A systematic review on E-learning environments for promoting critical thinking in Higher Education

1. Introduction

The 21st century has arisen out many challenges regarding the skills students and employees need in today's world (Rotherham & Willingham, 2010). These are associated with new forms of information and communication technologies (ICTs), which allow moving, presenting and representing information in easier ways. Furthermore, ICTs affect the teaching strategies providing different approaches to integrate core skills into educational curriculum.

There is some consensus among educators about the need to establish certain core skills that should be taught in schools and included in the curriculum (Binkley *et al*., 2012). According to Lee *et al*. (2016), core skills can include critical thinking (CT) skills, which are considered relevant since problems individuals have to face nowadays are ill defined and require CT in drawing on knowledge from a variety of fields (Gerber & Scott, 2011). CT is considered as a seminal goal in higher education (HE), however HE has made scarce progress towards this goal and there is little agreement about the conditions under which instruction could result in greater CT outcomes (Tiruneh, Verburgh, Elen, 2014). There is a wealth of theoretical studies on CT in HE, in contrast with few empirical investigations about which teaching strategies and learning environments do better promote CT. Part of these studies proposes E-learning as a way to enhance CT skills, using diverse approaches and learning activities for addressing this goal. In this context, the main purpose of this chapter is to develop a meta-analysis about empirical research in E-learning environments to foster CT in HE. The present review is necessary since no previous meta-analysis about CT interventions based on E-learning has been performed previously. Therefore, we aim to provide an overall overview about CT instruction through E-learning, paying special attention to the characteristics and teaching strategies used in those environments that make CT interventions successful.

2. Learning to think critically in Higher Education, Teaching approaches, interventions and learning environments

Researchers have offered many definitions of CT (e.g., Ennis, 1962; Facione, 1990; Siegel, 1988). The Delphi panel of the American Philosophical Association (APA), in which 46 leading experts in CT have participated, such as Ennis, Facione, and Paul, offers a consensual and broad definition of CT and identify six skills (interpretation, analysis, evaluation, inference, explanation, and self-regulation), 16 subskills and 19 dispositions (e.g., inquisitiveness, open-mindedness, understanding others).

According to the Delphi panel experts, CT cannot be considered as a body of knowledge to be delivered to students as one more school subject along with others. CT should be embedded in discipline-specific content programs, which rely on the events in everyday life as the basis for developing one's CT. Following Paul's (2005) opinion, CT can be expressed in different ways. Thus in HE, CT interventions could encompasses debates about critical pedagogy, political critiques of the role and function of education in society, critical approaches to curriculum, the development of critical thinking citizenship or any other education-related topic that uses the appellation "critical". Paul, Elder and

Bartell (1997) point that most college faculties of all levels lack a substantive concept of CT and most faculties do not realize they lack a robust concept of CT, instead they believe to understand CT sufficiently and to be already successful teaching it within their disciplines.

Trends in educational research have shown an increasing interest in how learning environments and teaching strategies may influence the development of CT. However, little is known about what characteristics of learning environments do better support the development of CT by students (Ennis, 2016). ten Dam and Volman (2004) highlighted some key aspects to foster students to think critically: a) paying attention to the development of the epistemological beliefs of students, b) promoting active learning, c) stimulating interaction between students, to exchange their point of view (Paul, 1992), and d) using real-life contexts (Brown, 1997).

According to Ennis (1989), there are four main approaches for promoting CT that emerged from the attempt to provide a framework that would help researchers and professionals. The first one, the *general approach*, takes place when the abilities and dispositions are taught separately from the content. In generic courses, CT skills and dispositions are the course objective with no specific subject matter (Abrami *et al*., 2008, 2015). The *infusion approach* is a subject matter instruction in which students are encouraged to think critically about the subject addressed. In this approach the general principles of CT are made explicit and the content of the courses is important (Abrami *et al*., 2008, 2015). The *immersion approach* is similar to the previous one; both of them integrate CT in subject matter instruction, but in the immersion approach the principles are not made explicit to the students assuming they will acquire the skills once they engage in the subject matter instruction (Tiruneh, Verburgh & Elen, 2014). The *mixed approach*, named by Sternberg (1986), consists on a combination of the general approach with either infusion or immersion approach, but we should keep in mind some practical and theoretical considerations such as the recurring question about if CT is a specific domain.

CT can be taught through the implementation of several teaching strategies. We present a summary of the most representative ones that also have a common characteristic: students must assume an active role in order to solve real-life problems (Niu, Behar-Horenstein & Garvan, 2013). According to these authors, the belief that CT can be taught and learned has spread and gained support in the last years; therefore educators are making an impressive effort to foster CT in their classrooms and CT has slowly made its way in different educational levels and specific instructional interventions.

Problem based learning (PBL) is one of the most widely learning approach used nowadays in CT instruction, since it's motivating, challenging and enjoyable (e.g., Norman & Schmidt, 2000; Niu, Behar-Horenstein & Garvan, 2013; Pithers & Soden, 2000). Ennis (2016) suggests that PBL should involve students in investigating, developing, testing, discussing hypothesis or solutions and alternatives. Furthermore, this author proposes a strategy to impart CT lectures in which the teacher would present, explain, challenge and interact with the students. Hitchcock (2015) also mentioned lectures as a strategy and adds computer-assisted instruction with built-in tutorial help using specific software named LEMUR, which stands for Logical Evaluation Makes Understanding Real.

The most popular categorization of instructional interventions in current research has been proposed by Abrami *et al*. (2015). In their study they opted for Facione's (1990)

CT definition and aimed to expand the analysis of CT beyond a single instructional classification scheme, trying to offer a fine-grained approach. In order to achieve this goal these authors develop a set of four categories, displayed in table 1.

Table 1. Abrami *et al*.'s Interventions (2015, p. 289)

Categories	**Description**
Individual Study (self-study)	Instructional techniques and learning activities that are based on students' individual work. It takes place whenever students study alone by engaging in reading, watching, listening to a teacher's explanations, reflecting on new information, and solving abstract problems on their own.
Dialogue	The didactic strategy used to integrate the dialogue is the discussion. When engaged in critical dialogue, individuals are discussing a particular problem together. The dialogue may be adversarial or cooperative, but in either case, some sort of question in under consideration. Critical dialogue can take multiple forms such as whole-class debates, within-groups discussions and/or online discussion forums.
Authentic or Anchored Instruction	Students are presented with genuine problems or problems that make sense to them, engage them and stimulate them to inquiry. Approaches included in this category can be simulations and role-playing, dilemmas (e.g., medical, ethical) presented to the students.
Mentoring	The key component of mentoring is one-on-one interaction between an expert, or more generally someone with more expertise, and a novice, or more generally someone with less expertise. Mentoring emphasizes one-on-one modelling and error correction based on critical analysis. One-on-one mentoring, tutoring, coaching, apprenticeship or modelling, are arguably the oldest form of teaching.

There have been several reviews focusing on the effects of instruction on CT. Pithers and Soden (2000) provided an overview of methods and practices related to teaching CT and Ritchhart and Perkins (2005) discussed a variety of challenges to school-based instruction in CT. Despite these efforts, little is known about which teaching strategies and interventions are the most effective. Abrami *et al*. (2015) point that the opportunity for dialogue, the exposure of students to authentic or situated problems and examples, and mentoring had positive effects on CT skills.

Apart from those aspects mentioned, the characteristics of learning environments are relevant for an effective CT instruction. In general, a learning environment or classroom social climate makes reference to the relationships of students' group characteristics and the dynamic of class group to create an atmosphere for a more effective educational intervention (Fraser, Anderson & Walberg, 1982). According to these authors, interactions between teachers and pupils or classroom structural characteristics, among others, determine the social behaviour of students, as a consequence their CT skills.

3. **Thinking critically in E-learning environments**

CT has received an increasing attention in HE in recent years (Ku, 2009), although, while there is a consensus among educators about its importance; there is not an agreement on how to teach it best. Trends in educational research indicate a rising attention on how E-learning environments may influence learning (Hirumi & Bai, 2010) and might support the development of core 21st century skills, such as CT skills.

There are diverse definitions of E-learning environments. We draw from Area's and Adell's definition (2009), who consider it an education offered to individuals who are geographically distant or who interact in different times with the teacher using computer resources. According to Szabo and Schwartz (2011), E-learning environment presents several benefits such as providing outside classroom time where students can work collaboratively and discuss about a topic through wikis, blogs or forums. Moreover, it seems to be an environment that favours CT skills among students (e.g., Yeh, 2009; Szabo & Schwartz, 2011; Saadé, Morin & Thomas, 2012) because it enhances problem solving, decision-making, collaboration and higher-order thinking skills (Hopson, Simms & Knezek, 2002). Drawing from Facione's CT definition (1991), a critical thinker should be a person well informed, diligent in seeking relevant information and with competences to make judgements based on evidence. E-learning offers students the possibility to practice some of these skills. It offers a learner-centered education with unlimited access to knowledge that requires contrasting information and discerning reliable information (Zhang, Zhao, Zhou, & Nunamaker, 2004), for which CT is an important skill to (Saadé, Morin & Thomas, 2012).

According to Area & Adell (2009), there are three main E-learning approaches: 1) *face-to-face or on-site classrooms,* using online learning resources; 2) *blended learning,* referring to join face-to-face and virtual classroom, also called flipped classrooms; 3) *online learning*, which takes place strictly in a virtual environment. The last two approaches have in common that allow asynchronous discussions, given the opportunity to use constructivist perspectives. Both facilitate also personalized learning regardless of time and space boundaries (Şendağ & Odabaşı, 2009). Previous studies in E-learning (Snodgrass, 2011; DeRuisseau, 2016) have reported flipped classrooms' advantages to promote CT. For instance, they allow more time to do CT activities in the classroom and enhance students to collaborate each other increasing their CT skills. In the comparison carried out by Schumm *et al.* (2006), between *face-to-face* and *online* classrooms, the results show that *online* discussions foster CT since they allow students to share knowledge, and engage them not only in analysing and assessing themselves, but also in supporting their assertions or refute the others opinions and views (Greenlaw & DeLoach, 2003).

One of the main concerns in E-learning environments, described by Gros (2011), refers to the creation of specific materials such as videoconference or instructional softwares. Currently, the E-learning model tries the collaboration of all participants, both students and teachers, making use of 2.0 tools. These tools present different functionalities. Hew and Cheung (2013) point that online collaboration is promoted by *wikis*, since participants interact each other to create and share information, whereas online reflection may be fostered through *e-portfolios* and *blogs*. In both cases asynchronous and synchronous discussions take place. Asynchronous discussion is developed when students ask questions and think about their ideas and different points of views after reflective thinking (Cho, Lee & Jonassen, 2011), whereas synchronous discussion is carried out by means of game virtual worlds and social networks (Hew & Cheung, 2013).

Research in E-learning has shown that students perceived this environment as an opportunity to participate in highly interactive dialogues with the teacher and other classmates, which facilitates the discussion and argumentations skills involved in CT

(Bolliger & Wasilik, 2009). Both, CT and argumentation overlapped in their territories of engagement, and both have pedagogical implications for learning and teaching in higher education (Andrews, 2015).

Nevertheless, fostering CT through E-learning, requires teachers' pedagogical knowledge on how to use effectively E-learning and digital tools (Szabo & Schwartz, 2011). Researchers advocate for active learning; implementing tasks of authentic situations, through project-based learning and sustained and challenging work in individualised or collaborative group (Ramirez & Bell, 1994). Moreover, teachers' knowledge on how to scaffold collaborative learning and foster dialogue is needed, as well as on tools to engage students in contrasting different information and/or points of views, what may part of CT skills (McLoughlin & Luca, 2000; Kim, 2015).

Despite previous studies have pointed out advantages offered by E-learning to promote CT, further research in this domain is needed in order to know: 1) how to implement instructional strategies, learning philosophies and collaborative learning in digital media (Saadé, Morin & Thomas, 2012), 2) how to design instructional strategies to promote CT in wiki-based learning environment (Kim, 2015) and 3) how to teach CT skills with the integration of E-learning (Yeh, 2009).

Aims of the study and methods

There is an extensive body of literature, which argues that Internet supports argumentation, the construction of knowledge and higher order thinking or CT. As such, many E-learning advocates have turned to the Community of Inquiry as an ideal pedagogy because it too shares these educational ideals (Bleazby, 2012). We seek to provide an insight into successful and emerging instructional models based on E-learning for supporting CT skills in HE. The two research objectives are: 1) to identify a repertoire of characteristics of E-learning environments for promoting CT and 2) to provide an insight into successful and emerging instructional models for the development of CT based in E-learning. For addressing these goals, a systematic review of the international literature is carried out integrating content analysis (Bardin, 2011).

Search strategy: The literature review was conducted searching relevant peer-reviewed English language papers published from January 2013 to June 2017 (last five years). The reason to limited the searching to this period is because E-learning develops at a fast pace; therefore their potential effects on learning outcomes and challenges are presumable different than they were 5 years ago.

Reference databases as ERIC and Web of Science were used to look for high impact and relevant articles. The following keywords, closely related to our research objectives were applied in the searching: E-learning environment and Critical Thinking. Moreover, we focused the search using Higher Education (HE) as a descriptor.

Inclusion criteria and study selection. From the total papers founded (N=45), we selected those studies, which fit with the aim of this chapter that is to examine the effects of HE interventions based in E-learning in the development of CT. To do so, articles must bring together these inclusion criteria: 1) being empirical, since a large part of the literature founded appeared to be theoretical, 2) having a clear E-learning scenario, 3) developed in HE, 4) a well defined intervention based in E-learning to promote CT, and 5) describing quantitative and/or qualitative results of this intervention.

The search concluded with 45 papers from electronic databases, which were screened to select those relevant for our study. Two authors of this chapter examined independently the articles applying the criteria above. In this examination the authors

read utterly the article to determine which of them were suitable for the study according to the inclusion criteria. The final outcome was a total of 19 studies, which are finally analysed in order to deal with the purpose of the present review. Figure 1 summarises this process.

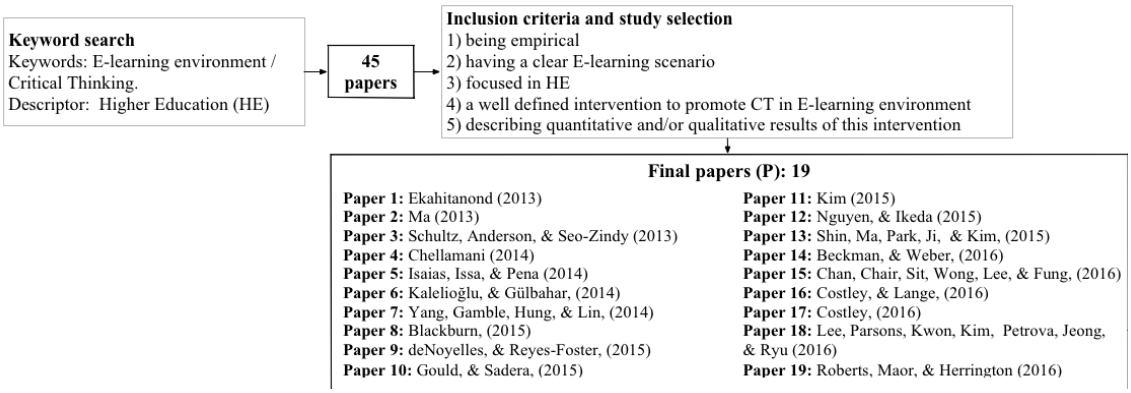

Figure 1. Summary of the process of selection E-learning papers.

Data analysis. For addressing the first research objective, about the characteristics of E-learning environments for promoting CT, we analyse four dimensions: 1) general overview (the type of study & field), 2) CT teaching approach (Ennis, 1989) and strategies (Ennis, 2016), 3) E-learning approach/tool/activity, and 4) type of intervention (Abrami *et al*., 2015).

For the second objective, the identification of successful instructional models in E-learning to promote CT in HE, the focus is on CT assessment methods and on the examination of CT results. This analysis will give us an insight into emerging and successful instructional models for promoting CT skills, as well as data about about quality research in E-learning environments for CT.

RESULTS

Characterization of E-learning environments for promoting critical thinking

This section provides an overview on E-learning environments to foster CT among HE students. First, a brief description of the studies analysed is presented and second, a detailed examination on CT and E-learning approaches and activities is developed. Table 2 summarizes the results. In a general view, the studies (N= 19) are carried out in diverse fields in HE: education (4), language (4), nursing (2), earth and environment (1), communication (1), health (1), computer science (1), business (1), industrial engineering (1). One study is developed in several fields and two studies do not specify the field. It needs to be highlighted that CT studies using E-learning are more frequent in social sciences than in sciences.

Regarding the E-learning approach, the majority of studies (13 out of 19) have opted for b-learning. The rest of the papers are conducted using online (4 out of 19) and on-site environments (2 out of 19). In these scenarios we have found diverse E-learning tools used for the promotion of CT. The most common are virtual platforms like virtual learning environments (VLE) (7) or Moodle (2), which mean a share space between teacher and students useful for both online and b-learning environments. Other E-learning tools apply in those studies include: blogs (2), e-portfolios (2), wikis (2), online posting

(2) and e-mail (1). These tools contribute to asynchronous discussions in b-learning and online environments allowing students to think about the topics and compare different points of view before giving an answer. Finally, other tools used in E-learning programmes are simulation courseware (1) and Scenario Based Learning interactive (SBLi) (1), although they set aside on-site environments.

Considering E-learning activities, most E-learning interventions promote CT engaging students in discussions about different topics like the necessary skills in a teacher to perform real situations applying different strategies (P4: Chellamani, 2014) and in other studies the discussions is related to the content of commercials (P3: Ekahitanond, 2013; P2: Ma, 2013). Another way to develop CT consists on dealing with potential real situations, closely to PBL, in which students have to investigate about the problem itself and try to make a solution. This is the E-learning activity choose, in P3, by Schultz, Anderson and Seo-Zindy (2013), asking students to create a forecast; in P10, Gould and Sadera, (2015) who propose PBL about diabetes, heart disease and diet therapy engaging students in clinical reasoning; in P14, Beckmann and Weber (2016) who ask students to create a business plan; among others.

The analysis shows that E-learning environments apply preferably the immersion approach (18 out of 19) for the development of CT, what means that CT is embedded in the discipline content. Only one study is conducted under an infusion approach that is when CT principles are taught explicitly. The authors of this paper, P7 , Yang, Gamble, Hung and Lin (2014), investigate the effectiveness of CT-infused approach in English literacy instruction. To do so, a professor from the Institute of Education teaches students CT concepts and skills during face-to-face workshops and, then, students apply CT into asynchronous online discussions. Although it is the only study identified using an infusion approach, previous investigations have pointed out the adequacy of CT instruction before applying it to achieve better learning outcomes (Abrami *et al*., 2008).

Table 2. Characteristics of E-learning studies (N=19) included in the systematic review.

E-learning approach	**E-learning tool**	**E-learning activities**	**CT teaching strategy (Ennis, 2016)**	**Interventions (Abrami *et al.*, 2015)**
Online (N=4)	Moodle (1)	- Online discussions about commercials. (P1:Ekahitanond, 2013)	Other: Online forum	Authentic instruction+ dialogue
	VLE (2)	- Argumentation online about commercials (P2:Ma, 2013)	Other: Argumentation	Authentic instruction
		- Create a business plan eLectures, peer review (P14:Beckmann, & Weber, 2016)	LDT+PBL	Authentic instruction
	Blog & e-portfolio (1)	- Assess prompts in a e-portfolio (P19: Roberts, Maor, & Herrington, 2016)	Other: Assessment	Self study
b-learning (N= 13)	VLE (3)	- Create a forecast consulting information, lectures. (P3:Schultz, Anderson, & Seo-Zindy,2013)	LDT+PBL	Authentic instruction
		- Online PBL about diabetes, heart disease and diet therapy (P10: Gould, & Sadera, 2015)	PBL	Authentic instruction
		- Case Based Learning (CBL)	PBL	Authentic

		(P15: Chan *et al.,* 2016)		instruction
	Wiki (2)	- Analyse and synthetize articles, case studies, discussions (P5: Isaias, Issa, & Pena, 2014)	LDT + PBL	Self study + dialogue
		- Critique, edit and create wikibook (P11: Kim, 2015)	Other Wikibook	Self study + dialogue
	Online posting (2)	- Online forum, online posting and offline discourse. (P16:Costley, & Lange, 2016; P17 Costley, 2016)	Other: Online discussions	Self study + dialogue
	Blog (1)	-Lectures, discussions, group work (p.4: Chellamani, 2014)	LDT	Self study + dialogue
	Mobile learning game (1)	-Mobile game-based learning (P18:Lee, Parsons, Kwon, Kim, Petrova, Jeong, & Ryu, 2016)	PBL	Authentic instruction
	Website & e-mail (1)	Small group discussions around a prompt (P9: deNoyelles, & Reyes-Foster, 2015)	Online discussions	Dialogue
	e-portfolio (1)	- e-portfolio. (P12:Nguyen, & Ikeda, 2015)	Other: e-portfolio	Self study
	Moodle (1)	- Collaborative online activities writing and reading English (P7: Yang,Gamble,Hung & Lin 2014)	Online discussions	Self study + dialogue
	Chat (1)	- Chat. (P6: Kalelioğlu & Gülbahar,2014)	Other: Online discussions	Dialogue
On-site classroom (N=2)	SBLi (1)	SBLi, Lectures, Real world simulation, PBL(P8:Blackburn, 2015)	LDT+PBL	Authentic instruction
	Simulation courseware (1)	Simulation courseware about nursing scenarios (P13: Shin, Ma, Park, Ji, & Kim, 2015)	PBL	Authentic instruction

As we can infer from these studies, most of them use CT teaching strategies proposed by Ennis (2016), particularly PBL (4) or LDT jointly PBL (4), however only one study have applied exclusively LDT. As Ennis (2016) suggests, PBL strategy should involve students in investigating, developing, testing, discussing hypothesis or solutions and alternatives, in which students should transfer knowledge to a real situation. Furthermore, this author proposes as a strategy to impart lectures about CT in which the teacher would present, explain, challenge and interact with the students; engage them in discussions presenting practices examples that foster argumentation and inquiry practices. Several researchers implement learning strategies similar to PBL such as mobile gamed-based learning (P18:Lee *et al.,* 2016), a simulation courseware (P13:Shin *et al*., 2015) or a scenario-based learning interactive presented through cases (Blackburn, 2015) in a b-learning environment. Nevertheless, ten studies apply CT teaching strategies to promote CT but different of Ennis' categories like online discussions (6), argumentation (1), e-portfolio (1), assessment (1) and wikibook (1). Thus, in P19, Roberts, Maor and Herrington (2016) engage students to CT when they have to assess different prompts in an e-portfolio.

As a consequence of a majority of PBL and LDT+PBL strategies most of interventions are associated with authentic instruction (9 out of 19), that is to say, problems that make sense to students motivating and promoting to think critically. For

instance, in P15, Chan *et al*. (2016), firstly, involve students into a case analysis, evidence collection and establish a solution regarding clinical case scenarios. Secondly, a forum of discussion is created about each case in order to stimulate CT. Apart from authentic instruction, other types of interventions are identified: dialogue (2), self-study (2) and dialogue & self-study (6), in all cases it is expected that self study implies solving abstract problems applying some CT skill and dialogue should be critical in sense of whole-class debates, within-groups discussions and/or online discussion forums.

Critical thinking based on E-learning: assessment, good practices and difficulties

For the examination of the second research objective, to provide an insight into successful and emerging instructional models for the development of CT based in E-learning, attention is on the implementation and assessment methods for CT development.

The analysis shows that most studies assessed CT explicitly (12) that means: CT skills (9), CT dispositions (2), CT skills & dispositions (1), although not all of them use the same methods. Table 3 synthetize those results regarding assessment methods. Few papers, three out of 19, apply the Likert method to get information about the improvement in CT skills and dispositions. We consider this methodology lacks rigor since it is focused on students' perception about their own CT development rather than on the examination of CT results through the application of specific rubrics. Another three studies use pre and post-test for the analysis of CT results based on three reliable test: California Critical Thinking Disposition Inventory (Facione & Facione, 1992), California Critical Thinking Skills Test (Facione *et al.,* 2002) and Holistic critical thinking scoring rubric (Facione & Facione, 1994). Four studies make a content analysis coding the data using the CT diagnosis model established by Newman *et al.* (1995) and one follows the CT categories proposed by Greenlaw & DeLoach (2003).

Apart from those studies that analyses CT, 5 out of 19 assess other characteristics but CT is implicit in the results. For instance, in P4, Chellamani (2014) has investigated how lectures and discussions in b-learning implies an improve interactive learning and as a consequence the author affirms a betterment also in CT. Finally, only 2 out of 19 assess the effectiveness of E-learning environment but without mention CT on their results, as P19, Roberts *et al*. (2016) who analyses the E-learning environment adequacy to get good results into e-portfolio but not how this has an impact on CT development.

Table 3. Summary of CT assessment and assessment method

CT assessment (N=19 papers)		**CT assessment method**
CT is explicitly assessed (N=12)	CT Skills (N=9)	**Survey Likert** (P5: Isaias, Issa & Pena, 2014) **Pre & post test** (P1:Ekahitanond, 2013; P7:Yang *et al.,* 2014; P12:Nguyen & Ikeda, 2015) **Content analysis** (P11: Kim, 2015; P14:Beckmann & Weber, 2016; P18:Lee *et al*., 2016; P16:Costley & Lange, 2016; P17: Costley, 2016)
	CT Dispositions (N=2)	**California Critical Thinking Disposition Inventory** (P6: Kalelioğlu, & Gülbahar, 2014) **Yoon's CT disposition tool with Likert scale** (P13: Shin *et al.*, 2015)
	Skills & Dispositions	**Questionnaire** (P9: deNoyelles & Reyes-Foster, 2015)

	(N=1)	
CT is implicitly assessed (N= 5)		P2: Ma (2013); P3: Schultz, Anderson, & Seo-Zindy (2013); P4: Chellamani (2014); P8: Blackburn (2015); P15: Chan, Chair, Sit, Wong, Lee, & Fung, (2016)
CT is not assessed (N= 2)		P10: Gould & Sadera, (2015); P19: Roberts, Maor, & Herrington (2016)

In order to capture good examples about how E-learning environments promote CT, we have selected those that assess explicitly CT (12 out of 19). Taking into consideration the characteristics of the environment itself, the studies which report better results has been carried out using diverse E-learning approaches and a large variety of activities and tools.

Regarding the improvement of CT skills, the research conducted in P1 by Ekahitanond (2013) shows that online (moodle) activities related to discussions about commercials promote students' CT skills (knowledge, comprehension, application, analysis, synthesis, evaluation) because of two reasons: 1) good adaptation of critical inquiry model and 2) peer feedback strategy. In P18, Lee *et al.*'s (2016) study reveals that students tent to use given ideas instead of using their owns when they have to design a solution for the mobile game-based. The main contribution of these authors consists on demonstrate empirically that this particular E-learning environment fosters collective interactions that contribute to develop CT skills such as: clarification, justification and linking ideas. This matches with, P9, deNoyelles and Reyes-Foster's (2015) investigation in sense of pointing out that CT and peer interaction have a positive correlation, therefore one affects positively to the other. In the study carries out by Kim (2015), in P11, students are faced to create and evaluate a wiki, hence, the results indicate that higher levels of CT are founded when students acted as author's chapter, and lower levels of CT when peer's chapters. In P16, Costley and Lange (2016) examine how social presence and CT interact each other. The results show that CT skills are poorly developed in social presence. However, in another study, P17, carried out by Costley (2016) the focus consists on examining how long the participation in forums improve CT. The results indicate that the more forums students followed the greater improvement on their CT skills (relevance, importance, liking ideas, justification outside knowledge, etc.). Also in a forum context, P14, Beckmann and Weber (2016) have founded that students introduce outside knowledge to the discussion and they argue, what implies better CT. The P7, Yang *et al*.'s (2014) study deserves a special mention to be the only one that comprises an infusion approach to develop CT skills. The quantitate results manifest a significant increase in overall CT skills (analysis, evaluation, inference, deductive and inductive reasoning) during asynchronous online discussion. Also, it has been proved that infusion approach allows a positive impact on CT skills and students' English literacy.

Concerning CT dispositions, in P6, Kalelioğlu and Gülbahar (2014) compare different E-learning tools to foster CT dispositions. From the quantitative analysis they conclude that there are not significant differences among those tools, what can occur because CT dispositions are closely related to personal characteristics. However, in the qualitative analysis they have founded that Socratic seminar group developed lower levels of CT dispositions being the Mixed techniques group who acquired higher levels of analycity, open-mind, inquisitiveness, self-confidence, truth-seeking and systematicity. According to the researchers, this could happen because mixed techniques favours students to realised about the relevance of discussion process and then their motivation. In P9, deNoyelles and Reyes-Foster (2015) have founded that online discussions around prompts favours students to think outside the box, which can be understood as open-

minded disposition. In P13, about CT dispositions developed by Shin *et al.* (2015), the authors conclude that the more exposures to nursing scenarios better scores of CT dispositions were acquired. Nevertheless, all students have a significant increase in the post-test to 4 dispositions (prudence, systematicity, healthy scepticism and intellectual eagerness).

Although all studies commented before have reported good results of implementing CT in E-learning environment, most of them point out limitations or difficulties in their studies. The main limitation makes reference to the small size simple. However, other studies have noted particular difficulties to consider in future research. Thus, in P1, Ekahitanond (2013) and, P13, Shin *et al*. (2015) point out that other variables, apart from those controlled in each study, could contribute to increase students' CT skills; or even in P12, Nguyen and Ikeda (2015) see the possibility that the improvement in some CT skills (particularly in self-regulation) has been due to the passage of time rather than the use of e-portfolio. Also, in P6, Kalelioğlu and Gülbahar (2014) have perceived that students were not familiar with virtual discussions what can influence the final results.

Conclusions and challenges for future research

This systematic review allows showing diverse E-learning scenarios that seem to promote CT among HE students, being the most common approach b-learning using online forums or discussions. However, as improvements on CT have been reported in environments with different characteristics, we cannot conclude which E-learning environment is the best for promoting CT, This meta-analysis provides an insight into some fundamental aspects that foster CT applying 2.0 online tools.

E-learning is used in different fields from education to health contexts, which reveals that is considered by teachers as an adequate scenario for promoting CT in HE. The most common didactical proposals are based on asynchronous discussions about real situations (eg. Ekahitanond, 2013; Kalelioğlu, & Gülbahar, 2014). These discussions are implemented through b-learning or online learning allowing students to have enough time to think about the topic and interact each other despite space boundaries, which are important aspects to consider into CT development (Şendağ & Odabaşı, 2009; Szabo & Schwartz, 2011). Even more, b-learning is the predominant approach, maybe because it is easy to integrate E-learning in a common classroom making use of different tools like moodle, wikis or forums. Particularly, forums have good results on development on students' CT skills such as relevance, importance, liking ideas or justification, as reported by Costley (2016). Some studies have reinforced that cooperative or collaborative learning favours CT skills, especially when students have to justify their ideas (deNoyelles & Reyes-Foster, 2015; Lee *et al.,* 2016) or discuss about a real-life problems as is pointed out by Niu *et al*. (2013). In fact, the majority of these studies comprise LDT or PBL strategies, being PBL one of the most widely learning approach used nowadays-in CT instruction, since it is motivating and challenging (Niu, BeharHorenstein & Garvar, 2013).

There are four main challenges that draw from this meta-analysis, related to different dimensions of CT: 1) CT assessment, 2) CT teaching strategies, 3) CT dispositions and 4) different variables that affect CT development, apart from the E-learning environment.

First one, most studies do not assess CT using reliable methods for evaluation CT skills and dispositions. The majority assess CT implicitly, what means that attention is not on the evaluation of CT skills and dispositions, but on the adequacy of E-learning

environment and/or development of the activity. These elements may affect CT development as Chellamani (2014) and Roberts *et al.* (2016) suggest. Studies that analyse CT explicitly apply Likert scale or subjective questionnaires focusing on students' perceptions, instead of using an objective method. Content analysis or pre and post-test are not carried out in most of these papers by the researcher or teacher.

Second challenge concerns to the type of CT teaching strategy. Although the literature on CT suggests that an infusion approach may be beneficial for the development of CT (Abrami *et al*., 2008), this meta-analysis shows that immersion approach is the most common, even though data from the systematic review doesn't allow discerning the reasons of choosing this approach. Only one investigation implements infusion approach (Yang *et al*., 2014) obtaining good results. Students improve CT skills, which can be associated to a previous instruction on CT concepts and skills, what is coherence with Abrami *et al*.'s (2015) view.

The third challenge can be considered also a limitation. It is related to the low number of studies that include CT dispositions. Only three papers out of 19 put emphasise on some dispositions as open-mindedness, self-confidence and systematicity, which was also founded in a recent literature review on CT in HE developed under the framework of an European Project on CT. We consider this as an important concern suggesting that educators and HE teachers may do more emphasis on CT dispositions.

Last challenge deals with one difficulty reported about other variables that can influence CT, apart from those included on the analysis. We must keep in mind that social presence can limit CT development in students as Costley and Lange (2016) point out. Further research is needed in order to understand deeply how social factors as personal interactions or mainstream could affect to be a critical thinker.

In conclusion, this review seeks to contribute to a better understanding on how E-learning might promote CT in HE, despite the challenges above. There is a need to develop more qualitative and in depth research on CT through E-learning, in order to improve the knowledge about the daily-work basis that may help to identify which learning strategies and activities better promote CT, turning ultimately into a better educational practice.

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