

Has Research on Collaborative Learning Technologies Addressed Massiveness? A Literature Review

Kalpani Manathunga^{1*} and Davinia Hernández-Leo²

¹ICT Department, Universitat Pompeu Fabra, Barcelona, Spain // ²Serra Hünter Fellow //
kalpani.manathunga@upf.edu // davinia.hernandez@upf.edu

*Corresponding author

(Submitted August 4, 2014; Revised March 16, 2015; Accepted March 25, 2015)

ABSTRACT

There is a growing interest in understanding to what extent innovative educational technologies can be used to support massive courses. Collaboration is one of the main desired elements in massive learning actions involving large communities of participants. Accumulated research in collaborative learning technologies has proposed and evaluated multiple models and implementation tools that engage learners in knowledge-intensive social interactions fostering fruitful learning. However, it is unclear to what extent these technologies have been designed to support large-scale learning scenarios involving arguably massive participation. This paper contributes with a literature review that aims at providing an answer to this question as well as offering insights about the context of use, characteristics of the technologies, and the types of activities and collaboration mechanisms supported. The main results point out that till 2013 the level of massiveness considered in top scientific journal papers on collaborative learning technologies was low, the scenarios studied were predominantly contextualized in co-located higher education settings using Learning Management Systems, the most common activities considered were open and structured discussion, followed by peer assessment and collaborative writing, and the most broadly used mechanism to foster fruitful collaboration was group formation following diverse policies.

Keywords

Literature review, Educational technologies, Collaborative learning, Large classes, Massive courses

Introduction

The interest in educational technologies for massive numbers of learners has recently increased because of the impact that Massive Open Online Courses (MOOCs) are having in the Media and the Society (Sonwalkar, Wilson, Ng, & Sloep, 2013). This impact is shaping a turning point in educational technologies research as it offers an excellent opportunity for the adoption of previous research achievements while creating new scalability research challenges for massive teaching, learning and assessment models (Kay, Reimann, Diebold, & Kummerfeld, 2013). Aligned with existing research evidences, MOOC initiatives recognize the importance of social interaction among learners. Many of them incorporate activities based on discussions and peer-review assessments (Tsai & Wong, 2013). The potential for different pedagogies and collaborative learning methodologies in massive class teaching is prospective and highly concerned. Yet, we envision that this potential is still in its infancy though undoubtedly relevant open discussions and peer-assessments are the main two examples of collaborative learning techniques with current practice in massive courses (Kay et al., 2013; Sonwalkar et al., 2013; Tsai & Wong 2013).

Collaborative learning techniques support the construction of joint knowledge and sharing of meanings by means of fostering potentially effective social interactions (Dillenbourg, 1999). Accumulated research in Computer-Supported Collaborative Learning (CSCL) has proposed and evaluated multiple models and implementation tools that engage learners in knowledge-intensive social interactions (debate, conflict resolution, artifact co-design, mutual explanation, etc.) with identified significant learning outcomes (Dillenbourg, 1999; Stahl, Koschmann & Suthers, 2006). These models involve the application of collaboration-triggering mechanisms such as group formation according to specific policies, role allocation and rotation, distribution of knowledge, etc. and the use of diverse collaboration spaces (shared boards, wikis, etc.) and implementing communication and coordination mechanisms (flow control, group awareness, etc.). However, the standout body of CSCL research is mostly known for its contributions focused on supporting small groups of learners (Stahl, Law, & Hesse, 2013). And the research around scalable collaborative learning approaches, technologies and issues for large classrooms or large learning communities is scattered across scientific publications without explicitly embracing a comprehensive visible body of knowledge.

This paper contributes with a systematic literature review (Kitchenham, 2004; Webster & Watson, 2002) synthesizing a framework that explains existing insights and gaps in the context of applying collaborative learning aimed at massive or large groups. This framework will serve as a foundation for advancing knowledge and uncovered areas (Webster & Watson, 2002) where further research in above aspects could be conducted accordingly. Hence, the rationale for the paper is not to identify CSCL as a branch of MOOCs providing collaboration aspects, but to understand to what extent previous research in CSCL has involved in the design or/and use of technologies suitable to support massive or large-scale participation. The ultimate aim is to characterize which technologies and approaches could be potentially used in MOOCs (or, more generally, in massive learning actions) to support collaboration - because its use with relatively large learner communities has been proved and studied. As a secondary aim, the paper also discusses challenges and promising avenues emerging from the literature review.

Therefore, a first aim of the analysis is identifying the context types for research works that have considered arguably (or potentially) massive / large quantities of learners in the concerned technology-supported collaborative learning scenarios. Then, the concrete focus is on understanding the types of tasks or activities supported by collaborative learning technologies in those scenarios, as well as the types of mechanisms and technological facets considered by these technologies to support collaboration. A systematic approach is followed consisting of stages as (1) identify research objectives (2) search articles (3) filtration and evaluation of data set (4) coding and analysis (5) interpretation of results obtained. The coding of the data is done using a qualitative data analysis tool (Atlas.ti), whose features facilitate researchers a systematic management and coding of text instances in articles. As the research objectives, following specific research questions were formulated:

In research involving arguably or potentially massive technology-supported collaborative learning environments,

RQ1: to what extent the scenarios considered are massive?

RQ2: what are the types of educational sectors and settings considered?

RQ3: what types of activities are proposed?

RQ4: what collaboration mechanisms are implemented?

RQ5: which are their technological facets?

Educational sectors or levels (from primary to adult education and informal learning) and the types of settings (co-located, remote, in physical or virtual spaces) characterize the context of the learning scenarios in which research on collaborative learning technologies have been framed. The literature review will provide insights about in which contexts these technologies have been applied with many learners. As mentioned above, collaboration environments have been proposed for a number of diverse activities (from debates to product co-development), the review will provide light about to what extent these environments have been used in massive situations. Group formation following specific policies and distribution of roles and knowledge are design techniques used in pedagogical methods and technologies (such as collaboration scripts) seeking potentially fruitful social interactions (Dillenbourg, 2002; Hernández-Leo et al., 2006; Dillenbourg, Järvelä, & Fischer, 2009). A potential research question is whether these approaches have been designed for massive scales also.

A realistic educational scenario could have multiple educational tools and technologies involved, including Learning Management Systems (LMS), generic tools, devoted tools, pervasive and ubiquitous devices (Harrer, Pinkwart, McLaren, & Scheuer, 2008; Suo, Miyata, Morikawa, Ishida, & Shi, 2009; Calvo, O'Rourke, Jones, Yacef, & Reimann, 2011). Therefore, inquiring about the technological platforms considered, the interactions between tools and to what extent they are seamlessly connected also has a scientific interest corresponding to massive learning situations. Also from the technological facets perspective, seamless learning implies certain type of interoperability between tools or an enabling technology that acts as a mediator to allow learners to feasibly switch and flow between diverse physical and virtual spaces (Chan et. al, 2006; Pérez-Sanagustín et al., 2012).

The remainder of the paper is structured as follows. Next section details the methodology followed, including the procedure applied to identify possible similar reviews, the search criteria for the literature considered and the method of analysis. Then, a results section is organized as subsections, based on the structure of the research questions. This is followed by a discussion section, which explains requiring concerns on the research aspects with prevailing challenges. The paper concludes with a conclusion of the main findings.

Methodology

Originality of the literature review

A first phase was devoted to identify if a similar literature review attempt was already available. A search clause was formulated including set of keywords denoting the focus of the targeted research topic (Webster & Watson, 2002). The search clause comprised of “review” or “state of the art” or “bibliography” or “survey” (as the nature of the targeted contribution) covering key aspects like “learning” or “education” in “collaborative” or “cooperative” “computer” or “technologically” supported environment targeting “large” or “massive” classes or even “communities” or “MOOCs.”

The resulting search clause with the complete criterion for title search was: (review OR state of the art OR bibliography OR survey) AND (education* OR learning) AND (collaborat* OR cooperat*) AND (large OR massive OR MOOC OR communit*) AND (comput* OR technolog*).

Databases including IEEE Xplore, Web of Science, ACM, Scopus, SpringerLink, ScienceDirect and GoogleScholar were considered for the search since they cover a significant wide range of Computer Science, Education and interdisciplinary scientific publications. The comprehensive search query returned 0 results indicating that this specific topic had not been studied so far. There were no journal articles (either peer reviewed or not), no conference publications neither any text available for that specific topic at the time of writing this article as search query did not present any specific time period.

Literature selection

The next iteration of the search process was to seek the relevant literature to consider in the review (Webster & Watson, 2002). Based on the above formed research questions, a series of keywords were recognized and search was extended up to title, abstract and keywords. Subset of keywords were (education* OR learning) AND (collaborat* OR cooperat*) AND (large OR massive OR MOOC OR communit*) AND (comput* AND technolog*).

For this literature selection Scopus was selected as the database source, given its wide scope that includes the relevant Educational Technology publications (Falagas, Pitsouni, Malietzis, & Pappas, 2008; Chou, 2012), such as those ranked in the “top peer reviewed journals with high impact factors” by Google Scholar (under “Engineering and Computer Science” or “Social Sciences” sub-field “Educational Technology”). Also Scopus gives the facility of maintaining lists of selected papers and provides a graphical view of publications over time. To select the most appropriate and accurate work, few limitations/criteria were implied; such as sources being either peer reviewed journal articles or conference proceedings, published date fallen between 2000 up to December, 2013 and concerned fields are being physical sciences and social sciences while eliminating life and health sciences as they are not related directly with technology enhanced learning. We decided to include aforementioned timespan (starting in 2010) since research on technology supporting collaborative learning was emerging at that time (Dillenbourg, 1999; Stahl, Koschmann, & Suthers, 2006).

Initial screening in Scopus resulted of 6514 papers containing above key terms in topics, abstracts or keywords in only peer-reviewed journal articles and conference proceedings. 3118 articles of them were journal papers. The temporal distribution of the publications is shown in Figure 1. Years from 2007 to 2011 experienced the highest rates of increase in terms of numbers of publications in the topics, reaching certain equilibrium as of 2011.

Out of the articles potentially relevant it was required a solid logical filtration for the final selection. Two researchers participated in the final selection phase. As for the first stage, top ranked educational technology journals according to an intersection of the rankings in ISI Journal Citation Report (ISI, 2013) and Google Scholar were concerned and this criterion narrowed down the count to 243 journal articles. During the next stage of article filtration, 100 articles (out of the 243) were chosen as relevant and appropriate by considering the topic, abstract and keywords of each article. The topics of those not considered relevant were diverse: e.g., misplaced topic, not addressing collaboration among learners but among teachers or other stakeholders, unclear role of technology supporting learning activities, etc. A summary of the selected papers (by journal) is presented in Table 1.

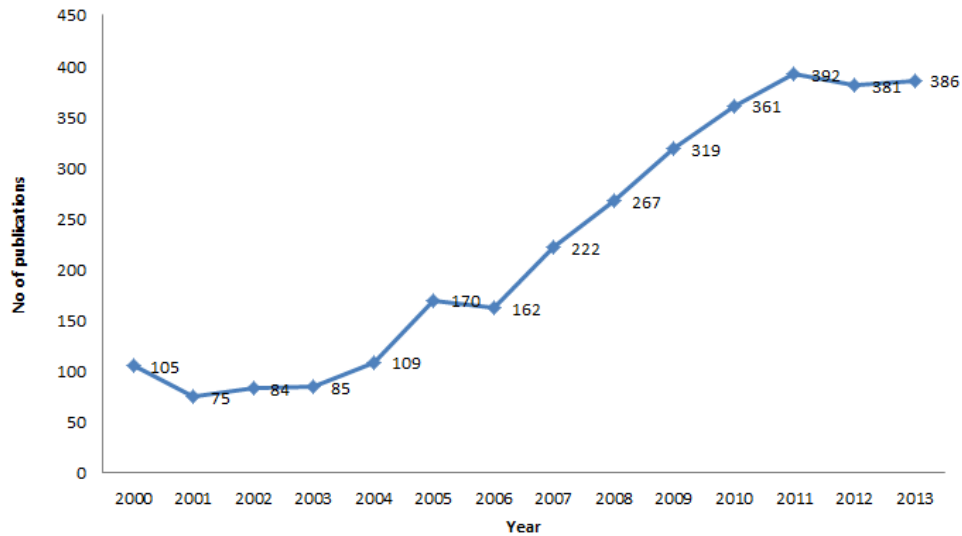


Figure 1. Temporal distribution of retrieved potentially relevant publications

Table 1. Journal papers selected (by journal)

No of selected papers	Journal (alphabetical order)
5	Australasian Journal of Educational Technology
9	British Journal of Educational Technology
39	Computers & Education
10	Educational Technology and Society
2	Educational Technology Research and Development
5	IEEE Transactions on Learning Technologies
2	Interactive Learning Environments
5	International Journal of Computer-Supported Collaborative Learning
6	International Review of Research in Open and Distance Learning
8	Internet and Higher Education
5	Journal of Computer Assisted Learning
4	Language Learning and Technology
100	Total Papers
	(Complete list of papers available at the online-appendix at http://tiny.cc/cl-massive)

Analysis method

Selected articles were coded using Atlas.ti, a qualitative data analysis tool (see <http://www.atlasti.com/index.html>) that helped the categorization process and also the exploration and annotation of articles while providing convenient navigation among the article collection. Most articles were experimental studies from which the two researchers could capture code instances by reading through the methodologies, experimental details and their pedagogical approaches. In this qualitative analysis process, thematic categories or code structure was formed considering the research questions and related classifications widely recognized in the educational and the CSCL fields. Besides, since qualitative data analysis involves the identification and interpretation of themes in textual data, additional codes or sub categories emerged during the analysis process (Kitchenham, 2004; Webster & Watson, 2002). Table 2 collects the structure (or tree) of codes used. The root categories relate directly to the research questions and level one to its main characteristics (see for instance the codes for RQ2 or RQ4). The categories in level two add another layer to the analysis. Most subcategories in this level were formulated at the beginning of the research process, in alignment with the research questions and considering existing categorizations. Examples are types of educational sectors or levels (RQ2), collaboration mechanisms (or CL mechanisms) - either designed by practitioners or socially by students - (RQ4) or “CL activity” type being open or structured discussions or peer assessment (RQ3) or the technological facets used (RQ5) (Dillenbourg, 2002; Hernández-Leo et al., 2006; Dillenbourg et al., 2009). Another set of codes emerged during the analysis, in particular, additional types of activities found in some articles like

game/role playing or collaborative presentations (RQ3) and the subcategories defined in the quotient of learners derived from the specific sample sizes revealed in articles (RQ1).

Table 2. Categories of analysis

Level two	Level one	Root
Less than 100		Quotient of learners (RQ1)
Between 100 and 1000		
More than 1000		
Primary	Co-located (same setting)	Educational setting profile (RQ2)
Secondary	Remote locations (across settings)	
Higher		
Vocational		
Adult		
Open Discussions		CL activity (RQ3)
Structured Discussions		
Peer assessment		
Game playing		
Collaborative writing		CL mechanism (RQ4)
Collaborative presenting		
Group formation	Designed by teacher	
Role distribution	Decided by learner	
Grouping based on previous performance		
Resource distribution		Technological facets (RQ5)
LMS or LMS-embedded tools	Platforms and tools	
Generic tools		
Completely new tool		
No seams	Addressing seams	
Seamful		
Seamless		

Regarding RQ5, “platforms and tools” is considered as a code and as sub-codes the categories considered were “LMS” or “LMS- embedded tools” or any “general tool” such as social media like Facebook or Blogger, communication tools like Skype or NetMeeting, etc. When researchers had suggested a complete new tool, the article was coded as a “complete new tool.” Seamless support is another aspect concerned in RQ5. Hence the articles were also analyzed highlighting such ideas as “seamless” and “seamful” (i.e., inflexible switch between learning spaces), if those had looked into being pervasive and the remaining as “no seams” where there is not a need of being seamless.

Results

Level of massiveness and educational setting profiles

The level of massiveness (research question RQ1), in terms of number of learners participating in activities supported by collaborative learning environments, found in the scientific journal papers selected was relatively low if compared to the many learners involved in MOOCs (Kay et al., 2013; Sonwalkar et al., 2013). 55% from the concerned sample have experimented with less than 100 of participants. 37% involved more than 100 students, yet these did not exceed 1000 (Table 3). Only 8% papers found with a quantity of learners larger than 1000 and this could be recognized as a practical issue observed with experiments addressing large class learning as mentioned in most of the papers. On the other hand several researches mentioned that having larger sample sizes of learners involved in the studies would be interesting from a quantitative research perspective (Walta & Nicholas, 2013; Junco, Elavsky, Heiberger, 2013; Williams, Lewis, Boyle, & Brown, 2011; Ferriman, 2013).

Regarding the types of educational sectors (RQ2), 66.4% of the researchers had experimented collaborative learning technological models and tools with students pursuing higher studies like undergraduate courses, post-graduate work

or any vocational studies such as training teachers, nurse, etc. 20.7% found addressing attempts implementing computer supported collaborative activities for primary or secondary schools. 7.7% articles were evident as attempts to embrace technology into adult learning context and another. 67.1% of research had been conducted in co-located situations (same location, physical space) rather than across physical and remote / virtual locations. A summary of the educational sectors by type of setting is provided in Figure 2. Majority (> 50%) from the articles that had experimented with more than 100 participants had been implemented upon higher educational set up and very few attempts were observed for primary or secondary education while another few targeting at vocational training.

Table 3. Quotient of learners

Percentage	Number of learners
55	Less than 100
37	Less than 1000, but greater than 100
8	Greater than 1000

Only 5.2% was observed as informal learning contexts; e.g., where learners share knowledge according to their co-interests in a community (Huang, Yang, Huang, & Hsiao, 2010; Li et al., 2011) These attempts had shown the potential in promoting further collaboration in informal contexts as discussed by Li et al. (2011) by providing a sustainable teamwork platform for researchers to aid in content sharing and managing knowledge resources to build up scholarly communities of knowledge. Further they envision on scaling up to larger learner communities using teamwork platform, SWiCLE to support lifelong learning (Li et al., 2011). Also Huang et al. (2010) article enlightens construction of mobile collaborative learning networks on top of an existing web based platform by the provision of intelligent grouping services to recommend users learning partners of the same interests and specialties. These studies inspire innovate opportunities of using personal data derived from social networks or any other informal contexts for new pedagogical approaches when scaling up collaborative learning strategies, for example in the context of MOOCs.

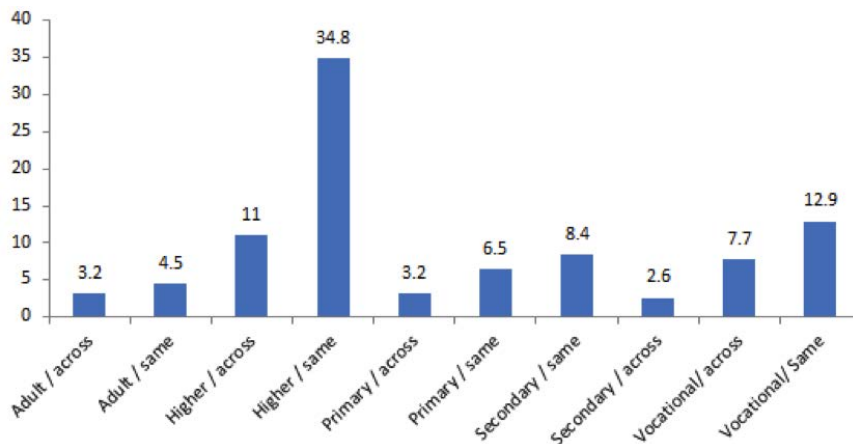


Figure 2. Percentages of educational sectors by settings

Types of collaborative learning activities supported

The third research question RQ3 refers to the type of collaborative activities attempted in the literature aiming fruitful social interactions. The analysis derived six main types of activities considered in “potentially massive” collaborative learning environments as using virtual discussion boards like forums and blogs, peer assessments, games and collaborative writing spaces like Wiki. Figure 3(a) provides a summary as presented in the literature and Figure 3(b) shows the variation of collaborative activities across educational sectors. Discussions could be considered as the most prevalent activity category with highest number of attempts in literature and generally every activity category has higher values for students pursuing higher studies such as undergraduate or postgraduate students.

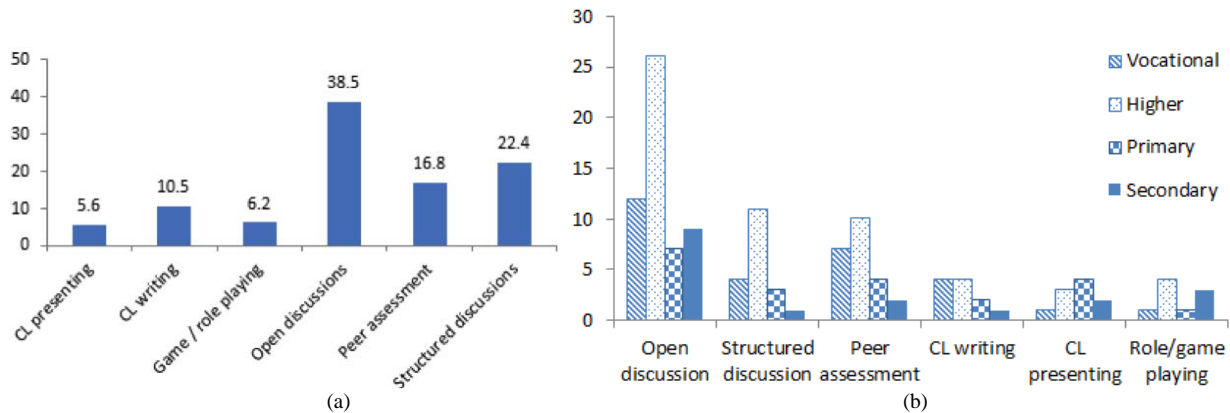


Figure 3. Percentages of main collaborative learning activities supported by technological environments: (a) total, (b) by educational sector

60.9% papers have implemented some sort of discussion forums; either structured or open discussions among learners in order to maintain collaboration while another 39.1% have attempted different types of techniques to implement a collaborative learning environment. The highest percentage (38.5%) is inspired by open discussions among learners with no interference of the instructor or a specified structure (Shaw, 2013; Oliveira, Tinoca, & Pereira, 2011; Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013). 22.4% of articles were promoting structured discussion, through scaffolding by practitioners along the discussion activity or via the implementation of collaborative inquiry models that propose the use of epistemic categories or distribution of roles that condition participation in discussions (Walta & Nicholas, 2013; Ferriman, 2013; So, Seah, & Toh-Heng, 2010; Schellens et al., 2007; Gerosa et al., 2010; Ligorio, Talamo, & Pontecorvo, 2005). Ferriman (2013) had let teachers to provide constructive feedback in the middle of an essay writing activity to guide learners and based on teacher feedback, students post content to the virtual discussion threads ensuring quality content. Walta and Nicholas (2013) use a Community of Inquiry model in which learners participated in structured discussions like designated blogs, journal spaces and small group tutorial discussions along with open discussions via LMS promoting collaboration and reflective learning. Another study uses collaborative inquiry-centred pedagogy (So et al, 2010) providing opening cues like “My theory,” “I need to understand” or “A better theory is” with the use of a collaborative knowledge building tool. Schellens et al. (2007) proposed discussion structuring by assigning roles to each participant as “moderator, theoretician, summariser, source searcher” at the beginning of the discussion. Another approach was a forum with seminar leaders initiating the conversation while group members develop the argumentation accordingly and mediators intervene when required (Gerosa et al., 2010). Ligorio et al. (2005) conducted an experiment on collaborative writing of fairy tales by two distant primary schools’ kids in which, practitioners monitor pupil interventions during the writing and discussion stages, resolve conflicts in group work, summarize what pupils stated in discussion flows and create space for the pupils with less involvement within activity.

As shown in Oliveira et al. (2011), role of the online teacher/instructor varied, according to the activity phase objectives; for example, during first phase, teacher worked as a facilitator and a critical observer but during the group work stage the responsibility for the discussion leadership was entirely the responsibility of the participants while teacher is a passive observer only. Furthermore, academic moderators had been assigned in certain learning scenarios to lever the learners and also to ensure ethical etiquette and confidentiality in a discussion environment (Walta & Nicholas, 2103). In another article, instructors had introduced few online activities like quick-answer competitions or whole-class ratings as to spark collaborative online learning Zhan, Xu, and Ye (2011) and as in Ferriman (2013) and Ligorio et al. (2005), initial guidance, feedback or topic selection had been done by the teacher in the collaborative activity.

Most of the articles have used technology-mediated discussions such as discussion boards or online chat forums while a few had mentioned only about face-to-face communication. The hybrid of these techniques was also found where learners meet each other face to face as well as they meet in virtual environment (Samarawickrema, Benson, & Brack, 2010; Ladyshewsky, & Gardner, 2008). Another interesting observation is that a significant amount of articles had attempted both synchronous communications like online chat or video conferencing and asynchronous communication techniques like blogs, discussion forums within the experiment to implement collaborative activity (Samarawickrema et al., 2010; Brett, & Nagra, 2005; Wang, 2009; Raymond et al., 2005; Calvo et al., 2011).

Apart from the discussions, the other CL activities observed were peer assessments (Saunders, & Gale, 2011; Freeman, & McKenzie, 2002; Ligorio et al., 2005) with critical evaluation among peers to construct knowledge, collaborative writing spaces such as wikis (Calvo et al., 2011; Brett & Nagra, 2005; Oliveira et al., 2011; Li, Dong, & Huang, 2011) as a medium for socially mediated learning, or either game playing (Susaeta et al., 2010) or role playing (Ioannidou et al., 2010) depending on target activity and collaborative presenting of an end-result of a group collaboration (Tsai, 2010; Raymond et al., 2005).

In the case of the article portion that had participants greater than 100 as the sample size, open discussions surpasses (42.4%) and apart from discussions peer assessment (15.3%), a widely used CL pedagogical technique with larger learner communities, seems prominent too as indicated in Figure 4. More than 50% of the experiments had exercised combination of collaborative learning activities as explained by Oliveira et al. (2011) in the article, after studying and reflecting individually students participated in online discussions, small group work, collaborative writing spaces to share ideas and played games to find the final solution. Hybrids of virtual and physical discussions along with peer assessment are also (Zhan, Xu, & Ye, 2011) seen as fruitful to be implemented upon larger groups. Wang (2009) shows better collaborations using shared spaces with large classes implementing instructional design strategies such as friendship in groups and allowing meaningful tasks to improve individual accountability and positive interdependence along with certain scaffolding like collaborative writing of progress reports and monitoring groups individually.

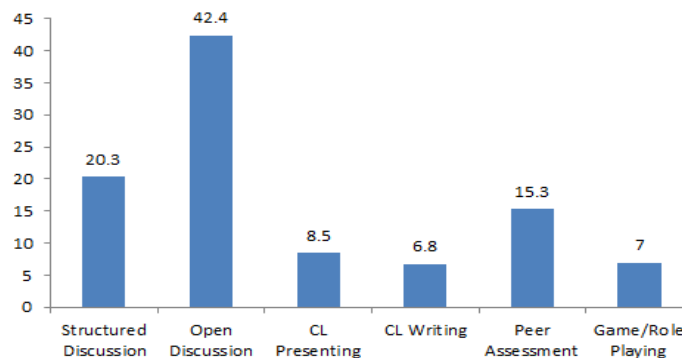


Figure 4. Percentage distribution of collaborative learning activities with experiment samples larger than 100 participants

Collaboration mechanisms

RQ4 refers on how to achieve potentially effective collaboration in a collaborative learning technological environment and the corresponding analysis code is “CL Structure” either mediated by the teacher or by learners themselves. Known collaboration mechanisms are group formation according to specific policies, or the progress along a learning flow, the distribution of roles and the distribution of knowledge / resources (Dillenbourg, 2002; Hernández-Leo et al., 2006). These mechanisms orchestrate the elements of a collaborative learning activity with the aim of triggering desired knowledge-intensive social interactions.

Group formation is the mechanism presented more in the analyzed papers. 40.88% of the papers discuss about a mechanism for group formation either by an external influence or individual willingness. Another 39.23% had mentioned a particular mechanism for distributing learning resources like learning materials or hardware devices within groups or any other component needed for the collaborative learning activity. Only 18.23% performed activity by assigning roles to group members whereas 1.66% had considered previous activities attempted by the student when grouping for collaborative activities.

Only very few instances were found conducting current learning activity by considering learner profile and previous performances (Capuruço & Capretz, 2009; So, Seah & Toh-Heng, 2010). Research in many areas has shown that learning within groups improves students’ learning experience by enabling peers to learn from each other (Ounnas, Davis, & Millard, 2009). Hence, almost all papers had discussed forming groups either by students themselves or by the teacher. Forming groups by teacher or by a particular software program have been considered as designed-by-

teacher Group Formation (GF). This mechanism is used in a high quantity of papers (43.4%) as shown in Figure 5. Various practices were observed in literature for forming groups as GF according to geographical location or gender (Samarawickrema et al., 2010; Walta & Nicholas, 2013), using GF algorithms (Sancho-Thomas, Fuentes-Fernández, Fernández-Manjón, 2009), based on the type of activity, experience level or knowledge proficiency (Oliveira et al., 2011; Calvo et al., 2011; Tsai, 2010); but there was a considerable trend for random group formation (Shaw, 2013) and some articles had not expressed their mechanism.

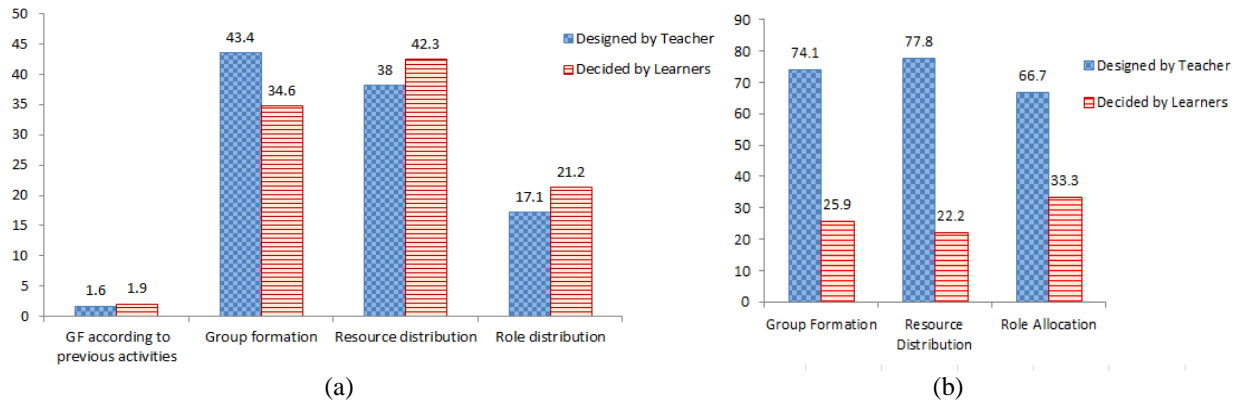


Figure 5. Percentage of use of collaboration mechanisms: (a) comparing if the mechanism has been designed by the teacher or decided by the learners, (b) considering larger learner groups (> 100 participants)

Social resource distribution was encouraged in a collaborative environment when learners exchange resources over teacher mediation. However, in most cases the distribution meant a collective sharing of knowledge. Especially when forums or blogs were used, there was a tendency of exchanging extra learning materials relevant such as additional reading references in web or a link to a video along with the forum or blog post (Schellens, Van Keer, De Wever, & Valcke, 2007). The general trend of resource allocation was sharing learning materials in a LMS or another shared space to be accessible for all. A more truly fostering-collaboration mechanisms based on distribution of knowledge (e.g., to promote positive interdependence and individual accountability within groups) was found in situations of individual resource allocation when teacher allocates resources due to the requirements of the activity or a specific collaboration flow (e.g., Jigsaw activity) (Bochicchio & Longo, 2009; Hernández-Leo et al., 2006; Susaeta et al., 2010) or when students select the content according to their preferences (Wang, 2009).

Only 18.23% papers had discussed about assigning roles in a collaborative activity. The types of techniques for role allocation vary. While in Sancho-Thomas et al. (2009) role distribution was done by using a standard algorithm, in Schellens et al. (2007) the assignment is random. Besides, a negotiated role assignment between learners is also a valued approach since students can select their own roles according to their interests.

As shown by Figure 5(b), teacher/instructor involvement or providing certain scaffolding mechanisms for learner collaboration within the flow design was seen as a common practice even with larger learner communities (>100) rather than letting learners to decide independently. Zhan, Xu, and Ye (2011) had highlighted the significance of different grouping mechanisms and the effects on heterogeneous groups vs homogenous based on learner style in online learning environment as limitations within their experiment with larger learner crowd even though they only had used heterogeneous groups and teacher mediated resources and role allocation. Instructor presence has a heavy influence for the interactions during group work due to the supportive facilitator role as explained by Oliveira et al. (2011) even among massive learner communities.

Technological facets

Following figure 6 demonstrates usage of different technological facets and tools observed in the concerned literature and how past research had shown interest for seamless aspects. When considering different technologies suggested by the papers (RQ5), it was observed that many researches had used either the existing LMS at their institutions (e.g., Moodle, BlackBoard, WebCT etc.) or a similar platform to a LMS or customized the LMS according to the requirements and embed more tools like discussion boards (Shaw, 2013; Noroozi et al., 2013), conferencing or

communication tools (Williams et al., 2011), podcasting tools (Saunders, & Gale, 2011) and reflective journal logs (Ladyshewsky & Gardner, 2008), repositories with required learning materials (Zhan, Xu, & Ye, 2011) or even additional assessment or feedback mechanisms (Saunders & Gale, 2011) to make the final tool more sophisticated. Hence learners are able to experience a comprehensive learning environment with asynchronous or synchronous learning tools (Raymond et al., 2005). As indicated by figure 6(a), total 44.6% from the sample set had used either LMS or LMS-embed tools for their experiments. Another 30.9% had used generic tools such as Wikis, YouTube, Facebook, Blogs, Skype or Presentation tools like Microsoft PowerPoint in order to promote collaborative learning and aid in the learning activity flow. Some of the researches (24.5) had introduced completely new platforms and applications or new hardware devices according to their proposed conceptual model of the research (Ferriman, 2013). It can be derived that a significant number of research work oriented towards relatively high number of participants apply well-known LMSs, generic Web2.0 and communication tools, or LMS integrating specific tools.

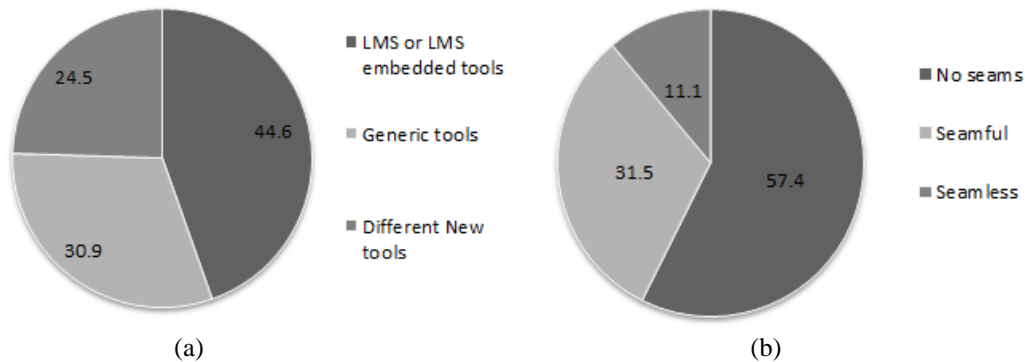


Figure 6. Technological facets: (a) types of platforms / tools, (b) achieving across seams

Ubiquitous and pervasive computing offers new possibilities to work collaboratively mediating social interactions in technology-rich diverse spaces and times and across-technologies seamlessly. Novel experiences for learners including mobile technologies rises new opportunities for collaborative learning (Looi et al., 2010; Suo et al., 2009), also when seamlessly combined with other devices and software tools (Pérez-Sanagustín et al., 2012). Most of the research found in the search had not been able to achieve broad seamless features (figure 6(b)), even though certain attempts have discussed being seamless within their context. 57.4% of the papers have not considered being seamless across neither technologies nor space or time. 11.1% of the papers had achieved seamless in their solutions, mostly technologically and the other 31.5% discuss that being seamless is advantageous and effective. Also they had convinced productive activity flow is achievable across seams with their solutions.

It was observed that the suggestions for being seamless are augmented by combining several technologies together and offering them as a single solution (Tsai, 2010; Walta & Nicholas, 2013; Saunders, & Gale, 2011). In Calvo et al. (2011) cloud concepts are embedded to continue a collaborative writing activity for a group of learners in diverse contexts or conducting physical lab experiments in a remote virtual environment (Bochicchio & Longo, 2009). Noroozi et al. (2013) propose the use of multiple devices and technologies to conduct an activity involving face-to-face discussions as well as virtual discussion boards and other communication facilities extending the learning experience.

Discussion

The analyzed papers identify a number of challenges that arise in technology-supported collaborative learning environments involving a large number of learners. These challenges are related with technological, cultural and lingual barriers (Samarawickrema et al., 2010; Saunders, & Gale, 2011; Ferriman, 2013; Tsai, 2010; So, Seah, & Toh-Heng, 2010), and also with maintaining interest throughout the learning activity in order to promote students' engagement and maximize the social interactions (Walta & Nicholas, 2013; Junco et al., 2013; Ferriman, 2013; Sancho-Thomas et al., 2009) that would lead to fruitful learning. Also as presented in Walta and Nicholas (2013), Wang (2009), Shaw (2013), Yang, Wang, Shen, and Han (2007) and Capuruço and Capretz (2009), minimizing the complexity of technologies and tools and making those flexible ensuring solid flow of learning activities, could be another challenge. Some papers had appreciated having a certain scaffolding structure that could also be mediated by

the teacher or instructor (So, Seah, & Toh-Heng, 2010; Wang, 2009). When considering the architectural models proposed, some attempts had reused an existing learning management system either by customizing it according to the needs or embedding new features/tools whereas others had practiced generic tools like Blogger, Skype, NetMeeting or social networking applications like Facebook or Twitter to promote learning. One frequent observation of the literature is that more than one technological approach had been utilized when designing the collaborative architecture as an alternative or complement to traditional LMS approach. Building learning communities by embedding more context-aware approaches such as artificial intelligent agents or contextualized knowledge bases were observed and those are seen as prominent and promising in future approaches (Calvo et al., 2011; Yang et al., 2007; Raymond et al., 2005).

Having homogenous student groups and small sample sizes for experiments had also been reflected as major concerns (Walta & Nicholas, 2013; Junco et al., 2013; Williams et al., 2011; Ferriman, 2013) by most of the researchers and had suggested that the experiments should have been extended to heterogeneous groups with larger sample sizes. This is interesting from a quantitative research perspective, but also important to evaluate the scalability of the technologies. While enabling communication is satisfactorily achieved by the current technologies, managing coordination and maintaining intense collaboration among many students are still challenging. When promoting collaborative activities like group formation, assigning roles or resource distribution teacher intervention had been seen as important by certain researchers. More articles recommended (Huang et al., 2010; Noroozi et al., 2013) forming groups as designed by teachers (manually or with software support), rather than letting students form their own groups according to their preferences since it would lead for subjective groups or free-passers because of friends. Adult guidance or collaboration with more capable peers (Vygotsky, 1978) in problem solving circumstances is encouraged in the learning sciences in order to achieve higher order cognitive levels. Learning being a continuous fluid process, when forming groups or distributing roles for activities, it would be an additional positive factor leading to potentially finest learning groups to be formed if learners' track record could be considered. But it was revealed that only least effort had been taken in literature with this regard and future research in embedding student profile to orchestrate learning activities will be welcoming.

Conclusion

The literature review presented in this paper has offered an understanding of the research situation (till 2013) around collaborative learning technologies for arguably large numbers of participants. The quotient of learners considered for massive classes or large communities was in 55% of the top scientific journal papers selected under 100 participants, in 37% between 100-1000, and in 8% over 1000. The scenarios studied were predominantly contextualized in higher education settings, followed by primary and secondary education. Scenarios of adult education and informal learning are less common in the reviewed studies. Overall, mainstream software such as general Web2.0 tools and LMS are the main platforms being used in the studies; only a reduced number of cases considered pervasive technologies and specific tools devoted to support collaborative learning. Activities mostly based on communication actions (open or structured discussion) are widespread in massive scenarios as well as peer review tasks devoted to distribute the assessment workload between learners. However, activities requiring higher coordination between learners (e.g., collaborative writing) are rare. Similarly, group formation techniques of diverse type are considered in those activities. Other collaboration mechanisms like allocation of roles or knowledge distribution among group members to structure the collaborative activity are less frequent.

Pedagogical models and platforms for massive courses can benefit from existing research result in technology-supported collaborative learning environments (e.g., application of group formation techniques, considering different types of intervention by instructors). However, there are still important challenges to address in massive collaborative learning. These challenges are of different nature, from cultural to technological, but its core relies on being able foster knowledge-intensive social interactions. Some of the reviewed papers tackle this critical aspect, and there is an additional corpus of research (not considered in the review since it is) deliberately oriented towards small groups of learners, that propose a number of solutions to that purpose. Understanding how these contributions for small groups can be scaled up is an interesting future research line. A related, but different, perspective is the exploration of innovative collaborative learning approaches that may work better at massive scale (Ferguson & Sharples, 2014). An analysis of the different perspectives and building on top of this literature review will allow the formulation of CSCL design aspects for MOOCs. This paper provides a founding framework of conceptual aspects to be considered and a set of discussion pointers that lead to further research directions.

The paper has answered the question of whether research on collaborative learning technologies has addressed massiveness. The question is answered considering top established journal publications in educational technologies. Further literature review is focused on other fora, such as new publication venues centered on MOOCs or recent conference proceedings can also provide a complementary view – to the review presented in this paper – of how research and practice on collaborative learning technologies is now being applied at a massive scale.

Acknowledgements

This research has been partially funded by the Spanish Ministry of Economy and Competitiveness in the EEE Project (TIN2011-28308-C03-03).

References

- Brett, P., & Nagra, J. (2005). An Investigation into students' use of a computer-based social learning space: lessons for facilitating collaborative approaches to learning. *British Journal of Educational Technology*, 36(2), 281–292.
- Bochicchio, M., & Longo, A. (2009). Hands-on remote labs: Collaborative web laboratories as a case study for IT engineering classes. *IEEE Transactions on Learning Technologies*, 2(4), 320- 330.
- Calvo, R., O'Rourke, S. T., Jones, J., Yacef, K., & Reimann, P. (2011). Collaborative writing support tools on the cloud. *IEEE Transactions on Learning Technologies*, 4(1), 88-97.
- Capuruço, R. A., & Capretz, L. F. (2009). Building social-aware software applications for the interactive learning age. *Interactive Learning Environments*, 17(3), 241–255.
- Chan, T. W., Roschelle, J., Hsi, S., Kinshuk, Sharples, M., Brown, T., Patton, C., Cherniavsky, J., Pea, R., Norris, C., Soloway, E., Balacheff, N., Scardamalia, M., Dillenbourg, P., Looi, C., Milrad, M., & Hoppe, U. (2006). One-To-One technology-enhanced learning: An Opportunity for global research collaboration. *Research and Practice in Technology Enhanced Learning*, 1(1), 3-29.
- Chou, P. N. (2012). Database comparison between Web of Science and Scopus: A Case of educational technology journals. *International Journal of Information and Educational Technology*, 2(6), 584-586.
- Dillenbourg, P. (1999). What do you mean by collaborative learning?. In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and Computational Approaches* (pp.1-19). Oxford, UK: Elsevier.
- Dillenbourg, P. (2002). Over-scripting CSCL: The Risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL. Can we support CSCL?* (pp. 61–91). Heerlen, NL: Open Universiteit Nederland.
- Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The Evolution of research on computer-supported collaborative learning. In N.vBalacheff, & S.vLudvigsen (Eds.), *Technology-Enhanced Learning: Principle and Products* (pp. 3-19). Netherlands: Springer. doi:10.1007/978-1-4020-9827-7_1
- Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *The Federation of American Societies for Experimental Biology (FASEB) Journal*, 22, 338-342.
- Ferguson, R., & Sharples, M. (2014). Innovative pedagogy at massive scale: Teaching and learning in MOOCs. In C. Rensing, S. de Freitas, T. Ley & P. J. Muñoz-Merino (Eds.), *Open Learning and Teaching in Educational Communities* (pp. 98-111). Springer International Publishing. doi:10.1007/978-3-319-11200-8_8
- Ferriman, N. (2013). The Impact of blended e-learning on undergraduate academic essay writing in English (L2). *Computers & Education*, 60(1), 243–253.
- Freeman, M., & McKenzie, J. (2002). SPARK, A Confidential web-based template for self and peer assessment of student teamwork: Benefits of evaluating across different subjects. *British Journal of Educational Technology*, 33(5), 551–569.
- Gerosa, M. A., Filippo, D., Pimentel, M., Fuks, H., & Lucena, C. J. (2010). Is the unfolding of the group discussion off-pattern? Improving coordination support in educational forums using mobile devices. *Computers & Education*, 54(2), 528-544.
- Harrer, A., Pinkwart, N., McLaren, B. M., & Scheuer, O. (2008). The Scalable adapter design pattern: Enabling interoperability between educational software tools. *IEEE Transactions on Learning Technologies*, 1(2), 131-143.

- Hernández-Leo, D., Villasclaras-Fernández, E. D., Asensio-Pérez, J. I., Dimitriadis, Y., Jorrín-Abellán, I. M., Ruiz-Requies, I., & Rubia-Avi, B. (2006). Collage, A Collaborative learning design editor based on patterns. *Journal of Educational Technology & Society*, 9(1), 58-71.
- Huang, J. J. S., Yang, S. J. H., Huang, Y. M., & Hsiao, I. Y. T. (2010). Social learning networks: Build mobile learning networks based on collaborative services. *Journal of Educational Technology & Society*, 13(3), 78–92.
- Ioannidou, A., Repenning, A., Webb, D., Keyser, D., Luhn, L., & Daetwyler, C. (2010). Mr. Vetro: A Collective simulation for teaching health. *Journal of Computer-Supported Collaborative Learning*, 5(2), 141–166.
- ISI Web of Knowledge (2013). *Journal Citation Report*. Retrieved from <http://admin-apps.webofknowledge.com/JCR/JCR?RQ=HOME>
- Junco, R., Elavsky, C. M., & Heiberger, G. (2013). Putting twitter to the test: Assessing outcomes for student collaboration, engagement and success. *British Journal of Educational Technology*, 44(2), 273–287.
- Kay, J., Reimann, P., Diebold, E. & Kummerfeld, B. (2013). MOOCs: So many learners, so much potential. *IEEE Intelligent Systems*, 28(3), 70-77.
- Kitchenham, B. (2004). Procedures for performing systematic reviews (Keele University Technical Report TR/SE-0401). Keele, UK: Keele University.
- Ladyshewsky, R. K., & Gardner, P. (2008). Peer assisted learning and blogging: A Strategy to promote reflective practice during clinical fieldwork. *Australasian Journal of Educational Technology*, 24(3), 241-257.
- Li, Y., Dong, M., & Huang, R. (2011). Designing collaborative e-Learning environments based upon semantic wiki: From design models to application scenarios. *Journal of Educational Technology & Society*, 14(4), 49–63.
- Ligorio, M. B., Talamo, A., & Pontecorvo, C. (2005). Building intersubjectivity at a distance during the collaborative writing of fairytales. *Computers & Education*, 45(3), 357–374.
- Looi, C. K., Seow, P., Zhang, B., So, H. J., Chen, W., & Wong, L. H. (2010). Leveraging mobile technology for sustainable seamless learning: A Research agenda. *British Journal of Educational Technology*, 41(2), 154-169.
- Noroozi, O., Teasley, S. D., Biemans, H. J., Weinberger, A., & Mulder, M. (2013). Facilitating learning in multidisciplinary groups with transactive CSCL scripts. *Journal of Computer-Supported Collaborative Learning*, 8(2), 189–223.
- Oliveira, I., Tinoca, L., & Pereira, A. (2011). Online group work patterns: How to promote a successful collaboration. *Computers & Education*, 57(1), 1348–1357.
- Ounnas, A., Davis, H. C., & Millard, D. E. (2009). A Framework for semantic group formation in education. *Journal of Educational Technology & Society*, 12(4), 43–55.
- Pérez-Sanagustín, M., Santos, P., Hernández-Leo, D., & Blat, J. (2012). 4SPPIces: A Case study of factors in a scripted collaborative-learning blended course across spatial locations. *International Journal of Computer-Supported Collaborative Learning*, 7(3), 443-465.
- Raymond, D., Kazuhide, K., Matsuura, K., Baudin, V., Gayraud, T., Yano, Y., & Diaz, M. (2005). A Model for content and communication management in synchronous learning. *Journal of Educational Technology & Society*, 8(3), 187-205.
- Samarawickrema, G., Benson, R., & Brack, C. (2010). Different spaces: Staff development for Web 2.0. *Australasian Journal of Educational Technology*, 26(1), 44-49.
- Sancho-Thomas, P., Fuentes-Fernández R., & Fernández-Manjón, B. (2009). Learning teamwork skills in university programming courses. *Computers & Education*, 53(2), 517–531.
- Saunders, F. C., & Gale, A. W. (2011). Digital or didactic: Using learning technology to confront the challenge of large cohort teaching. *British Journal of Educational Technology*, 43(6), 847–858. doi: 10.1111/j.1467-8535.2011.01250.x
- Schellens, T., Van Keer, H., De Wever, B., & Valcke, M. (2007). Scripting by assigning roles: Does it improve knowledge construction in asynchronous discussion groups?. *Computer-Supported Collaborative Learning*, 2(2-3), 225–246.
- Shaw R. S. (2013). The Relationships among group size, participation, and performance of programming language learning supported with online forums. *Computers & Education*, 62, 196–207.
- Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An Historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409-426). Cambridge, UK: Cambridge University Press.

- Stahl, G., Law, N., & Hesse, F. (2013). Reigniting CSCL flash themes. *International Journal on Computer-Supported Collaborative Learning*, 8(4), 369-374.
- So, H. J., Seah, L. H., & Toh-Heng, H. L. (2010). Designing collaborative knowledge building environments accessible to all learners: Impacts and design challenges. *Computers & Education*, 54(2), 479-490.
- Sonwalkar, M. N., Wilson, P. J., Ng, A., & Sloep, P. (2013, September). State-of-the-Field Discussion. In *MOOCs FORUM* (Vol. 1, No. P, pp. 6-9). New Rochelle, NY: Mary Ann Liebert, Inc.
- Suo, Y., Miyata, N., Morikawa, H., Ishida, T., & Shi, Y. (2009). Open smart classroom: Extensible and scalable learning system in smart space using web service technology. *IEEE Transactions on Knowledge and Data Engineering*, 21(6), 814-827.
- Susaeta, H., Jimenez, F., Nussbaum, M., Gajardo, I., Andreu, J. J., & Villalta, M. (2010). From MMORPG to a classroom multiplayer presential role playing game. *Journal of Educational Technology & Society*, 13(3), 257-269.
- Tsai, C. W. (2010). Do students need teacher's initiation in online collaborative learning?. *Computers & Education*, 54(4), 1137-1144.
- Tsai, F. S., & Wong, K. H. (2013). The State of Massive Open Online Courses (MOOCs) in engineering education: Where do we go from here?. In *Proceedings of the 120th ASEE Annual Conference and Exposition* (Paper no. 6416). Atlanta, DC: American Society for Engineering Education. Retrieved from <http://www.asee.org/public/conferences/20/papers/6416/view>
- Vygotsky, L. S. (1978). *Mind in society: The Development of higher psychological processes*. Cambridge, MA: Harvard College Press.
- Walta, C., & Nicholas, H. (2013). The iPod Touch in association with other technologies in support of a community of inquiry in off-campus teacher education. *Australasian Journal of Educational Technology*, 29(6), 870-886.
- Wang, Q. (2009). Design and evaluation of a collaborative learning environment. *Computers & Education*, 53(4), 1138-1146.
- Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, 26(2), 13-23.
- Williams, B., Lewis, B., Boyle, M., & Brown, T. (2011). The Impact of wireless keypads in an interprofessional education context with health science students. *British Journal of Educational Technology*, 42(2), 337-350.
- Yang, F., Wang, M., Shen, R., & Han, P. (2007). Community-organizing agent: An artificial intelligent system for building learning communities among large numbers of learners. *Computers & Education*, 49(2), 131-147.
- Zhan Z., Xu, F., & Ye. H. (2011). Effects of an online learning community on active and reflective learners' learning performance and attitudes in a face-to-face undergraduate course. *Computers & Education*, 56(4), 961-968.