSCL streams were highlighted. In the research of "representation, discourse, and pattern" (factor 1), one of current research trends is to point out important patterns in CSCL. For example, researchers in this area have suggested that the patterns of teachers' assisting roles were one of important aspects in CSCL environments (Onrubia and Engel 2012). For those focused on intervention and comparison (factor 3), some works endeavored to compare the impact of role assignment (such as De Wever et al. 2010; Hämäläinen and Häkkinen 2010).

In addition, the effects of rule, guidance, and even timing have been argued as the critical factors influencing the formal quality of argumentation and cognitive elaboration in factor 2 (e.g., Janssen et al. 2010; Noroozi et al. 2012; Scheuer et al. 2010; Stegmann et al. 2012). Moreover, argumentative activities in e-discussion environment (Asterhan and Schwarz 2010) and distributed interaction (Suthers et al. 2010) have also attracted researchers' attentions to the issues of critical reasoning (factor 4) and social construction (factor 5).

Conclusions and limitations

This present study endeavored to identify core documents and examine the scholarly communication structure in the CSCL knowledge domain based on document co-citation profiles.

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This is the very first attempt to integrate the bibliographical method, statistical analysis, and visualization techniques to investigate the intellectual structure of CSCL empirical studies. As a result, six intellectual subfields are mapped, and major core documents and publications were identified. In addition, several boundary spanning documents and research trends within the CSCL field were presented and discussed.

Without exception, every method has its own limitations (Nerur et al. 2008). Two inevitable limitations are addressed below. First, the co-citation method may cause a bias in that it is difficult for newly published documents to enter the set of source documents. Older published papers are favored to be selected into the core set. Since selected documents needed to meet certain criteria of the frequency of times cited, it is difficult for new papers to accumulate enough citations in a relatively short time. Second, although this paper used a board keyword searching strategy in the SCI/SSCI and CPCI-S/CPCI-SSH databases, only journal and conference articles were included. Some other book chapters were excluded despite of their influential stands, for example, the seminal review of Stahl et al. (2006). Future research may consider including book chapters.

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Core papers listed in Table 3 are preceded by an asterisk

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