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Lessons Learned from the Design of Situated Learning Environments to Support Collaborative Knowledge Construction

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Abstract

The main characteristics of situated learning environments (SLEs) are: to provide authentic contexts, activities, expert performances and integrated assessment; to support multiple roles and perspectives, collaborative knowledge construction, coaching and scaffolding; and to promote reflection and articulation. However, current SLEs have two limitations: (1) not all of these characteristics are included, particularly lacking collaborative knowledge construction, in most cases; and (2) most SLEs are designed to support learning activities outdoors, but not indoors. This paper presents the implementation of a SLE that overcomes these two limitations. This SLE is based on bidirectional Quick Response (QR) codes, which are enhanced QR codes that not only provide information when scanned but also collect user-generated content. This “Bidirectional SLE” is evaluated in an experiment in which it is compared with an equivalent “Traditional SLE”, which is built upon traditional QR codes. The purpose of this comparison is to understand if using bidirectional QR codes as a mechanism to support collaborative knowledge construction in indoor settings has an impact on students’ learning outcomes and on their impression of the learning experience. Two hundred fifty-three students participated in this experiment. Data collected from this experiment indicate that the students who worked in the Bidirectional SLE (1) received better scores, providing better and more complete answers, and (2) evaluated their learning experience as better than their peers’ who worked in the Traditional SLE. Finally, a cross-analysis of these results including teachers’ opinions led to a set of lessons learned about the design of SLEs to support collaborative knowledge construction.

Keywords: collaborative learning; computer-mediated communication; improving classroom teaching; post-secondary education; teaching/learning strategies.

1. Introduction

Situated Learning (SL) practices have gained importance in recent years given the need to train “21st century professionals” who are capable of collaborating and solving problems in different contexts and situations (Gardiner, Corbitt, & Adams, 2009; Lunce, 2006; Meyers, & Lester, 2013; Redecker et al., 2011). Lave and Wenger (1991) defined SL as “the product of the activity, context and culture in which learning is developed

and used.” SL was first introduced by Brown, Collins and Duguid (1989) as a model for classroom instruction; since then, several researchers have contributed, expanding upon and working on this idea, proposing different definitions, instructional design strategies and models (Clancey, 1995). In 1993, McLellan (1993) proposed a model for SL instructional design in which technology was used as a mechanism for simulating authentic “micro-worlds” (as an alternative to real-life settings). For the first time, technology was proposed as a “real world” anchor that expanded the context of practice for the learner. Later, Stein (1998) defined the four critical elements of a SL environment (SLE): (1) content, the tasks and processes that learners have to perform; (2) context, the situations and environmental cues surrounding learners, and supporting them in the meaning creation process; (3) community, the group of people with whom learners communicate to create negotiated meaning; and (4) participation, through which learners become the center of the learning process, working together with others in their community.

Inspired by Stein’s work, Herrington and Oliver (2000) proposed a framework made up of nine elements to define the characteristics SLEs should include to support SL: (1) to provide an *authentic context* that reflects the way knowledge will be used in real life; (2) to provide *authentic activities*; (3) to provide access to *expert performances* and modeling of processes; (4) to support *multiple roles and perspectives*; (5) to support *collaborative construction of knowledge*; (6) to promote *reflection*; (7) to promote *articulation* (negotiate, defend and discuss the activity) to enable tacit knowledge; (8) to support *coaching* and *scaffolding* at critical times; and (9) to provide *integrated assessment*. This model was tested, with successful results, through a multimedia program for training secondary school teachers to assess mathematics. The findings of this study highlight the importance of collaboration and interactivity between the program and the learner for supporting knowledge construction.

Despite the continued evolution of SL, it has only been in the last decade that researchers have seen a greater opportunity to support critical elements of SL due to the widespread adoption and use of mobile technologies and context-aware technologies. Furthermore, operationalizing SL in order to design and carry out meaningful, practical learning activities has become a challenge in the mobile learning community (Chu et al., 2010). Here, we will present a digested description of the most representative works on SL supported by mobile technologies. However, readers who wish to explore this subject further can find an extended list of references in the review by Naismith, Lonsdale, Vavoula, and Sharples (2004), an earlier but extensive review of literature on the implementation of mobile projects that promoted learning within an authentic context and culture; as well as in the paper by Baloian, Casas, Ochoa, and Zurita (2012), which collected and analyzed representative research projects that supported SL making use of geo-location and collaboration.

Researchers in the field of mobile learning have addressed SLE from different perspectives, mainly proposing applications to support activities beyond the classroom (Ashford, 2010; Ceipidor, Medaglia, Perrone, De Marsico, & Di Romano, 2009; Pérez-Sanagustín et al., 2012; Pérez-Sanagustín, Hernández-Leo, Santos, Delgado Kloos, & Blat, 2014; Santos, Hernández-Leo, & Blat, 2013; Wu, Yang, Hwang, & Chu, 2008). All of these approaches use technology in order to integrate the digital and physical worlds, supporting two critical elements in SLEs (Stein, 1998): context and content. These approaches also provide mechanisms to track student activity and to use scaffolding, providing immediate, in-context feedback. However, from a review of the literature on SLEs supported by mobile technologies, we have identified two limitations: (1) few studies propose SLEs that incorporate all nine characteristics proposed by Herrington and Oliver (2000), particularly lacking characteristics to support collaborative knowledge construction, in most cases; and (2) the few SLEs proposed that incorporate all nine characteristics have been designed to support only outdoor learning activities; these SLEs are built upon Geographic Positioning System (GPS) technologies, which are very limited when working indoors.

Regarding the first limitation, Frohberg, Göth, and Schwabe (2009) analyzed 102 mobile learning projects and concluded that, despite the potential of mobile devices for communication, and although cooperation and collaboration have been proved important for increasing reflection and supporting deeper knowledge, most

mobile learning projects did not support cooperation and collaboration. These authors identified different degrees of communication in the projects they analyzed: (1) loose pairs, in which learners are put together to work on tasks together, but without any additional forced communication or interaction; (2) tight pairs or collaboration in groups, in which students use the same learning material, but the environment fosters the completion of tasks that enhance communication and interaction; (3) group communication or within-team collaboration, in which interaction and communication are forced to improve mutual reflection; and (4) cooperation or across-team collaboration, in which teams work together to fulfill the learning goal. Out of the 104 projects analyzed by these authors, only seven supported within-team communication and eight across-team collaboration. By way of example, a recent study by Zurita, Baloain, and Frez (2013) proposed a SLE based on GPS to support collaborative geo-located activities. This SLE was designed to support exploratory activities outdoors in which students looked for patterns or data about topics addressed in class (e.g., the technical characteristics of antennas). In these activities, collaboration was observed within-teams, but not across-teams. In the same study by Zurita, Baloain, and Frez (2013) the authors conducted a review of literature, looking at six SLEs based on Location Based Services with a focus on supporting collaboration. None of these six initiatives included all of the essential characteristics of SLEs (Herrington, & Oliver, 2000). Therefore, the literature points to the lack of SLEs that incorporate all of the characteristics defined by Herrington and Oliver (2000) with a particular focus on the support of collaborative knowledge construction.

Regarding the second limitation, and to the best of our knowledge, there are no works that support the nine characteristics outlined by Herrington and Oliver (2000) in indoor settings. For example, all of the SLEs identified by Zurita, Baloain and Frez (2013) are based on GPS technologies and only support SL activities outdoors. In the literature review by Frohberg, Göth and Schwabe (2009) however, several mobile learning projects that support SL activities indoors, and which are classified as “physical context projects” can be found. As in any SLE, the learner’s place or environment, such as a tour or trip to a museum, is relevant to the topic of study in these “physical context projects”. One example of this can be seen in the project MyArtSpace (Vavoula et al., 2009), in which students use their mobile devices in a museum to collect evidence that they later share in the classroom. However, and according to the authors, these indoor mobile learning projects “miss to implement elements that support deep reflection, knowledge application and cooperation”, among other characteristics that should be incorporated in SLEs. Therefore, and according to the literature, there is a need for studies that propose SLEs that support indoor learning activities and that include all nine characteristics defined in the framework by Herrington and Oliver (2000).

In order to overcome these limitations, this paper introduces and discusses the implementation of a technologically enhanced SLE designed to support learning activities in indoor settings, and which incorporates all of the critical characteristics defined by Herrington and Oliver (2000), with special focus on collaborative knowledge construction. This SLE is based on “bidirectional” Quick Response (QR) codes. Bidirectional QR codes extend the properties of traditional (unidirectional) QR codes accepting user-generated content apart from providing information when scanned (Pérez-Sanagustín, Martínez, & Delgado Kloos, 2013). Traditional QR codes have been shown to be a versatile, cost-effective and low-threshold (easy-to-adopt, and easy-to-implement) technology to create SLEs in which digital educational content augments physical indoor settings, such as libraries (Ashford, 2010; Schultz, 2013) or museums (Melero, & Hernández-Leo, 2014). Furthermore, traditional QR codes have been used as effective procedural scaffolding to promote participation and to foster discussion within groups in the classroom, when used to complement paper-based activities (Huan, Wu, & Chen, 2012). While traditional QR codes allow for the implementation of SL activities indoors, bidirectional QR codes add the opportunity to implement SLEs with an emphasis on collaborative knowledge construction.

This paper contributes by discussing the implementation of a SLE that: (1) incorporates all of the critical characteristics defined by Herrington and Oliver (2000), including collaborative knowledge construction, and

(2) supports indoor SL activities through the use of bidirectional QR codes. This study aims to provide insights and practical implications for the design of SLEs that support collaborative knowledge construction in indoor settings. To evaluate the effects of this “*Bidirectional SLE*” when applied in a real educational setting, we have presented a mixed method experiment carried out in the context of a mechanical engineering lab session at the Universidad Carlos III de Madrid (Spain). In the experiment, the Bidirectional SLE is compared with an equivalent SLE based on traditional QR codes, which we refer to as the “*Traditional SLE*”. The objective of this comparison is to understand whether the Bidirectional SLE, because of its design focused on supporting collaborative knowledge construction, has a more positive effect on student learning outcomes and students’ impressions of the experience than the Traditional SLE. Two research questions guide this experiment: (RQ1) *What are the differences between the Bidirectional SLE and the Traditional SLE in terms of student learning outcomes?*, and (RQ2) *What are the differences between the Bidirectional SLE and the Traditional SLE in terms of students’ impressions of their learning experience regarding: a) the technological system employed, b) the collaborative process, and (c) the meaningfulness of the activity as a whole?* Quantitative statistical data about student performance and qualitative data gathered from both student and teacher opinions will allow for insights into the differences in design of each SLE; these insights will be presented in this paper as lessons learned.

In the following section, the Bidirectional SLE designed to support a mechanical engineering course laboratory session will be described. This Bidirectional SLE was built upon two dimensions: the technological and the educational. The experiment conducted to compare the Bidirectional SLE with the Traditional SLE, and the hypotheses to be tested will then be outlined. Next, the results of the experiment will be detailed and discussed in order to derive a set of lessons learned about the implications of designing SLEs focused on supporting collaborative knowledge construction in indoor settings. The paper will end with the conclusion and ideas for further work.

2. The Bidirectional SLE

This section describes the Bidirectional SLE designed to support an in-person mechanical engineering laboratory session. The objective of the laboratory session was for students to learn about five industrial machines: the Hydraulic Press (M1), the Punch Press (M2), the Numerical Control Lathe (M3), the Machining Center (M4) and the Vertical Drilling Machine (M5). Learning objectives included knowledge about machine pieces, functionality and usage. The machines were located in a lab that is usually in use; because of this, students could only visit it once a year. During visits to the lab, students found that some machines were being used and that time constraints hindered the availability of demonstrations to show how each machine worked. Due to these logistical constraints, teachers usually showed videos of the machines to show how they worked instead. These videos were shown in the classroom, meaning SL did not happen. Fig. 1 shows images of the five industrial machines involved.



Fig. 1 Pictures of the five industrial machines: Hydraulic Press (M1), Punch Press (M2), Numerical Control Lathe (M3), Machining Center (M4) and Vertical Drilling (M5).

2.1. Description of the Bidirectional SLE

The Bidirectional SLE discussed here was built upon the integration of two dimensions: the technological and the educational. The *technological dimension* consisted of a system based on mobile devices (students' smartphones, and also tablets provided by teachers for students who did not wish to use their own smartphones) and bidirectional QR codes generated with etiquetAR (Pérez-Sanagustín, Martínez, & Delgado Kloos, 2013). etiquetAR is an authoring tool that takes advantage of QR code technologies to support the generation of special "tags". When these tags are scanned with any QR code reader, they provide information (as do traditional QR codes), but they also collect user-generated content. Hence, these tags add a new dimension to traditional QR codes, extending opportunities for interaction and collaboration. During the laboratory session in the study, a bidirectional QR code was attached to each machine. The code contained a link to a video showing how the machine worked, another link to an image showing the main components of the machine, and a final link to a question students had to answer about the machine. The answers that students provided through the bidirectional QR codes became available to anyone that scanned them, opening a channel for collaborative construction of knowledge.

The *educational dimension* consisted of a laboratory session activity based on answering questions. The questions were related to machine usage and maintenance. Two types of questions were included: closed questions (also called lower-order questions), and open questions (also called higher-order questions) (Kahn, & Inamullah, 2011). Closed questions have a single answer (either one word, or the solution to a formula), while open questions allow for multiple and more elaborate answers. According to Bloom's taxonomy, closed questions involve recall, comprehension and application, all lower levels of thinking, while open questions help develop the ability to analyze and evaluate (Lord, & Baviskar, 2007). Two of the questions included were open (those about M2 and M3) and three of them were closed (those about M1, M4 and M5). An example of an open question about M3 is: "Do you think it is advantageous to have a continuous chip when using this machine?" An example of a closed question about M5 is: "Describe the differences between a hand drill and a vertical drill."

2.2. Characteristics of the Bidirectional SLE

Table 1 shows how the characteristics described by Herrington and Oliver (2000) are present in the educational and technological dimensions of the Bidirectional SLE. We generated an *authentic context* using etiquetAR tags. Tags were used as the anchor between the real world and the virtual world, expanding upon the properties of industrial machines and mediating interactions with *content* and *context* (the lab). Students' smartphones (and tablets) were the instruments used to interact with the extended environment. The problems and questions that students had to solve and answer were *authentic activities*. These activities included situations in which students had to play *different roles* and address the same problems from *multiple perspectives*: in some cases students played the part of the engineer, defining the characteristics of the piece to be made; in other cases, students played the part of the technician in charge of maintaining the machinery.

The Bidirectional SLE was designed to promote *collaborative construction of knowledge*. Students worked in teams to answer questions, and they had to collaborate in order to agree on common solutions. Students gained and constructed knowledge through the use of bidirectional tags, which mediated interactions among classmates (their *community*). These tags were also the mechanism used to promote *reflection*, pushing students to think about others' answers and contribute with new ideas. Students finished the activity with an individual task for reflection: a peer-evaluation of their classmates' answers. Students *articulated* their understanding of how the machines worked by discussing their peers' answers with their team (and across teams when interacting with bidirectional tags).

Assessment was integrated into the activity through the use of closed and open questions that were later graded by teachers. Students could ask teachers and technicians to review their answers throughout the entire activity. *Scaffolding* and *coaching* were provided to students by teachers and technicians in the form of hints and support. In addition, teachers could access teams' answers in real time through the etiquetAR web interface and could check whether answers were correct or if they required particular attention.

Table 1
Manifestation of critical elements described by Herrington and Oliver (2000) in the Bidirectional SLE.

Key SLE Characteristics	Technological dimension	Educational Dimension
(1) <i>authentic context</i>	Bidirectional tags and mobile devices are the technological support proposed to expand upon the physical <i>industrial machines</i> , and to transform the lab into a digitally augmented learning space <i>simulating an authentic environment</i> .	<i>Not applicable.</i>
(2) <i>authentic activities</i>	<i>Not applicable.</i>	Questions designed by teachers <i>simulate challenges</i> that professionals face on a daily basis.
(3) <i>expert performances</i> and modeling of processes	<i>Not applicable.</i>	<i>Expert performances</i> are included through videos linked to tags associated with each machine. These videos show how professionals use the machines in real environments.

(4) <i>multiple roles and perspectives</i>	<i>Not applicable.</i>	Questions simulate the role of <i>engineers</i> in charge of designing and making pieces, and the role of <i>technicians</i> in charge of machinery maintenance. Students are able to play multiple roles (engineer and technician) and gain different perspectives .
(5) <i>supporting collaborative construction of knowledge</i>	Collaboration occurs <i>across teams</i> via bidirectional tags: students provide answers to questions using the codes attached to the machines; students who scan the codes after them will be able to see these answers.	Collaboration occurs <i>within teams</i> : students collaborate in teams to solve problems and answer questions.
(6) <i>promoting reflection</i>	Students have access to their colleagues' answers through bidirectional tags, and can use them as a reference point to <i>support, contest or expand upon</i> them.	Open (higher-order) questions are included for 2 of the 5 machines to promote reflection. Answering these questions involves <i>analysis, synthesis and evaluation</i> . In addition, the final <i>peer-evaluation</i> proposed aims to promote reflection on answers given, compared to classmates' answers.
(7) <i>promoting articulation to enable tacit knowledge</i>	Students articulate their understanding of how machines work by <i>discussing</i> answers to questions posed with their team (and across teams when interacting with bidirectional tags)	The activity is designed so that each team can move at its own pace, answering questions about the machines and providing different content. Students take <i>diverse paths towards solving problems, distributing tasks and discussing them until they agree on a final answer</i> .
(8) <i>supporting coaching and scaffolding at critical times</i>	<i>Not applicable.</i>	Throughout the entire activity, teachers and lab technicians provide students with <i>coaching and scaffolding</i> whenever needed.
(9) <i>providing integrated assessment</i>	When students work with bidirectional codes, teachers <i>have real-time access to teams' answers</i> during the session. If they detect any common errors or problems, they can stop the class and provide students with helpful hints.	With <i>closed and open questions</i> that are later graded by teachers.

3. Methodology

3.1. Experimental design

To evaluate the Bidirectional SLE we used a mixed-method experiment. In this experiment we compared the Bidirectional SLE with a Traditional SLE (an equivalent SLE based on traditional QR codes) to obtain data about student performance and perception, as well as to gain feedback from teachers. The Traditional SLE differed from the Bidirectional SLE in two ways: technologically, the Traditional SLE used unidirectional tags (traditional QR codes) containing links to videos or images, but questions were presented to students in paper (dossiers); educationally, the Traditional SLE did not include a peer-review task, since students did not have access to their colleagues' answers.

Two research questions were addressed in this experiment:

- *RQ1: What are the differences between the Bidirectional SLE and the Traditional SLE in terms of student learning outcomes?*
- *RQ2: What are the differences between the Bidirectional SLE and the Traditional SLE in terms of students' impressions of their learning experience regarding: a) the technological system employed, b) the collaborative process, and (c) the meaningfulness of the activity as a whole?*

3.2. Participants

A total of 253 (N=253) students participated in the experiment over the course of two academic years (2012-13 and 2013-14). Students were distributed alphabetically by surname, into teams of 4 to 7 (depending on the number of students enrolled in each laboratory group, which typically had between 25 and 45 students). Nineteen teams were assigned to the Control Group (CG) (N=103), using the Traditional SLE to support the lab session. Twenty-eight teams were assigned to the Experimental Group (EG) (N=150), using the Bidirectional SLE to support the lab session. The number of participants in the EG was higher for two

reasons: (1) there were an odd number of laboratory groups, and the remaining group was assigned to the EG; and (2) a larger number of students enrolled in the second year and the groups assigned to the EG had more students. Three lecturers (N=3) also participated in the study, generating the QR codes for each of the machines (using the etiquetAR web application). In addition, the lecturers graded the teams' answers and participated in a focus group.

3.3. Procedure

Students in both the EG and the CG used smartphones and tablets to read the tags. Teams worked at each machine for 10 to 15 minutes. Each team was assigned to its first machine before the activity started. Then, teams continued through to the remaining machines in sequential order. Each team proceeded at each machine as follows:

1. Students scanned the QR code and watched the content (images and video). They could replay the video as many times as desired, while seeing the authentic machine in the lab;
2. Students answered the final question associated with the machine. Teams in the EG used the QR codes to answer questions, while teams in the CG answered questions using a dossier they had to hand in at the end of the session. Figure 2 shows a screenshot of the page students in the EG used for leaving comments on the tags.

In addition, students in the EG participated in a peer-review task after visiting each of the five machines. Each student individually assessed the correctness and completeness of the answers provided by each team (including his/hers) using a scale of 1-5 points. The answers were removed after each laboratory session; students in the EG could only see answers left by teams participating in their own laboratory session. Students were instructed to evaluate a question as entirely correct if it did not contain any errors (numerical or conceptual). A question was considered to be complete only if it contained all possible parts of the solution.

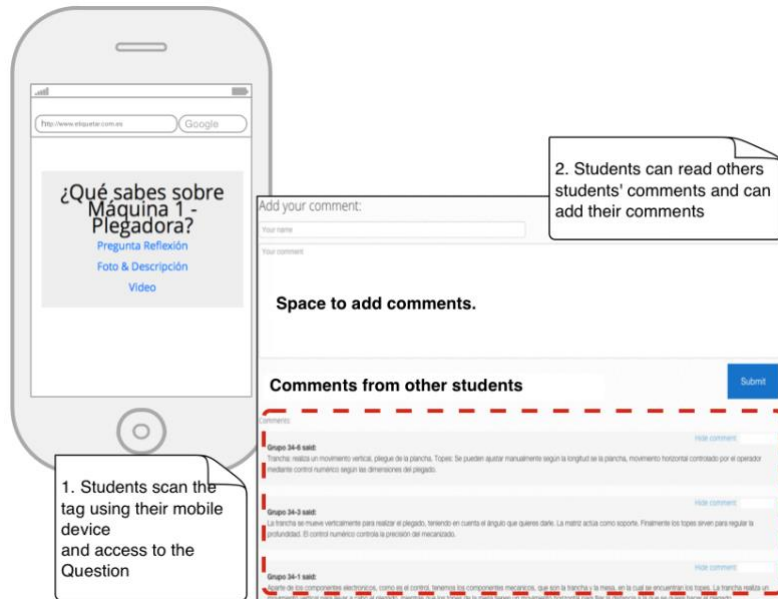


Fig. 2 Screenshot of the pages students accessed when scanning the Bidirectional QR code to answer questions posed by teachers.

3.4. Hypotheses

Six hypotheses have been tested and analyzed in this experiment; each of them is related to one of the two research questions under study.

- H1: The EG scores better than the CG in correctness of answers.
- H2: The EG scores better than the CG in completeness of answers.
- H3: The EG scores better than the CG in correctness and completeness of open question answers (where many answers are possible), rather than in closed question answers.
- H4: Students in the EG assessed their impression of the SLE as better regarding:
 - H4.a) the technological system employed for supporting the activity (T);
 - H4.b) the collaboration process (C);
 - H4.c) the meaningfulness of the activity as a whole (M).

H1, H2, and H3 are related to RQ1, which aims to compare both SLEs in terms of student learning outcomes. Correctness and completeness are metrics that are useful for measuring an answer's quality of information in community-driven environments (John, Chua, & Goh, 2011). Correctness measures the accuracy of the answer, while completeness measures the extent to which the answer covers all relevant points included in the question. These two measures are used in this study because the Bidirectional SLE is designed to support a process of collaborative knowledge construction driven by the community of students, who can discuss answers not only within the same team, but also with the entire class (their community). Discussion and argument are aspects related to higher-order skills. According to Dede (1990), two of the conditions in which higher-order skills are better acquired are when learners construct knowledge, and when there is collaborative interaction between peers. Although both the EG and the CG work actively, getting information from tags, and collaborate with team members to answer questions, the Bidirectional SLE offers students the

possibility of extending the collaboration across teams. Therefore, we expect the EG's answers to be more correct (H1), and also more complete (H2) compared with those of the CG. Regarding the types of questions, closed questions involve recall, comprehension and application, while open questions help develop the ability to analyze and evaluate (Lord, & Baviskar, 2007). Accordingly, we expect both the EG and the CG to get similar results in closed questions, since they require less higher-order skills. However, we expect better results from the EG in open questions, since in the Bidirectional SLE students can analyze and evaluate peer answers in order to improve upon them (H3). If this proves true, the Bidirectional SLE's technological dimension would become more effective when combined with an educational dimension designed to include open questions.

H4 is derived from RQ2, which explores students' impressions of the SLE regarding three aspects of the same: the technological system employed (H4.a), the collaboration process (H4.b), and the meaningfulness of the activity as a whole (H4.c). Recent studies show that QR codes are gaining traction in Europe and that their use is becoming extensive (Pitney Bowes, 2012). Several studies have explored the adoption of this technology as a link between the physical and virtual world in informal learning spaces (e.g. libraries or museums) with good acceptance rates from users (Ashford, 2010; Schultz, 2013). In addition, QR codes allow users to use their own devices. And some studies have reported that allowing students to bring their own devices has a positive effect on students' self-confidence and performance in learning activities, since they are familiar with the technology employed in the activity (Ceipior et al., 2009). All of these studies suggest that both the Bidirectional and the Traditional QR code-based SLEs might be easily adopted by teachers and students in terms of the technology employed, because they use familiar technologies and offer the possibility of transforming a traditional activity into an interactive activity (H4.a). However, we expect to see differences between the two SLEs in terms of collaboration, since the Bidirectional SLE opens a new channel for communication and interaction across teams. This new channel helps to promote reflection and contributes to deeper learning (Frohber, Göth, & Schwabe, 2009), which suggests that the Bidirectional SLE would be better received in terms of the collaboration process (H4.b). Finally, the affordances that the Bidirectional SLE provide compared to those provided by the Traditional SLE are expected to lead to students' better impressions of the meaningfulness of the activity as a whole (H4.c).

3.5. Instruments and data collection

The data were collected using mixed methods, combining quantitative and qualitative data gathering techniques (Johnson, Onwuegbuzie, & Turner, 2007). Quantitative data are useful for showing trends, while qualitative data provide an in-depth understanding of the learning experience (Guba, & Lincoln, 1997). Combining these two techniques allows one to obtain the contextual information needed to perform a more complete comparison between the Bidirectional SLE and the Traditional SLE (Martínez-Monés et al., 2006; Pérez-Sanagustín, Santos, Hernández-Leo, & Blat, 2012b). Specifically, we have three main sources of data in the study:

- *Teachers' scores for team answers (Quantitative Data)*. The three teachers received an assessment rubric along with each team's answers to the questions posed at each machine. Teachers had to individually grade the correctness and completeness of the answers provided using a rubric with a scale from 1 to 5 points (1 being the lowest score and 5 being the highest). The scores given by the three teachers were combined to extract one mean value for correctness and one mean value for completeness for each team, and for each machine. These mean values were later arranged for open questions and for closed questions. The assessment rubric was designed as an adaptation of John, Chua and Goh's (2011), which defined a set of metrics to assess the information quality of answers including correctness (or accuracy) and completeness.

- *Student opinions (Qualitative Data)*. At the end of the laboratory session students individually completed a form with 12 statements regarding their impressions of the learning experience. Students assessed the statements using a 5-point Likert scale (with 1 as fully disagree, and 5 as fully agree). The 12 statements belonged to three categories: (1) students' impressions of the adoption of the technological system employed for supporting the activity (T); (2) students' impressions of the collaboration process (C); and (3) students' impressions of the meaningfulness of the activity as a whole (M). Table 2 contains the 12 statements included in the form. The process of defining statements based on categories of analysis is a common technique in studies that follow mixed-methods approaches (Martínez-Monés et al., 2006; Pérez-Sanagustín et al., 2012b) to understand how technology is used in authentic contexts (Johnson et al., 2007; Maxwell & Loomis, 2003), and to make sense of participants' impressions and experiences (Creswell, 2009). The study by Picciano (2002), in which the author measured the effects of students' interaction, sense of presence, and performance in an online course that offered communication among students, provided hints to help formulate most of the statements. The values given to each statement in each category of the form were combined to give an overall value to that category ranging from 1-5.
- *Teachers' comments and opinions about the experience (Qualitative Data)*. The three teachers involved in the study participated in a focus group in which they discussed the operational aspects of the Bidirectional SLE and their feelings about how it improved the laboratory session, as compared to previous years. Focus groups are a commonly used method for qualitative data collection, particularly as part of mixed method approaches.

Table 2

12 statements included in the form completed by students at the end of the laboratory session. Questions marked with * had to be slightly adapted to each group.

Category	#	Statement presented to students
Technological Adoption (T)	1	I now understand how the supporting technology works well enough to do the activity on my own.
	2*	Functionalities for reading and commenting using tags fit in with the way I like to study/work.
	3	This activity fits in with my usual style of study/work.
	4	I quickly learnt how the activity works.
	5*	I found it easy to perfectly control the mechanisms of the activity.
	6*	I would use this system as a support for other activities again in the future.
Collaboration (C)	7	My classmates do not maliciously take advantage of the work of others, even when there is an opportunity to do so.
	8	I like and enjoy helping my classmates because it helps me better reach my goals.
	9*	I feel that, by contributing answers to the questions posed, I earn respect from my classmates.
	10*	By working together, I receive feedback from my peers that allows me to understand my reputation (beliefs or opinions about me) as a student.
Meaningfulness (M)	11	I would recommend this activity to my classmates.
	12	I would like to participate in similar activities in the lab in the future.

3.6. Data analysis

In order to test H1, H2 and H3, two mixed ANOVAs (one for correctness as the dependent variable and another for completeness as the dependent variable) were applied, along with corresponding associated post hoc tests for pairwise comparisons. The ANOVA and the associated post-hoc tests are suitable for comparing the mean of a continuous variable (at least interval data) in different groups defined by categorical variables (i.e. the factors). Because we wanted to compare two different interval variables (i.e. correctness for H1, completeness for H2, and both correctness and completeness for H3), we performed two different ANOVAs.

It is important to note that although the correctness and completeness variables could only take 5 different values, they were considered continuous intervals (instead of ordinals), because teacher scores were objective, following a predefined rubric, and we could assume that equal intervals on the scale represented equal differences in the completeness and correctness of answers based on the design and criteria of the rubric. Because of this, the ANOVA technique was applied in these cases since it can be applied to interval variables.

As a result of the considerations outlined above, the two mixed ANOVAs used the type of group (EG or CG for H1, H2 and H3) as the between-subjects variable because the subjects in each group were different, and the type of question (open or closed for H3) as the repeated measures variable because the same subjects answered both open and closed questions. The mixed ANOVAs provided insights into the effect of both independent variables (type of group and type of question) on the dependent variables (correctness and completeness).

Using the typical steps of analysis used in ANOVA, the scores for correctness and completeness were analyzed in three phases. We first compared CG and EG scores in order to analyze H1 and H2. We ran tests on between-subjects effects as well as pairwise comparisons for the mixed ANOVAs for both correctness and completeness scores. In order to analyze H3, we observed whether there were differences between open and closed questions by running tests on within-subjects effects and pairwise comparisons for the mixed ANOVAs. Finally, we analyzed the combined effect of the type of group and the type of question on both correctness and completeness.

In order to test H4.a, H4.b and H4.c, we considered student opinion data collected from the 12 statement forms. Firstly, each student had three different scores, one for each category T, C and M (and by extension for each hypothesis). Each score was calculated as the average of the values given to the statements in the category. We compared the values of the variables T, C and M in two groups (EG and CG) in order to know whether T, C and M were better in the EG or not. In this case, the data collected came from the subjective opinions of students using a 5-Likert scale. Since we consider T, C and M categories ordinal variables, we ran a Mann-Whitney test for each of them in order to know if there was a statistically significant difference between the EG and the CG.

Finally, we analyzed teacher opinion qualitatively to complement the trends identified in the statistical analysis of student opinions. This final analysis provided insights into aspects of the Bidirectional SLE that could be improved, and aspects of it that improved upon laboratory sessions of previous years.

4. Results

This section details the main results obtained from the data analysis carried out. The results are arranged according to the hypotheses under study. Complementary results extracted from teacher opinions are presented at the end of this section.

4.1. Hypothesis 1: *The EG scores better than the CG in correctness of answers*

Table 3 shows the mean and standard deviation for correctness for the four groups derived from combining the between subjects factor (CG or EG) and the within subjects factor (open/close) as well as for the union of the different groups (total row and column).

Table 3

Descriptive statistics (mean and std. deviation) for correctness for the four groups divided by the two factors (type of group and open/close) under analysis

Within subjects group	Experimental group		
	CG	EG	Total
Open questions	2.52 (1.09)	3.74 (0.81)	3.25 (1.10)

Closed questions	3.53 (0.77)	3.74 (0.65)	3.66 (0.70)
Total	3.02 (0.15)	3.74 (0.12)	

The mixed ANOVA analysis revealed that, in terms of *correctness*, the type of group has a statistically significant effect, $F(1, 45) = 14.209$, $p=0.000$, being the difference in favor of the EG in terms of scores received from teachers. The mean score for correctness was 3.02 for the CG, and 3.74 for the EG. A pairwise comparison reveals that the difference between the mean scores of the EG and the CG was within the interval [0.334, 1.099] with a probability of 95%. Therefore, as a conclusion, we can state that students in the EG received significantly higher scores than students in the CG for correctness.

4.2. Hypothesis 2: The EG scores better than the CG in completeness of answers

Table 4 shows the mean and standard deviation for completeness for the four groups derived from combining the between subjects factor (CG or EG) and the within subjects factor (open/close) as well as for the union of the different groups (total row and column).

Table 4
Descriptive statistics (mean and std. deviation) for completeness for the four groups divided by the two factors (type of group and open/close) under analysis

Within subjects group	Experimental group		
	CG	EG	Total
Open questions	2.47 (1.10)	3.55 (0.74)	3.12 (1.04)
Closed questions	3.14 (0.88)	3.55 (0.72)	3.88 (0.81)
Total	2.81 (0.16)	3.55 (0.13)	

The mixed ANOVA analysis revealed that, in terms of *completeness*, the type of group also has a statistically significant effect, $F(1, 45) = 12.635$, $p=0.001$, being the difference in favor of the EG. The mean score for completeness was 2.81 for the CG, and 3.55 for the EG. A pairwise comparison reveals that the difference between the EG and the CG mean scores was within the interval [0.323, 1.168] with a probability of 95%. Therefore, as a conclusion, we can state that students in the EG received significantly higher scores than students in the CG for completeness.

4.3. Hypothesis 3: The EG scores better than the CG in the correctness and completeness of open question answers (where many answers are possible), rather than in closed questions

The factor open/close had a statistically significant effect on correctness, $F(1, 45) = 10.738$, $p=0.002$, as well as on completeness, $F(1, 45) = 5.697$, $p=0.021$. This means that if we ignore whether scores came from the EG or from the CG, the type of question (open or closed) had an effect on the correctness and completeness of the answer. The confidence interval for the difference in mean scores between closed and open questions was [0.196, 0.820] for correctness with a probability of 95%, and [0.052, 0.613] for completeness.

Analyzing closed and open question scores for the CG and EG group separately, we found some differences. There was a statistically significant interaction effect regarding correctness between the type of question (open or closed) and the type of group (CG or EG), $F(1, 45) = 10.53$, $p=0.002$; the way that

correctness is affected by question type differs between the CG and the EG. Applying pairwise comparisons, the difference in correctness, in favor of the EG and against the CG, was an interval of [0.662, 1.777] for open questions with a probability of 95%. However, there was no statistically significant difference for closed questions in favor of any group, with a confidence interval of [-0.207, 0.635] and a probability of 95%.

Similar results were found when analyzing completeness of closed and open question scores for each group separately. There was a statistically significant interaction effect regarding completeness between the type of question and the type of group, $F(1, 45) = 5.903, p=0.019$. Applying pairwise comparisons, the difference in completeness, in favor of the EG and against the CG, was an interval of [0.545, 1.623] for open questions with a probability of 95%. However, there was no statistically significant difference for closed questions in favor of any group, with a confidence interval of [-0.66, 0.881] and a probability of 95%.

Figure 3 shows these results graphically. These results mean that increased learning outcomes (in terms of correctness and completeness) is greater for open questions than for closed questions comparing the EG and the CG.

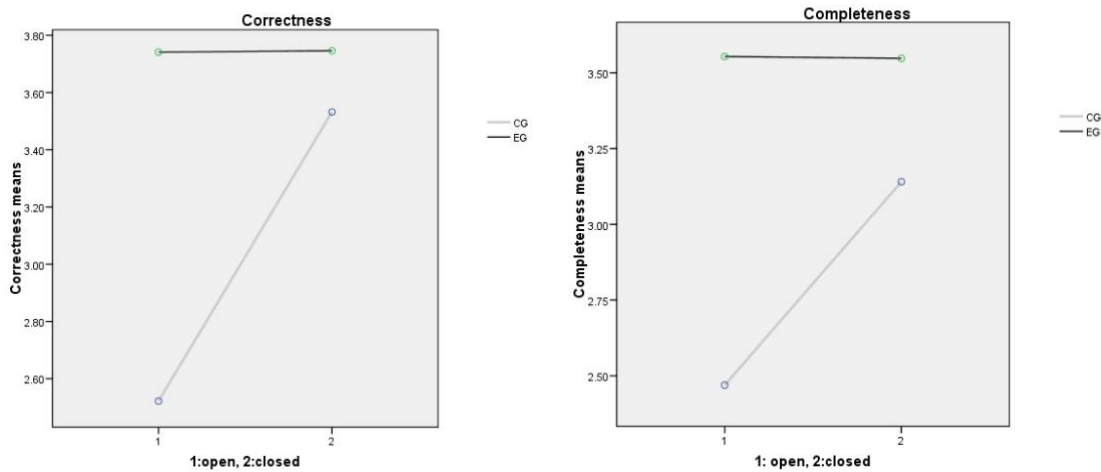


Fig. 3 Differences between EG and CG scores. The x-axis represents open and closed questions; the y-axis represents mean scores for correctness (left) and completeness (right). The EG is represented in dark grey and the CG in light grey.

4.4. Hypotheses H4.a, H4.b and H4.c: Students’ impressions of the learning experience regarding technology, collaboration, and the meaningfulness of the activity as a whole

Students in the EG reported significantly higher values in their evaluation of the learning experience in terms of technological adoption (T), collaboration (C), and the meaningfulness of the activity as a whole (M), compared to those in the CG. Table 5 shows the median values for T, C, and M in the EG and the CG and the results of the Mann-Whitney tests. The main conclusions of this analysis are that: the EG had less difficulty adopting the technology provided and understanding how the activity worked (T); the EG perceived the activity as more collaborative (C); the EG found the activity more meaningful (M). This validates hypotheses H4.a, H4.b and H4.c, respectively.

Table 5
Statistical results of the Mann-Whitney tests for the comparison of the EG and CG regarding T, C and M. Medians for the CG and EG are reported for each category

Category	Statistical results			
	CG (Mdn)	EG (Mdn)	U	p
H4.a. Technological Adoption (T)	3.5	4.00	5161	0.000
H4.b. Collaboration process (C)	3.75	4.00	6192	0.000

H4.c. Meaningfulness (M)	4.00	4.50	5802	0.001
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4.5. Complementary results

Teachers assessed the *Bidirectional SLE* positively because it *promoted self-learning, increased the time that students spent in the lab interacting with a real environment and supported articulation within the activity as well as scaffolding and assessment*. Specifically, the following conclusions regarding the Bidirectional SLE were obtained from the analysis of teacher opinions:

- *Promotion of self-learning*. “(The Bidirectional SLE) allows them (the students) to learn in a more self-taught manner. They interact with the machines, play, study and engage in discussions with their teammates.”
- *Increased time for students to interact with a real environment in the lab*. “(In previous years) students only saw how the machines worked and had less time to interact with them. Now, there is more interaction with the machines, between teams and even with the teacher.” “There are four students working with a machine at the same time, and not 20 as in previous years. Students can see, touch and study the machines better. They are more independent.” “In this environment students can take advantage of all of the time they spend in the lab. They can be with the machines 100% of the time, which is really good for them.”
- *Support of articulation through videos and tags, and provision of integrated assessment and scaffolding at critical times*. “Students can access interactive information. They can see how a machine works as many times as they want. They can work at their own pace and adapt the activity to their needs.” “It (the SLE) makes it easier for students to see how a piece is made by a particular machine because they have access to videos. This is a good way to save on costs, since we cannot perform demonstrations for all of the pieces in the lab.” “Videos help support comprehension, especially in this case; students can see how a machine works in a real environment.”

However, teachers also highlighted two important limitations of this Bidirectional SLE:

- *The Bidirectional SLE does not support enough reflection*. Teachers stressed the need to include more tasks that make students reflect on and pay more attention to their classmates’ answers. When teachers discussed how the activity worked for the EG among themselves they agreed that: “Sometimes students accept erroneous answers from others; they do not reflect on others’ answers enough.” Another teacher emphasized this idea: “However, I think this happens because students do not pay enough attention. For a couple of machines, three teams answered incorrectly, but the fourth and fifth teams corrected the errors.”
- *The Bidirectional SLE is not designed to operate in settings with slow or limited Internet connectivity*. Teachers indicated that during the activity students experienced some difficulties accessing content because the Internet connectivity was limited at times. “It is important to improve Wi-Fi connectivity; students spent too much time loading videos.”

5. Lessons Learned

In this section we detail the lessons learned from designing a SLE that supports collaborative knowledge construction. These lessons relate the results of the study to the nine elements of the SLE framework established by Herrington and Oliver (2000).

- (1) Provide an *authentic* SLE, using reliable technologies that allow a real physical setting to be expanded upon through interactivity. Teachers’ opinions comparing the experiment with their previous experiences indicate that using bidirectional tags to augment a real physical setting allowed students to spend more time interacting within that real environment, while helping them become more autonomous during the activity. However, in order to support this autonomy and foster students’ self-

directed learning, the teachers emphasized the point that it is important to provide a technological setting that is reliable and does not interfere in their learning process, but rather supports it.

- (2) Use mobile and context-based technologies to enhance the *authenticity* of the SLE. Mobile devices, combined with context-based technologies such as QR codes, can help contextualize information about an object or information imparted at a particular physical location, adding authenticity to the SLE. Due to the difficulties involved in showing each machine while it was functioning, teachers pointed out the importance of using multimedia resources associated with the machines, which allowed students to see how the machines worked in a real environment while they were standing next to them.
- (3) Use mobile and context-based technologies to include *expert performances* in the SLE. Mobility and global access to information are two characteristics that can be used to support a SLE that includes specific complementary digital content from various sources, such as videos from experts, in its educational dimension. Teachers appreciated the complementary digital content included in the SLE.
- (4) Design SLEs based on questions that can be addressed from several *perspectives*, and on technologies that enable cross-collaboration between participants to *support multiple roles*. The validation of H1, and H2, which proved a more positive impact was made in the EG, suggests that this SLE included a successful mechanism to support cross-collaboration between students. Furthermore, the validation of H3 suggests that designing SLEs based on open questions rather than on closed questions better supports the exchange of different perspectives. The results of the study indicate that providing a technological setting based on bidirectional tags and learning activities based on open questions is recommendable for teachers who want to design SLEs that support collaborative knowledge construction.
- (5) Include technologies that support students' understanding of the cross-collaboration process to motivate *collaborative knowledge construction*. The validation of H1, H2 and H3 indicates that designing a SLE based on bidirectional tags has a positive impact on students' impressions of the learning experience in terms of technological support, collaboration, and meaningfulness. These results suggest that this SLE offered new channels for collaboration, and awareness about the collaborative process.
- (6) Design the SLE to include activities in the educational dimension that *foster student reflection*. According to teachers' comments, there were cases in which students did not reflect enough on their classmates' answers, assimilating others' errors into their own answers. Providing a channel for answering questions collaboratively, and designing activities based on open questions help support the application of contents in context. However, these conditions are not enough to support other elements of Bloom's taxonomy such as analysis, evaluation and reflection. To support higher levels of thinking it is important to design SLEs that include exercises that inspire students to better evaluate the information and answers provided by their peers. Some suggestions for addressing this issue are proposed in the next section.
- (7) Use technology and scripts to support the technological dimension of your SLE and teamwork orchestration, to promote *articulation* within the learning activity, and to adapt to different student paces. Teachers indicated that using a script to organize teamwork at each machine, and bidirectional tags to support adaptation to students' paces and needs, helped students organize themselves.
- (8) Design the SLE based on technologies that enable contextualizing digital content to provide personal *coaching* and *scaffolding* at critical times. Teachers usually face constraints during learning activities that hinder their ability to solve all of the issues that occur, especially when dealing with big groups and complex environments, such as labs. The results of the study indicate that teachers saw the use of technology and teamwork as advantageous in addressing students' doubts more effectively. Since each team worked independently at different machines in this SLE, teachers had time to address doubts team by team.

- (9) Design the SLE to use a technological setting that allows teachers to monitor students' activity and provide *assessment* in real time. Teachers positively assessed having several groups working on different questions at the same time. It was seen as an opportunity to interact more, and more effectively with students. Continuous interactions with students helped teachers identify common misconceptions and understand the critical errors made by students during the activity.

6. Conclusions and Future Work

This paper has discussed the implementation of a SLE designed to support collaborative knowledge construction (Bidirectional SLE), comparing it with an equivalent SLE that did not support collaborative knowledge construction (Traditional SLE). The cross-analysis of the quantitative data collected, together with the opinions of teachers and students led to four main conclusions about the positive effects of the Bidirectional SLE on student learning outcomes and impressions, compared with the Traditional SLE. Firstly, students in the Bidirectional SLE had better learning outcomes (in terms of correctness and completeness). This result is in line with the results reported by Schawbe et al. (2005), which showed that individual learners show lower levels of activity and lower rates of reflection than those working in groups. In our work, collaborative knowledge construction was achieved through the use of bidirectional QR codes and open and closed questions. Secondly, the difference in favor of the Bidirectional SLE regarding learning outcomes was greater for open questions, suggesting that the Bidirectional SLE was more effective when activities that invited students to think from different perspectives were included. This result is in line with Bloom's taxonomy, which explains that closed questions involve lower levels of thinking, while open questions require higher-level abilities such as analysis and evaluation (Lord & Baviskar, 2007). Our results show statistical evidence proving that different types of questions have different effects on student learning outcomes. Thirdly, students in the Bidirectional SLE came away with better impressions of the technological setting, the collaboration process and the meaningfulness of the activity. This result also corroborates the study carried out by Schawbe et al. (2005), which observed that students working in groups built teams more effectively and had more fun. Finally, the Bidirectional SLE was positively assessed by teachers (as compared to previous laboratory sessions), who stressed its benefits for promoting self-learning, increasing the time students had with the machines in the lab, supporting activity articulation, scaffolding and assessment. Similar results were observed in other studies in which learners used mobile devices in exploratory activities without the direct support of teachers (Pérez-Sanagustín et al., 2012; Santos et al., 2011). Our study shows that the same effect can be had in a practical classroom session. All of these conclusions are distilled into a set of lessons learned about the educational and technological implications of designing SLEs for supporting collaborative knowledge construction. This study has been carried out, and the results detailed herein have been presented, in an effort to help researchers and practitioners translate SL theories into meaningful, practical classroom applications to support collaborative knowledge construction through SLEs.

However, this study includes limitations that should be considered when interpreting its results, and areas that deserve further study. Firstly, during the experiment teachers only acted as orchestrators, guiding students through different phases of the activity, and supporting them when required. But, what would the effect on student learning outcomes have been if teachers had played a more active role (i.e. motivating students to engage in further reflection upon their answers)? A more active role by teachers may have effected students' scores, especially in the CG, in which students were only able to interact within teams; however, this role may have also had a negative impact on self-learning. Secondly, there were no mechanisms in place, in this study, to structure the collaborative process within teams. A common strategy to structure collaboration and foster interactions such as argumentation, explanation and mutual regulation is the use of scripts (Dillenbourg & Hong, 2008). It would have been interesting to analyze if the use of scripts to promote collaboration within teams would have had an effect on student learning outcomes.

We plan to continue to study the types of questions and problems that have a greater impact on collaborative knowledge construction processes in further work. The results gathered from the EG did not show differences between scores for open and closed question scores. Different types of closed questions, such as multiple choice and fill-in-the-blanks, will be included in further studies to better understand these results. The design of the SLE will also be expanded upon to promote reflection and critical thinking. Classical techniques for inspiring critical thinking, such as Socratic questioning (Yang, Newby, & Bill, 2005) or introducing unstructured problems (Chin & Chia, 2004), which have been helpful in promoting knowledge construction, should be considered in this design. More mechanisms that promote awareness and collaboration will also be included in the technological dimension of future SLEs. We believe that this component will help increase the confidence intervals regarding students' impressions of the collaborative process included in this study. And finally, more experiments using this Bidirectional SLE need to be conducted in order to explore whether the results obtained in this study can be applied to other educational settings.

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References

- Ashford, R. (2010). QR codes and academic libraries: reaching mobile users. *College & Research Libraries News*, 71(10), 526–530.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, 18(1), 32–42.
- Ceipidor, U. B., Medaglia, C. M., Perrone, A., De Marsico, M., & Di Romano, G. (2009). A museum mobile game for children using QR-codes. In *Proceedings of the 8th International Conference on Interaction Design and Children, (IDC'09)* (pp. 282–283). Como, Italy.
- Chin, C., & Chia, L. G. (2004). Problem-based learning: Using students' questions to drive knowledge construction. *Science Education*, 88(5), 707-727.
- Chu, H. C., Hwang, G. J., Tsai, C. C., & Tseng, J. C. (2010). A two-tier test approach to developing location-aware mobile learning systems for natural science courses. *Computers & Education*, 55(4), 1618-1627.
- Clancey, W. J. (1995). A tutorial on situated learning. *Proceedings of the International Conference on Computers and Education*, 49–70.
- Creswell, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.
- Dede, C. (1990). Imaging technology's role in restructuring for learning. In K. Sheingold & M.S. Tucker (Eds.), *Restructuring for learning with technology*. New York: Center for Technology in Education, Bank Street College of Education, and National Center on Education and the Economy, pp. 49-72.
- Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. *International Journal of Computer-Supported Collaborative Learning*, 3(1), 5-23.
- Frohberg, D., Goth, C., & Schwabe, G. (2009). Mobile learning projects – a critical analysis of the state of the art. *Journal of Computer Assisted Learning*, 25(4), 307–331.
- Gardiner, L. R., Corbitt, G., & Adams, S. J. (2009). Program assessment: Getting to a practical how-to model. *Journal of Education for Business*, 85(3), 139–144.
- Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of qualitative research*, 2, 163-194.
- Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational technology research and development*, 48(3), 23–48.
- Huang, H.-W., Wu, C.-W., & Chen, N.-S. (2012). The effectiveness of using procedural scaffoldings in a paper-plus-smartphone collaborative learning context. *Computers & Education*, 59(2), 250–259.
- Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of mixed methods research*, 1(2), 112-133.
- John, B. M., Chua, A. Y., & Goh, D. H. L. (2011). What makes a high-quality user-generated answer?. *Internet Computing, IEEE*, 15(1), 66-71.

- Kahn, W. B., & Inamullah, H. M. (2011). A study of lower-order and higher-order questions at secondary level. *Asian Social Science*, 7(9), 149–157.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Lord, T., & Baviskar, S. (2007). Moving students from information recitation to information understanding: Exploiting Bloom's taxonomy in creating science questions. *Journal of College Science Teaching*, 36(5), 40–44.
- Lunce, L. M. (2006). Simulations: Bringing the benefits of situated learning to the traditional classroom. *Journal of Applied Educational Technology*, 3(1), 37–45.
- Martínez, A., Dimitriadis, Y., Gómez-Sánchez, E., Rubia-Avi, B., Jorrín-Abellán, I., & Marcos, J. A. (2006). Studying participation networks in collaboration using mixed methods. *International Journal of Computer-Supported Collaborative Learning*, 1(3), 383–408.
- Maxwell, J.A., & Loomis, D.M. (2003). Mixed methods design: An alternative approach. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 241–272). US: Sage Publications.
- McLellan, H. (1993). Evaluation in a situated learning environment. *Educational Technology*, 33(3), 39–45.
- Melero, J., & Hernández-Leo, D. (2014). A model for the design of puzzle-based games including virtual and physical objects. *Educational Technology and Society*, 17(3), 192–207.
- Meyers, S., & Lester, D. (2013). The effects of situated learning through a community of partnership in a teacher preparation program. *SAGE Open*, 3(3), 1–9.
- Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). *Literature review in mobile technologies and learning*. Futurelab Series Report 11. Bristol: Futurelab. Retrieved from <http://www.nfer.ac.uk/publications/FUTL15> Last visited: October 2014.
- Pérez-Sanagustín, M., Hernández-Leo, D., Santos, P., Delgado Kloos, C., & Blat, J. (2014). Augmenting reality and formality of informal and non-formal settings to enhance blended learning. *IEEE Transactions on Learning Technologies*, 7(2), 118–131.
- Pérez-Sanagustín, M., Martínez, A., & Delgado-Kloos, C. (2013). etiquetAR: Tagging learning experiences. In D. Hernández-Leo, T. Ley, R. Klamma & A. Harrer (Eds.), *Scaling up Learning for Sustained Impact* (pp. 573–576). Springer Berlin Heidelberg.
- Pérez-Sanagustín, M., Ramirez-Gonzalez, G., Hernández-Leo, D., Muñoz-Organero, M., Santos, P., Blat, J., et-al. (2012). Discovering the campus together: A mobile and computer-based learning experience. *Journal of Network and Computer Applications*, 35(1), 176–188.
- Pérez-Sanagustín, M., Santos, P., Hernández-Leo, D., & Blat, J. (2012b). 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.
- Picciano, A. G. (2002). Beyond students' perceptions: Issues of interaction, presence, and performance in an online environment. *JALN*, 6(1) pp. 21- 40.
- Pitney Bowes (2012). Getting ahead of the emerging QR code marketing trend. A Pitney Bowes report into current levels of QR code usage across Europe and the U. S. Retrieved January 2015 from <http://pressroom.pitneybowes.co.uk/getting-ahead-of-the-emerging-qr-code-marketing-trend/>
- Redecker, C., Leis, M., Leendertse, M., Punie, Y., Gijssbers, G., Kirschner, P., et-al. (2011). The future of learning: Preparing for change. *JRC Scientific and Technical Reports*. Retrieved October 2014 from <http://ftp.jrc.es/EURdoc/JRC66836.pdf>
- Santos, P., Pérez-Sanagustín, M., Hernández-Leo, D., & Blat, J. (2011). QuesTInSitu: From tests to routes for assessment *in situ* activities. *Computers & Education*, 57(4), 2517–2534.
- Santos, P., Hernández-Leo, D., & Blat, J. (2013). To be or not to be *in situ* outdoors, and other implications for design and implementation, in geolocated mobile learning. *Pervasive and Mobile Computing*, 14(1), 17–30.
- Schultz, M. K. (2013). A case study on the appropriateness of using quick response (QR) codes in libraries and museums. *Library & Information Science Research*, 35(3), 207–215.
- Stein, D. (1998). *Situated Learning in Adult Education*. ERIC Clearinghouse on Adult Career and Vocational Education Columbus OH. (ED418250).
- Schwabe, G. & Göth, C. (2005). Mobile Learning with a mobile game: Design and motivational effects. *Journal of Computer Assisted Learning*, 21, 204–216.
- Vavoula, N., Sharples, M., Rudman, P., Meek, J., & Lonsdale, P. (2009). Myartspace: Design and evaluation of support for learning with phones between classrooms and museums. *Computers & Education*, 53(4), 286–299.
- Wu, T.T., Yang, T.C., Hwang, G. J., & Chu, H. C. (2008). Conducting situated learning in a context-aware ubiquitous learning environment. *Proceedings of the 5th International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, (pp. 82–86), Beijing, China.
- Yang, C.-C., Hwang, G.-J., Hung, C.-M., & Tseng, S.-S. (2013). An evaluation of the learning effectiveness of concept map-based science book reading via mobile devices. *Educational Technology and Society*, 16(3), 167–178.
- Yang, Y.-T. C., Newby, T. J., & Bill, R. L. (2005). Using Socratic questioning to promote critical thinking skills through asynchronous discussion forums in distance learning environments. *The American Journal of Distance Education*, 19(3), 163–181.
- Zurita, G., Baloian, N., & Frez, J. (2013). Using the cloud to develop applications supporting geo-collaborative situated learning. *Future Generation Computer Systems*, 34(2), 124–137.