Journal of Universal Computer Science, vol. 20, no. 12 (2014), 1670-1689
submitted: 31/5/14, accepted: 15/10/14, appeared: 1/11/14 © J.UCS

City Ads: Embedding Virtual Worlds and Augmented Reality in Everyday Educational Practice

Juan A. Muñoz-Cristóbal
(Universidad de Valladolid, Spain
juanmunoz@gsic.uva.es)

Alejandra Martínez-Monés
(Universidad de Valladolid, Spain
amartine@infor.uva.es)

Juan I. Asensio-Pérez
(Universidad de Valladolid, Spain
juaase@tel.uva.es)

Sara L. Villagrá-Sobrino
(Universidad de Valladolid, Spain
sarena@pdg.uva.es)

Javier E. Hoyos-Torío
(Universidad de Valladolid, Spain
javierht@gsic.uva.es)

Yannis Dimitriadis
(Universidad de Valladolid, Spain
yannis@tel.uva.es)

Abstract: The use of immersive environments such as 3D virtual worlds (3DVWs) and augmented reality (AR) in education has been profusely explored during the last decades, showing significant evidence of its benefits for learning. However, the attempts to integrate immersive environments in everyday educational practice are hampered by the difficulties that these environments pose to teachers willing to set them up within the already demanding ecology of technological resources present in the classroom. GLUEPS-AR is a system aimed to help teachers deploy and enact learning designs that make use of web technologies (Virtual Learning Environments and Web 2.0 tools), as well as immersive environments such as virtual globes (e.g. Google Earth) used as 3DVW, and general-purpose mobile AR apps. This paper presents the evaluation of the support provided by GLUEPS-AR for teachers that want to appropriate immersive environments in their everyday practice with an affordable orchestration effort. The evaluation followed an interpretive research perspective, and it was carried out in the context of an authentic learning situation about advertising, conducted at a university undergraduate course for pre-service teachers. The results of the evaluation showed that GLUEPS-AR effectively supported the teacher in seamlessly embedding 3DVWs and AR in her practice.

Keywords: Virtual world, Augmented reality, Immersion, Ubiquitous learning, Seamless learning
Categories: K.3.1, K.3.2, L.3.0, L.3.6, L.7

1 Introduction

3D Virtual Worlds (3DVWs) and Augmented Reality (AR) are immersive environments [Dede 2009] that have been explored extensively by the Technology Enhanced Learning (TEL) research community [Duncan et al. 2012] [Wu et al. 2013] with positive results regarding their learning benefits. Thus, for example, they enable the perception of objects from multiple perspectives, the simulation of experiences difficult to enact in the real world, while they may also enhance both the transfer of knowledge to reality and the engagement of students [Dede 2009] [Duncan et al. 2012] [Billinghurst and Duenser 2012] [Wu et al. 2013].

However, embedding these immersive technologies within everyday educational practice is still a challenge [Dörner et al. 2011] [Gregory et al. 2013]. As a consequence, the proposals that make use of immersive environments tend to take the form of isolated systems, disconnected from other technologies existing in the classroom [Gregory et al. 2013]. Moreover, most of these proposals explore new ad-hoc learning situations, specifically created for the use of immersive environments, instead of incorporating those environments into already existing learning situations (see, e.g., [Facer et al. 2004] [Mennecke et al. 2008] as examples of learning situations created for a specific mobile AR application and a 3DVW respectively). In addition, teachers have to face many difficulties when they try to include immersive environments into the classroom technological ecology. Some of these complications refer to the preparation and deployment of the learning situation itself, its management and adaptation during the enactment, and the coordination of the different technological resources toward the learning goals [Dörner et al. 2011] [Warburton 2009]. These difficulties, also applicable to other non-immersive environments, have been conceptualized by the TEL community under the "orchestration" metaphor [Prieto et al. 2011], i.e., the coordination of learning activities in complex authentic educational settings.

Trying to overcome these problems we have created GLUEPS-AR [see Section 3.3]: a system aimed to help teachers put into practice learning situations that may make use of web-based Virtual Learning Environments (VLEs), as well as of immersive environments such as mobile AR apps and Virtual Globes (VGs) [Rakshit and Ogneva-Himmelberger 2008]. VGs are 3D virtual representations of the surface of the Earth, such as Google Earth[1]. GLUEPS-AR adds some characteristics of 3DVWs to these VGs, such as avatars and the possible interaction of users with learning artefacts and other users. Issues related to the deployment of immersive learning experiences with GLUEPS-AR have been previously evaluated in a study wherein a teacher tested the use of the system in a controlled laboratory environment [Muñoz-Cristóbal et al. in press]. However, this study did not include an authentic enactment with real students, in which the orchestration support provided by GLUEPS-AR could be evaluated. Therefore, in this paper we present a new evaluation study, following an interpretive research perspective [Cohen et al. 2007] [Orlikowski and Baroudi 1991], to explore the research question of *how does GLUEPS-AR help teachers appropriate immersive environments such as 3DVWs and mobile AR in their current educational practice and technological ecology of the*

[1] http://www.google.com/earth/. Last access September, 2014

classroom with an affordable orchestration effort. In the study, a lecturer of an undergraduate course for pre-service teachers included immersive environments (VGs and mobile AR) in a regular learning situation of the course. We explored how GLUEPS-AR helped the lecturer put into practice such learning situation, integrating immersive environments into her everyday practice.

The structure of the paper is the following. [Section 2] describes the aforementioned learning situation, which we consider illustrative of the difficulties for the inclusion of immersive environments in everyday educational practice. [Section 3] reviews different approaches for using immersive environments in education, identifying some of the challenges for the incorporation of immersive technologies into everyday practice. Also, the GLUEPS-AR system is presented as a technology aiming to overcome such challenges. [Section 4] describes the evaluation performed, and finally, some conclusions are outlined.

2 City Ads: A Learning Situation Integrating Immersive Environments into the Regular Ecology of the Classroom

City Ads is an educational scenario conducted in the first year (out of four) of the Degree in Early Childhood Education, at the University of Valladolid, Spain, in spring 2014. It aimed to help students understand the learning effects of advertising in everyday life. The learning goals of the scenario included the fostering of skills for the critical analysis of advertisement, as well as the familiarization with the educational possibilities of Web 2.0 tools, VGs and AR browsers. The City Ads scenario was carried out in a course on ICT in Education with 30 enrolled students, by a regular teacher of the course. The usual wiki-based VLE of the course was employed as a central hub, where students and groups could access the description of the different activities, as well as the learning tools and artefacts to use.

[Fig. 1] describes the City Ads learning situation. It consisted of six activities which were conducted in a Ubiquitous Learning Environment (ULE) [Li et al. 2004] involving different physical and virtual spaces: a classroom, the AR-enabled streets of the town (by means of the Junaio[2] and Layar[3] mobile AR browsers), the students' homes, a wiki, Google Earth and Google Street View. Significantly, immersive environments such as mobile AR (Junaio and Layar) and VGs (Google Earth and Google Street View) used as 3DVWs, were integrated with other non immersive technologies used regularly in the course, like the wiki-site and several Web 2.0 tools (e.g., Google Drive[4]). It is noteworthy that this learning situation had been conducted during the previous years without the use of immersive technologies. In City Ads, the teacher decided to include immersive technologies in order to further enrich the situation and to seamlessly connect the activities in different spaces. Thus, demanding technological enhancements were included, such as the incorporation of mobile AR browsers as well as the replacement of the previous isolated 2D version of Google Maps with 3D VGs integrated with the rest of the environments.

---

[2] http://www.junaio.com. Last access September, 2014
[3] https://www.layar.com. Last access September, 2014
[4] https://drive.google.com. Last access September, 2014

	Location	Environment	Description
① 2h face-to-face	Classroom	Wiki	Using an interactive whiteboard and a presentation with multiple multimedia contents, the **teacher lectures** about the different types of ads, their elements, and the ways to analyze critically an ad. She also performs a demonstration of the subsequent activity.
② 1h remote	Streets, Home Classroom	QR code reader Wiki	Each student, with her own mobile phone, must **take ten pictures of ads in the city**. Scanning in-situ a given QR code, the picture is automatically geopositioned and uploaded to Picasa, as well as integrated with the rest of the environments (wiki, VGs and AR apps). Alternatively, the students can store the pictures in their mobile phones, doing the uploading and geoposition tasks later, at their homes or in the classroom, using the wiki.
③ 1h face-to-face + 1h remote	Classroom Home	Google Earth Street View Wiki	Groups of 4-5 students, using the 2D map view and the 3D view of the VGs, explore the virtual city and spot their geopositioned pictures of ads as well as the avatars of other students. They have to write **analysis reports of their ads** creating Google Drive documents at the 3D view, positioned at the locations of the corresponding ads. Such documents are automatically integrated with the rest of the environments (wiki, other VG and AR apps).
④ 1h face-to-face + 1h remote	Classroom Home	Google Earth Street View Wiki	Each group has to choose one of the ads of any group and **create a counter-ad campaign** about it in a Google Drive document they have to place at a VG in the corresponding ad location. In order to select any of the ads of the different groups, in this activity all the pictures (near 300) taken by all the students are accessible for everybody in both VGs.
⑤ 0,5h remote	Streets	Junaio Layar	All the geopositioned **artefacts created during the learning situation are accessible from the streets using Junaio and Layar**, and they remain accessible after the end of the learning situation, for their possible use in informal settings by the students.
⑥ 0,5h remote	Home	Google Earth Street View Wiki	Each group, from within a VG, has to create a **final report** in a Google Drive document about the eventual use in education of the different technologies utilized during the learning activity: Web 2.0 tools, VGs and AR.

Figure 1: The six activities of the City Ads learning situation

The following section identifies some challenges that different approaches in the literature pose for the teachers' appropriation of immersive environments in their everyday practice like in the case illustrated with the City Ads scenario.

3 Immersive Environments in Education and Challenges for Their Embedding in Everyday Practice

Despite all the research efforts regarding the use of immersive technologies such as 3DVWs and AR in education, as well as the new learning opportunities that this sort of environments may provide, the use of immersive technologies in everyday educational practice is still a problem. This section reviews existing approaches for using 3DVWs and AR in education and identifies some challenges posed for the inclusion of such technologies in the teachers' everyday practice.

3.1 Approaches for Using Immersive Environments in Education

Several proposals have explored the use of immersive environments like AR and 3DVWs in education [Duncan et al. 2012] [Wu et al. 2013]. One of these approaches consists in the use of head-mounted displays. That is the case of [Kaufmann and Schmalstieg 2002], who proposed AR and 3D models for mathematics and geometry education; [Vlahakis et al. 2002], who used AR for augmenting archaeological sites; and [Fernández-Panadero and Delgado Kloos 2013], who explored the use of virtual reality (VR) for navigating in a 3DVW with a wheelchair simulator. Also [Billinghurst and Duenser 2012] studied the use of head-mounted displays, enabling both to augment a book with AR and to take part into the virtual scene with VR.

Other authors have used mobile AR apps to conduct learning situations wherein virtual objects enriched or transformed physical environments. [Facer et al. 2004] converted the surroundings of a school in a savannah. [Klopfer et al. 2011] proposed different authoring tools for creating AR games. [Santos et al. 2011] used a web app to create geopositioned questionnaires. [Pérez-Sanagustín et al. 2011] employed mobile devices to provide information about different buildings in a university campus. [Billinghurst and Duenser 2012] proposed a mobile app to enable virtual views of buildings destroyed by an earthquake. [Di Serio et al. 2013] and [Fernández-Panadero and Delgado Kloos 2013] enriched, using AR, paintings and other artefacts. [Kamarainen et al. 2013] used AR and probes for environmental education.

Similarly, a number of research works have explored the use of non-mobile AR (e.g., desktop or whiteboard based) in education. That is the case of [Kerawalla et al. 2006] for teaching science, [Alcañiz et al. 2010], with different educational applications (e.g., for geometry, anatomy or natural sciences), as well as [Spikol and Eliasson 2010], using AR and 3D models for learning geometry. Also [Billinghurst and Duenser 2012] proposed an authoring tool for creating 3D AR scenes.

In addition, several authors have researched the application of 3DVWs in education. Thus, for instance, [Dede et al. 2004] and [Lim et al. 2006] explored the use of ad-hoc 3DVWs in education, and [Dickey 2005] studied a 3DVW based on Active Worlds[5] in distance learning. Other authors have employed existing 3DVWs, such as [Jarmon et al. 2008] and [Mennecke et al. 2008], who used Second Life[6] for project-based learning and for an e-commerce course respectively.

Also, there is a growing use of VGs in education [Rakshit and Ogneva-Himmelberger 2008], including their emerging use as 3DVWs, with avatars as well as interaction between users (e.g., using a chat) [Dordevic and Wild 2012].

Some research works have explored the problem that the authoring of learning situations and the execution of sequences of activities when using 3DVWs pose for teachers. Thus, a number of authors have followed a learning design approach [Koper 2005], which suggests the generation of abstract learning designs, represented in languages or models independent of the enactment tools to be used. Thus, such authors propose to enable the deployment and execution of learning designs modelled

---

[5] https://www.activeworlds.com. Last access September, 2014
[6] http://secondlife.com. Last access September, 2014

in one of such languages (IMS-LD[7]) in Open Wonderland[8] [Maroto et al. 2011], Second Life and OpenSim[9] [Fernández-Gallego et al. 2010].

In addition, a number of authors have integrated 3DVWs with other widespread technologies, such as VLEs or Web 2.0 tools. [Pourmirza and Gardner 2013] integrated Facebook[10] with Second Life. [Livingstone and Kemp 2008] proposed Sloodle, which integrates Moodle[11] with Second Life and OpenSim. Several works have used Sloodle during the last years in multiple educational scenarios (e.g., see [Callaghan et al. 2009] [Schaf et al. 2012]).

Finally, some works have explored the integration of 3DVWs with physical spaces. Some authors connected physical objects with their virtual representation in a 3DVW, enabling interaction with remote or virtual laboratories [Peña-Rios et al. 2013] [Schaf et al. 2012]. In other cases, AR connected physical spaces with 3DVWs [Ibáñez et al. 2012] [Izadi et al. 2002] [Okada et al. 2001], or with VGs [Ternier et al. 2012] and Web 2.0 tools [Chen and Choi 2010] [Zurita et al. 2014].

3.2 Challenges for Embedding Immersive Environments in Everyday Educational Practice

The aforementioned approaches, which explore the use of immersive technologies in education, present several challenges for their utilization in everyday educational practice [Warburton 2009] [Gregory et al. 2013] [Dörner et al. 2011]. We identify below some of these challenges, which are also illustrated by the City Ads scenario (a situation derived from the normal practice of a teacher) [see Tab. 1].

Works studying the use of immersive technologies in authentic educational scenarios use to explore new learning situations that have been created specifically for such technologies. *These situations are not part of the authentic learning situations conducted regularly by the involved teachers and therefore, of their everyday practice* (see challenge #1 in [Tab. 1]). That is the case of most approaches mentioned above, although some of them include immersive technologies in learning situations conducted regularly by the involved teachers [Jarmon et al. 2008] [Santos et al. 2011] [Alcañiz et al. 2010] [Billinghurst and Duenser 2012] [Dickey 2005] [Kerawalla et al. 2006] [Ternier et al. 2012] [Di Serio et al. 2013].

In addition, *approaches using immersive environments are usually isolated, disconnected from the widespread technologies used in everyday educational practices (e.g., VLEs and Web 2.0 tools)* (see challenge #2 in [Tab. 1]), complicating the transitions between different environments. Exceptions to this limitation are approaches exploring the integration of 3DVWs with Moodle [Callaghan et al. 2009] [Livingstone and Kemp 2008] [Schaf et al. 2012] and Facebook [Pourmirza and Gardner 2013], as well as systems proposing the integration of AR, VGs and Web 2.0 tools [Chen and Choi 2010] [Zurita et al. 2014].

Also, most of the existing proposals typically *preclude teachers from using different types of immersive environments (e.g., AR and 3DVWs) and multiple existing*

---

[7] http://www.imsglobal.org/learningdesign/. Last access September, 2014
[8] http://openwonderland.org. Last access September, 2014
[9] http://opensimulator.org. Last access September, 2014
[10] https://www.facebook.com. Last access September, 2014
[11] https://moodle.org. Last access September, 2014

immersive technologies of the same type (e.g., different mobile AR apps) (see challenge #3 in [Tab. 1]). Hence, teachers depend on the constraints of the proposed immersive technology. Many of the approaches described above allow teachers to use different types of immersive environments (e.g., AR and 3DVW [Chen and Choi 2010] [Ibáñez et al. 2012] [Izadi et al. 2002] [Okada et al. 2001] [Ternier et al. 2012] [Zurita et al. 2014]). However, among all these approaches, only the system proposed by [Okada et al. 2001] supports more than one 3DVW and only the framework proposed by [Zurita et al. 2014] could be potentially used with more than one specific VG. It is worth noting that the systems proposed by [Livingstone and Kemp 2008] and [Fernández-Gallego et al. 2010] allow multiple 3DVWs, but on the contrary, their use is limited to that specific type of immersive technology.

Moreover, several approaches propose *systems that entail several difficulties for teachers when orchestrating their learning situations* (see challenge #4 in [Tab. 1]). This limitation complicates their potential use in the teachers' authentic everyday practice. Some of the proposals mentioned above try to help teachers in some specific orchestration aspects (but not in all aspects encompassed under the orchestration metaphor by the TEL community, see [Prieto et al. 2011]), such as enabling them to create and deploy by themselves their learning designs by means of authoring tools (see e.g., [Billinghurst and Duenser 2012] [Fernández-Gallego et al. 2010] [Kamarainen et al. 2013] [Klopfer et al. 2011] [Livingstone and Kemp 2008] [Maroto et al. 2011] [Santos et al. 2011] [Ternier et al. 2012] [Pérez-Sanagustín et al. 2011]). There are also proposals that include monitoring functionalities to help in the assessment of students (see e.g., [Facer et al. 2004] [Callaghan et al. 2009] [Santos et al. 2011] [Pérez-Sanagustín et al. 2011] [Ternier et al. 2012] [Zurita et al. 2014]), or aim to help teachers in the management of the learning situation (e.g., by means of intelligent non-player-characters [Ibáñez et al. 2012], or automating the creation of tool instances [Livingstone and Kemp 2008] [Pourmirza and Gardner 2013]).

Despite some of the reviewed approaches may help teachers in some of the identified challenges, to the best of our knowledge none of these approaches have dealt with potential solutions for all of them. The following section describes GLUEPS-AR, a system that aims to overcome all these challenges.

Challenges	Examples in the City Ads scenario
1. Including immersive environments in authentic learning situations regularly conducted by teachers	VGs and mobile AR apps have to be included in a learning situation conducted regularly in the course
2. Integrating immersive environments with widespread technologies commonly used by teachers, such as VLEs and Web 2.0 tools	VGs and AR have to be integrated with the wiki-based VLE and the Web 2.0 tools frequently used by the teacher
3. Enabling the use of multiple existing immersive environments of different types	Two VGs and two mobile AR browsers have to be used
4. Helping teachers in the multiple aspects of the orchestration of learning situations that include immersive and non-immersive environments	The learning situation has to be created and enacted by the teacher. It requires the creation and access from different environments of more than 500 artefacts

Table 1: Challenges for the integration of immersive environments in the teacher's everyday practice and examples of these challenges posed by the City Ads scenario

3.3 GLUEPS-AR

[Fig. 2] describes GLUEPS-AR [Muñoz-Cristóbal et al. in press], a system that aims to help teachers put into practice their own learning situations in ULEs involving multiple physical and virtual spaces. Such ULEs may be composed of different types of existing immersive and non-immersive environments, such as widespread web VLEs (e.g., Moodle), general-purpose mobile AR apps (e.g., Junaio) and broadly used VGs (e.g., Google Earth). In addition, virtual artefacts (e.g., 3D models, web pages or multiple Web 2.0 tool instances) may be created and accessed from within any of the different environments. The VGs are used as 3DVWs by including avatars and interaction (users may interact with learning artefacts and with other users, e.g., by means of a chat or other collaborative tools).

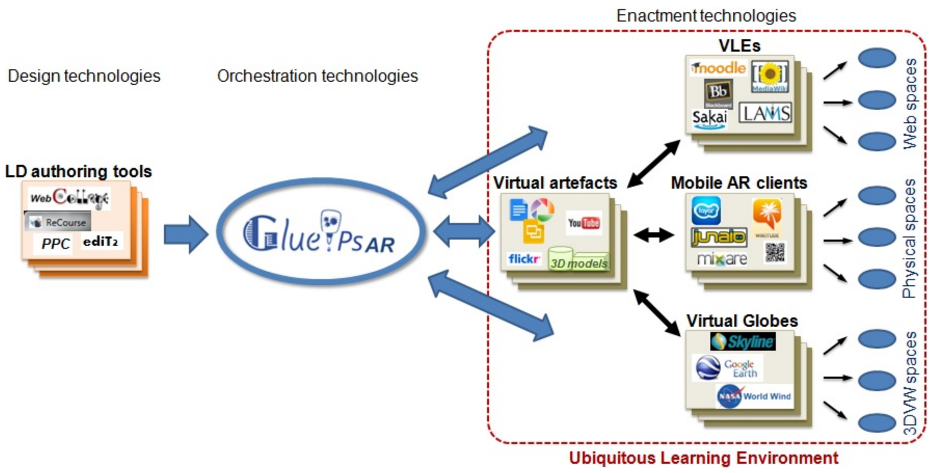

Figure 2: The GLUEPS-AR system: an orchestration technology that integrates immersive and non-immersive learning environments used across multiple physical and virtual spaces

GLUEPS-AR has been designed with an architecture based on adapters that facilitates its extensibility [Muñoz-Cristóbal et al. in press]. Thus, a new technological learning environment (i.e., VLE, VG, AR client) can be easily integrated in the architecture by creating an adapter. Allowing the potential use of several existing technologies and different types of immersive and non-immersive environments may help to overcome the challenges #2 and #3 of [Tab. 1]. Moreover, GLUEPS-AR enables teachers to deploy their own learning situations, which may be created by themselves using multiple learning design authoring tools[12]. This feature addresses the challenge #1 of [Tab. 1]. Also, as shown in [Fig. 2], GLUEPS-AR has been conceived as an orchestration technology [Sharples 2013], trying to provide support for multiple orchestration aspects, and therefore, addressing challenge #4 of [Tab. 1].

[12] See a list of learning design authoring tools at http://www.ld-grid.org/resources/tools. Last access September, 2014

Thus, in addition to enabling teachers to deploy their designs, GLUEPS-AR provides them with a user interface, wherein they can manage, adapt and monitor the learning situation. GLUEPS-AR automates the creation of Web 2.0 tool instances by means of integration adapters [Alario-Hoyos and Wilson 2010]. GLUEPS-AR also allows a degree of self-regulation for the students in the management of learning artefacts, and therefore, sharing the orchestration load with them [Sharples 2013]. This last feature is achieved by the concept of *learning bucket* [Muñoz-Cristóbal et al. 2013]. A learning bucket is a container of learning artefacts (written reports, drawings, pictures, etc). Teachers may include learning buckets in their learning designs and configure constraints for their use (e.g. number and types of artefacts to be generated). During the enactment, learning buckets may be filled by the students with artefacts that they generate and position in different spaces (e.g., a Google Drive document in a specific geographical location or a picture in an AR marker).

In the following section, we evaluate how GLUEPS-AR helps teachers to embed immersive environments in their everyday practice.

4 Evaluation

We have conducted an evaluation in order to explore the research question we posed: *How does GLUEPS-AR help teachers appropriate immersive environments such as 3DVWs and mobile AR in their current educational practice and technological ecology of the classroom with an affordable orchestration effort?*

The evaluation relayed in a qualitative research study [Cohen et al. 2007], wherein a teacher (with pedagogical background and 5 years of teaching expertise) used GLUEPS-AR to design, deploy and enact the City Ads learning situation described in [Section 2]. The study involved the 30 students enrolled in a mandatory course about ICT on Education of the first year of the University Degree in Early Childhood Education at the University of Valladolid (Spain). The evaluation was carried out from February to April 2014.

4.1 Method and Evaluation Happenings

For the evaluation, we have followed the Evaluand-oriented Responsive Evaluation Model (EREM) [Jorrín-Abellán and Stake 2009], which is a framework based on a responsive evaluation approach [Stake 2004]. This kind of evaluation process is framed within the interpretive research paradigm [Orlikowski and Baroudi 1991], which does not pursue statistically-significant results, rather aiming to a deep understanding of the particularity and the richness of concrete phenomena [Guba 1981], in this case provided by the use of GLUEPS-AR in an authentic setting.

To explore the research question, we have followed an anticipatory data reduction process [Miles and Huberman 1994] during the evaluation design [see Fig. 3]. Thus, we defined an issue as the main conceptual organizer of the evaluation process, and we split the issue into two more concrete topics, to help us understand the different dimensions within the issue: *the appropriation of immersive environments in the teacher's everyday practice* (topic 1), and *the orchestration support provided by GLUEPS-AR to the teacher* (topic 2). Each topic is explored with a number of informative questions, which are finally mapped to data gathering techniques.

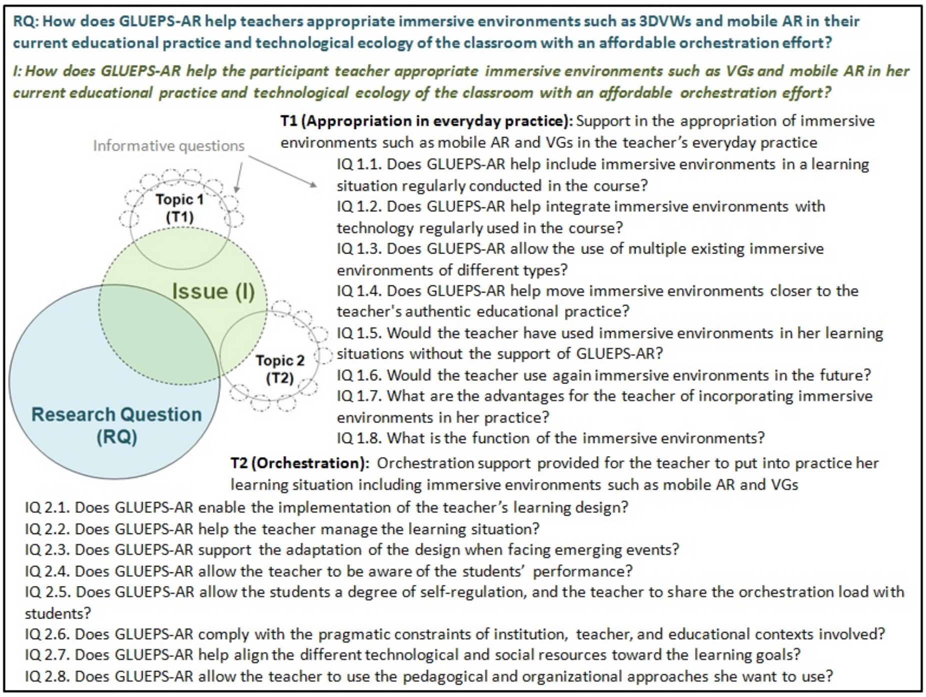

Figure 3: Anticipatory data reduction showing research question (RQ), issue (I), topics (T) and informative questions (IQ).

A profuse set of qualitative data gathering techniques and sources were used during the evaluation [see Fig. 4]: teacher and students' generated artefacts (e.g., learning design, learning resources or emails), screen recordings, naturalistic observations (including pictures, audio, video and observation notes), web based exploratory questionnaires, and interviews. We used different strategies to increase the credibility, transferability, dependability and confirmability of our research, and therefore, to ensure the quality of the research process, attending to our qualitative perspective [Cohen et al. 2007] [Guba 1981] [Miles and Huberman 1994]: prolonged engagement during three months of work with the teacher and persistent observation in the field; acknowledgement of participant opinions, by interviewing the teacher; integration of the thorough collaborative observation reports in a single portfolio, thus enabling a thick description of the phenomenon under scrutiny, reported in detail to the whole evaluation team; peer review within the evaluation team to avoid bias; triangulation of data sources and researchers (five different observers participated in the evaluation, at least two in every observed event) to cross-check data and interpretations. [Fig. 4] illustrates the evaluation flow, divided in three happenings (evaluation events). It also shows the different data gathering techniques and data sources employed, indicating the labels used to refer to them throughout the text.

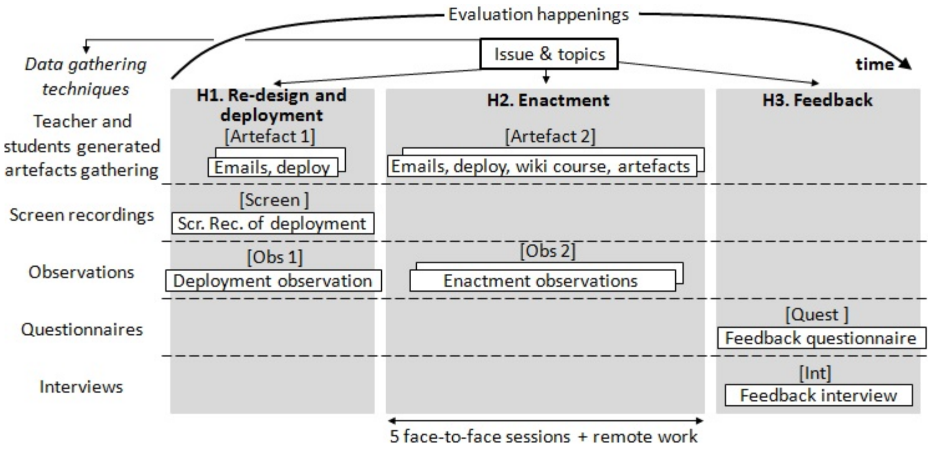

Figure 4: Evaluation happenings and data gathering techniques used during the evaluation.

In a first happening, the teacher reused a previous design she had created months ago [see Muñoz-Cristóbal et al. in press] using the WebCollage authoring tool [Villasclaras-Fernández et al. 2013]. Thus, with occasional support of one of the researchers, she re-designed the City Ads learning situation, particularizing it for the current class and context, as well as including some modifications in the activities. Then, she deployed the design using GLUEPS-AR. GLUEPS-AR is a system for the deployment of learning designs in immersive and non-immersive learning environments. It also enables the teachers to position learning artefacts in different spaces, to embed virtual artefacts in the different environments, and to configure artefact flows, by specifying whether an artefact will be reused in subsequent activities, at the same or a different environment. In this case, the teacher, using GLUEPS-AR, deployed the design in the ULE formed by the wiki-based VLE of the course, the Google Earth and Google Street View VGs, the Junaio and Layar mobile apps, as well as any common QR code reader. She also performed some validation tests to verify that everything had been deployed correctly. The second happening consisted of the enactment of the City Ads learning situation during March 2014 [see Fig. 4]. For the activities 3 and 4 [see Fig. 1] the class was split in two and each half attended different face-to-face sessions. Therefore, in the second happening we collected data from five face-to-face sessions and remote work. In the third and last happening, feedback from the teacher was gathered on April 2014, consisting of a web-based questionnaire and an interview.

4.2 Results

This section presents the main findings obtained in the evaluation study, classified using the topics defined in the anticipatory data reduction process [see Fig. 3], with selected excerpts of evidence supporting these findings.

4.2.1 Appropriation in Everyday Practice (Topic 1)

This topic has been explored deriving informative questions to study both the teacher appropriation of the immersive environments involved and whether GLUEPS-AR promoted their incorporation in her educational practice. Results were positive regarding the inclusion of AR and VGs in the learning situation that had been regularly conducted in the same course the previous years. Also, AR and VGs were integrated with the widespread technologies used frequently by the teacher, such as the wiki-based VLE of the course and some Web 2.0 tools like Google Drive [Quest, Int, Obs 2] (the teacher rated 6, "*Strongly agree*", in a 1-6 scale the two assertions stating that GLUEPS-AR allowed her such inclusion and integration [Quest]; she also declared that "*The wiki is the virtual platform we use regularly in the course [...]. It is a familiar environment for the students and therefore it is important to be able to continue using the same platform that we use in other activities*" [Quest]).

In addition, GLUEPS-AR enabled the use of different existing AR applications and VGs [Quest, Int, Obs 2] (the teacher rated 6, "*Strongly agree*", in a 1-6 scale, the assertion that GLUEPS-AR allowed her to include in the design multiple existing VGs and AR apps [Quest]). The teacher valued it as an important feature that provides flexibility to adapt the design to different technological constraints, contexts and teacher needs ("*It is important to provide teachers with multiple possibilities, because each person designs in a different way, and has different interests. Thus, a good system [...] offers different possibilities for adapting to different tools and devices. For instance, maybe Layar does not work well in some devices and Junaio does.*" [Int]).

The teacher acknowledged that GLUEPS-AR helped her to move AR and 3DVWs closer to her everyday practice (she rated 6, "*Strongly agree*", such assertion in a 1-6 scale [Quest]; it was also confirmed in the interview: "*Yes, because there are things that I would not have imagined I would be able to do. For example, the system provides you with the visualization of resources in Google Earth and Street View*" [Int]). Prior to the evaluation, she considered such immersive technologies interesting and she was curious about them. In spite of her interest, she had not used them because she saw them difficult to embed in her practice ("*several things about AR, 3DVWs, the game-based learning field, etc, were, and still are, very unknown to me. [...] They seemed like science fiction for me, actually. […] I have read some articles about game-based learning and all that, and I thought it was very interesting, […] some things for learning history […] were great. […] But of course I thought they were very complicated*" [Int]). Thus, she recognized that she would not have used 3DVWs without GLUEPS-AR, and despite she had thought about using AR, she did not dare to do it [Quest, Int]. However, after conducting the learning situation, she indicated in both the questionnaire and the interview, that she would use immersive technologies again in the future ("*I will use them for sure. The next year I will modify this design and I will use it, with modifications. I have to think how to make AR and 3DVWs transversal in another block of the course, to get a higher impact in the WebQuest, which is the multimedia didactic resource they have to elaborate at the end of the course*" [Int]). Some of the advantages she considered for incorporating immersive environments had to do with carrying out authentic ubiquitous learning experiences, and also with the possibility of enriching the educational resources in multiple disciplines ("*to be able to design situations that really promote ubiquitous* *learning, the possibility of enriching the learning contents in different disciplines [...], improving the student's interactivity, an inquiry based learning, the possibility of a 3D view of monuments, constructions, museums, [...]*" [Quest]; "*In addition, the students have the possibility of walking through the [virtual] city, and see where the ads are geopositioned*" [Int]). The main drawback that she perceived was that she would need time for increasing her knowledge about these immersive technologies and the pedagogical possibilities they provide [Quest, Int].

Finally, the immersive environments played an instrumental role toward the objective of seamlessly connecting the different physical and virtual spaces of the learning situation [Quest, Int, Obs 2]. An example of this role is that the 3D view of the VGs was mostly used for creating geopositioned artefacts ("*the [virtual] walk in Google Earth isn't long, just enough to visit the picture and create the associated document*" [Obs 2]).

4.2.2 Orchestration (Topic 2)

For the exploration of this topic we have used the orchestration framework of [Prieto et al. 2011], since it is a generic conceptualization that takes into account multiple aspects that different approaches in the TEL literature encompass under the umbrella of orchestration: design, management, adaptation, awareness, roles of the teachers and other actors, pragmatism, alignment and theories.

Evaluation evidence indicates that GLUEPS-AR helped the teacher in the multiple aspects of orchestration. GLUEPS-AR enabled the teacher to implement, with eventual support, her learning *design* in a ULE formed by a wiki-based VLE, Web 2.0 tools, mobile AR apps and VGs [Artefact 1&2, Screen, Obs 1, Quest, Int] ("*I totally agree. The system enables the deployment of the learning design. But about doing it completely alone the first time..., I think that a little help is needed at a first stage. Otherwise I should have studied the manual, which I didn't*" [Int]).

She also admitted that GLUEPS-AR helped her in the *management* of the learning situation by enabling her to structure its activities for different groups, and through the automatic creation of artefacts (she rated 6, "*Strongly agree*", in a 1-6 scale the three assertions regarding the help provided by the system for managing the learning situation, the groups of students, and the educational tools and resources [Quest]; she also recognized that "*GLUEPS-AR also allowed the automatic deployment of the groups in the wiki, which is an advantage, because in general, I have to create the groups manually*" and "*[regarding the automatic creation of tool instances] that's great, because without that functionality, I would have had to create manually document by document, which would have been like hell. It is wonderful that it is directly deployed*" [Int]). She considered affordable the time devoted to GLUEPS-AR, acknowledging that it would be reduced with some more practice [Quest, Int]. It took her 57 minutes re-designing her learning situation using WebCollage and 46 deploying it using GLUEPS-AR [Screen, Obs 1]. Subsequent refinements in the design were performed quickly by the teacher herself using the GLUEPS-AR user interface [Artefact 1&2]. In addition, she recognised that GLUEPS-AR saved time in the overall learning situation, since in the previous years several operations had to be performed manually, such as the uploading of pictures and their positioning in a map ("*Now we save time. For example, for taking the pictures, previously the students took and stored them in their mobiles, and they had* *to load them in their computers and upload them to the VLE. Now, everything is automatically geopositioned*" [Int]). GLUEPS-AR enabled the teacher not only to fine-tune the design after its first deployment and between sessions, but also to *adapt* it when emerging events occurred [Artefact 1&2, Quest, Int, Obs 2]. For instance, during the sessions, she changed the groups' configuration, she included new learning resources to the learning design, and she modified the accessibility of several artefacts in order to allow their access from different environments (e.g., from VGs, from the wiki or from AR) (e.g., some observation notes illustrate this feature, such as "*the teacher goes to her computer. She has to add a student to a group. She accesses the GLUEPS-AR user interface and does it in less than two minutes*" and "*The teacher tells us that the use of GLUEPS-AR for a deployment during a session is amazing. She has added a new resource (a tool's manual), deployed it, and it already appears in the wiki*" [Obs 2]). Also, one of the components of the architecture failed during one day (it reached its maximum configured java memory, since it had not been used previously with such a high load as the one produced with the uploading of about 300 pictures). Consequently, several pictures could not be uploaded and geopositioned by the students from the location in which they were taken. GLUEPS-AR allowed the teacher to change the positioning type of the buckets, enabling students to upload and position the pictures later, from their homes or from the classroom ("*[...] some students had problems for the automatic uploading of pictures. [...] Having the possibility of configuring the bucket to allow that the students manually geoposition [the pictures] is great, because there is a back-up plan [...]. And I think it is very relevant in these learning situations [...]*" [Int]). The feedback from the teacher was very positive in this aspect, acknowledging that with GLUEPS-AR she was able to change the activities at runtime (she rated 6, "*Strongly agree*", in a 1-6 scale the seven assertions regarding the support provided by GLUEPS-AR to adapt and modify the design and its elements (activities, groups, resources, etc) [Quest]; she also recognized that "*the possibility of making changes at runtime is what I value most. [...] making changes is super-easy*" [Int]; "*The teacher tells us that GLUEPS-AR is useful and usable, and now she can go calmly to the classroom, because if she has forgotten something [in the system], she can do it during the class*" [Obs 2]).

The GLUEPS-AR user interface acted also as a dashboard for the teacher, allowing her to review and assess the students' work (she rated 5, "*Agree*", in a 1-6 scale the different assertions regarding the GLUEPS-AR support to the *awareness* of students actions during and after the end of the activities in both, physical and virtual spaces [Quest]). In addition, she was able to review the work using the wiki and the VGs ("*I was able also to access Google Earth and know if each group was uploading correctly the pictures [...] this way we identified the persons who had had problems in the automatic uploading of pictures*" [Int]). The main limitation of the awareness aspect was that the teacher did not have enough time during the enactment sessions to review the work that was being carried out by the students [Quest, Int] ("*[...] the challenge is the [short] time we have to review in situ so much information and provide feedback to the students*" [Quest]). She indicated that technology could provide solutions with respect to this facet, for instance by providing summarized information of key indicators [Int].

The *role* of the students in the orchestration of a ubiquitous learning situation like City Ads can be an essential factor to make it affordable. By using learning buckets, GLUEPS-AR allowed moving part of the orchestration load from the teacher to the students, giving them a level of self-regulation in the management of artefacts within the different immersive and not immersive environments (wiki, AR apps and VGs) [Quest, Int, Obs 2] (e.g., the teacher acknowledged that "*the orchestration load decreases a lot when you give the students the possibility of deciding what artefacts they create, not being myself who creates every document wherein the students have to work. In addition, they are more active in the process [...]*" [Int]; such student self-regulation was also observed, e.g., "*These two students are creating documents for the [analysis of the] pictures. They are concentrated on working*" [Obs 2]). The students created finally 570 artefacts (e.g., pictures uploaded to Picasa or Google Drive Documents) [Artefact 2].

Evaluation evidence shows that GLUEPS-AR provided the teacher with a *pragmatic* mean for conducting the City Ads scenario, since it fitted with her technological and pedagogical constraints, as well as with those of the institution and context [Quest, Int] ("*it fitted very well with my needs as a teacher [...]. A benefit of the system is that it gives you new possibilities, which you haven't even thought they could exist. [...] Now our institutions ask us for using VLEs [...] and active methodologies, and since GLUEPS-AR supports these requirements, it fits well with these constraints*" [Int]). The teacher considered GLUEPS-AR easy to use [Quest, Int] (she rated 5, "*Agree*", or 6, "*Strongly agree*", the different assertions regarding the easiness and usefulness of the system), although some minor usability problems were detected in the user interface [Quest, Int, Obs 2] ("*Maybe the fields required to complete for creating artefacts are confusing*" [Quest]; "*She has some problems with the interface: too many scrolls, etc.*" [Obs 2]). The teacher expressed her intention of using GLUEPS-AR the next term to conduct again the City Ads scenario (she rated 6, "*Strongly agree*", in a 1-6 scale the three assertions regarding its future use [Quest], and she confirmed it in the interview: "*Yes, I'm motivated to learn. Really, I'll do. Moreover, I already know what I'm going to change the next year*" [Int]).

Another interesting aspect was that GLUEPS-AR helped the teacher *align* the different technological and social resources as a necessary means for achieving the learning goals. GLUEPS-AR converted a set of independent physical and virtual, immersive and non-immersive spaces in a ULE, where students were able to learn seamlessly (she rated 5, "*Agree*", and 6, "*Strongly agree*", the assertions regarding the integration of the different spaces, as well as the continuity of the learning activities performed between them [Quest]; she also confirmed it during the interview: "*yes, because in the end, all the different learning spaces were well defined and very clear [...]. 'First, we go to the streets and take pictures. We geoposition them in Google Earth. We arrive to the classroom, create the documents and geoposition them close to the pictures in Google Earth. ¿And where do we access all the information of the activity? In the wiki'. I think [all the spaces] were very clear*" [Int]). However, she found that not all learning goals were achieved by some students (e.g., that was the case of the use of the AR browsers and the subsequent students' reports about the potential affordances of AR in education, where several students just copied information from Internet [Int]). She recognised that this problem was due to a lack of an assessment design she should have created, as well as to the excess of students' workload, not being related to GLUEPS-AR ("*I think I made them suffer so much because there were few classroom-hours and too many things I asked them to do. [...]*

There are students that didn't work very well. The evaluation criteria should have been clearer to help them achieve the objectives, because we had never carried out such a deep analysis, and it was also new for me [...]. Therefore, I think that if they haven't achieved the learning objectives, the responsibility is shared between them and me" [Int]).

Finally, GLUEPS-AR did not modify significantly the pedagogical and organizational *theories* of the teacher [Quest, Int], although when she reviewed the performance of the students, she realized she should modify her design in subsequent years ("*When I made the design I used the pedagogical methodologies I wanted to use and I was happy with my design. But afterwards I realized that there are several things to improve and refine*" [Int]).

5 Conclusions

City Ads is a ubiquitous learning scenario that integrates immersive technologies, such as mobile AR and VGs, with other widespread technologies used in education, like a wiki-based VLE and Web 2.0 tools. The immersive environments enriched a learning situation that had been regularly conducted previously. The City Ads scenario illustrates several existing challenges that refer to the appropriation of immersive environments in everyday educational practice, namely, the inclusion of such environments in learning situations conducted regularly by the teachers, their integration with the widespread technologies already used by the educators, as well as the support to the orchestration of the resulting learning situations.

The evidence gathered in the evaluation reported in this paper indicates that GLUEPS-AR aided the involved teacher to appropriate immersive environments such as mobile AR and VGs in her educational practice, enabling her to design, deploy and enact the City Ads learning situation. Moreover, GLUEPS-AR helped her to overcome the difficulties of orchestrating the complex ecology of technological and social resources created with the integration of such immersive technologies.

Although the teacher included and orchestrated immersive technologies that she recognized would not have incorporated without the use of GLUEPS-AR, some of the immersive affordances of the environments had a limited use. For example, the teacher did not include in her design collaboration in VGs using avatars and chats since she did not considered it necessary to achieve the learning goals. We plan further research exploring learning situations with higher use of interaction and presence in the immersive environments.

One of the main benefits of using VGs rather than other more classical 3DVWs like Second Life is their widespread use, which may contribute to their adoption by the teachers. However, VGs have also limitations, such as the current lack of 3D buildings in some areas in Google Earth. We plan to further explore the integration of other more classical 3DVWs, as well as other types of environments (e.g., tabletops and AR/VR glasses). Other open issues, which have not been explored in this case, are the analysis of these situations from the point of view of the students, to analyze the achievement of the learning goals and the acquisition of knowledge by the participants, as well as the study of GLUEPS-AR scalability, to evaluate whether it enables the set-up of more massive scenarios. Also, further research is necessary to explore the effects of different didactic and pedagogical approaches in the teacher appropriation and orchestration of learning situations such as City Ads.

Acknowledgements

This research has been partially funded by the Spanish Project TIN2011-28308-C03-02 and the European Project 531262-LLP-2012-ES-KA3-KA3MP. The authors thank Mario Marinero, Judith Samaniego, Quico Arribas, Angélica Lozano, Rafael Cano and the rest of the GSIC/EMIC research team for their ideas and support.

References

[Alario-Hoyos and Wilson 2010] Alario-Hoyos, C. and Wilson, S.: "Comparison of the main alternatives to the integration of external tools in different platforms"; Proceedings of the International Conference of Education, Research and Innovation, ICERI 2010 (2010), 3466-3476.

[Alcañiz et al. 2010] Alcañiz, M., Contero, M., Perez-Lopez, D.C., and Ortega, M.: Augmented Reality Technology for Education. In: Soomro, S. (ed.) New Achievements in Technology Education and Development. pp. 247-256. InTech, (2010)

[Billinghurst and Duenser 2012] Billinghurst, M. and Duenser, A.: "Augmented Reality in the Classroom"; Computer, 45, 7 (2012), 56-63.

[Callaghan et al. 2009] Callaghan, M.J., McCusker, K., Losada, J.L., Harkin, J.G., and Wilson, S.: "Engineering Education Island: Teaching Engineering in Virtual Worlds"; Innovation in Teaching and Learning in Information and Computer Sciences, 8, 3 (2009), 2-18.

[Cohen et al. 2007] Cohen, L., Manion, L., and Morrison, K.: "Research methods in education"; Routledge (2007)

[Chen and Choi 2010] Chen, X. and Choi, J.H.: "Designing Online Collaborative Location-Aware Platform for History Learning"; Journal of Educational Technology Development and Exchange, 3, 1 (2010), 13-26.

[Dede 2009] Dede, C.: "Immersive Interfaces for Engagement and Learning"; Science, 323, 5910 (2009), 66-69.

[Dede et al. 2004] Dede, C., Nelson, B., Ketelhut, D.J., Clarke, J., and Bowman, C.: "Design-based research strategies for studying situated learning in a multi-user virtual environment"; Proceedings of the 6th international conference on Learning sciences. ICLS '04 (2004), 158-165.

[Di Serio et al. 2013] Di Serio, Á., Ibáñez, M.B., and Delgado Kloos, C.: "Impact of an augmented reality system on students' motivation for a visual art course"; Computers & Education, 68, 0 (2013), 586-596.

[Dickey 2005] Dickey, M.D.: "Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education"; British Journal of Educational Technology, 36, 3 (2005), 439-451.

[Dordevic and Wild 2012] Dordevic, M.M. and Wild, S.C.: "Avatars and multi-student interactions in Google Earth–based virtual field experiences"; Geological Society of America Special Papers, 492, (2012), 315-321.

[Dörner et al. 2011] Dörner, R., Lok, B., and Broll, W.: Social Gaming and Learning Applications: A Driving Force for the Future of Virtual and Augmented Reality? In: Brunnett, G., Coquillart, S., Welch, G. (eds.) Virtual Realities. pp. 51-76. Springer Vienna, (2011)

[Duncan et al. 2012] Duncan, I., Miller, A., and Jiang, S.: "A taxonomy of virtual worlds usage in education"; British Journal of Educational Technology, 43, 6 (2012), 949-964.

[Facer et al. 2004] Facer, K., Joiner, R., Stanton, D., Reid, J., Hull, R., and Kirks, D.: "Savannah: mobile gaming and learning?"; Journal of Computer Assisted Learning, 20, 6 (2004), 399-409.

[Fernández-Gallego et al. 2010] Fernández-Gallego, B., Lama, M., Vidal, J.C., Sánchez, E., and Bugarín, A.: "OPENET4VE: A Platform for the Execution of IMS LD Units of Learning in Virtual Environments"; IEEE 10th International Conference on Advanced Learning Technologies (ICALT) (2010), 472-474.

[Fernández-Panadero and Delgado Kloos 2013] Fernández-Panadero, C. and Delgado Kloos, C.: "PhyMEL. A Framework to Integrate Physical, Mental and Emotional Learning in Meaningfull Experiences and Multidimensional Reports"; 3rd European Immersive Education Summit (EiED'13), London, UK (2013), 203-208.

[Gregory et al. 2013] Gregory, S. et al.: "Virtual worlds in Australian and New Zealand higher education : remembering the past, understanding the present and imagining the future"; ASCILITE 2013 "Electric Dreams", Macquarie University, Sydney, Australia (2013), 312-324.

[Guba 1981] Guba, E.: "Criteria for assessing the trustworthiness of naturalistic inquiries"; Educational Communication and Technology Journal, 29, 2 (1981), 75-91.

[Ibáñez et al. 2012] Ibáñez, M.B., Maroto, D., García Rueda, J.J., Leony, D., and Delgado Kloos, C.: "Architecture for Collaborative Learning Activities in Hybrid Learning Environments"; Journal of Universal Computer Science, 18, 15 (2012), 2187-2202.

[Izadi et al. 2002] Izadi, S., Fraser, M., Benford, S., Flintham, M., Greenhalgh, C., Rodden, T., and Schnädelbach, H.: "Citywide: Supporting Interactive Digital Experiences Across Physical Space"; Personal and Ubiquitous Computing, 6, 4 (2002), 290-298.

[Jarmon et al. 2008] Jarmon, L., Traphagan, T., and Mayrath, M.: "Understanding project-based learning in Second Life with a pedagogy, training, and assessment trio"; Educational Media International, 45, 3 (2008), 157-176.

[Jorrín-Abellán and Stake 2009] Jorrín-Abellán, I.M. and Stake, R.E.: "Does Ubiquitous Learning Call for Ubiquitous Forms of Formal Evaluation? An Evaluand Oriented Responsive Evaluation Model"; Ubiquitous Learning: An International Journal, 1, 3 (2009), 71-82.

[Kamarainen et al. 2013] Kamarainen, A.M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M.S., and Dede, C.: "EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips"; Computers & Education, 68, 0 (2013), 545-556.

[Kaufmann and Schmalstieg 2002] Kaufmann, H. and Schmalstieg, D.: "Mathematics and geometry education with collaborative augmented reality"; ACM SIGGRAPH 2002 conference abstracts and applications. SIGGRAPH '02, New York, NY, USA (2002), 37-41.

[Kerawalla et al. 2006] Kerawalla, L., Luckin, R., Seljeflot, S., and Woolard, A.: "“Making it real”: exploring the potential of augmented reality for teaching primary school science"; Virtual Reality, 10, 3 (2006), 163-174.

[Klopfer et al. 2011] Klopfer, E., Sheldon, J., Perry, J., Rosenheck, L., Squire, K., Mathews, J., Shapiro, R.B., Coulter, B., and Dunleavy, M.: "Augmented reality games: place-based digital learning"; Proceedings of the 9th International CSCL Conference, Hong Kong, China (2011), 1023-1028.

[Koper 2005] Koper, R.: An Introduction to Learning Design. In: Koper, R., Tattersall, C. (eds.) Learning Design. A Handbook on Modelling and Delivering Networked Education and Training. pp. 3-20. Springer, (2005)

[Li et al. 2004] Li, L., Zheng, Y., Ogata, H., and Yano, Y.: "A framework of ubiquitous learning environment"; The Fourth International Conference on Computer and Information Technology (CIT 2004), Wuhan, China (2004), 345-350.

[Lim et al. 2006] Lim, C.P., Nonis, D., and Hedberg, J.: "Gaming in a 3D multiuser virtual environment: engaging students in Science lessons"; British Journal of Educational Technology, 37, 2 (2006), 211-231.

[Livingstone and Kemp 2008] Livingstone, D. and Kemp, J.: "Integrating Web-Based and 3D Learning Environments: Second Life Meets Moodle"; UPGRADE, 9, 3 (2008), 8-14.

[Maroto et al. 2011] Maroto, D., Leony, D., Delgado Kloos, C., Ibáñez, M.B., and Rueda, J.J.G.: "Orchestrating learning activities in 3D virtual worlds: IMS-LD in open wonderland"; Proceedings of the 6th European conference on Technology enhanced learning: towards ubiquitous learning. EC-TEL'11, Berlin, Heidelberg (2011), 455-460.

[Mennecke et al. 2008] Mennecke, B., Hassall, L.M., and Triplett, J.: "The Mean Business of Second Life: Teaching Entrepreneurship, Technology and e-Commerce in Immersive Environments"; Journal of Online Learning and Teaching, 4, 3 (2008), 339-348.

[Miles and Huberman 1994] Miles, M.B. and Huberman, A.M.: "Qualitative Data Analysis. An Expanded Sourcebook"; SAGE Publications Inc. (1994)

[Muñoz-Cristóbal et al. 2013] Muñoz-Cristóbal, J.A., Prieto-Santos, L.P., Asensio-Pérez, J.I., Jorrín-Abellán, I.M., Martínez-Monés, A., and Dimitriadis, Y.: "Sharing the Burden: Introducing Student-Centered Orchestration in Across-Spaces Learning Situations"; Proceedings of the 8th European Conference on Technology Enhanced Learning (EC-TEL), Paphos, Cyprus (2013), 621-622.

[Muñoz-Cristóbal et al. in press] Muñoz-Cristóbal, J.A., Prieto, L.P., Asensio-Pérez, J.I., Martínez-Monés, A., Jorrín-Abellán, I.M., and Dimitriadis, Y.: "Coming down to Earth: Helping teachers use 3D virtual worlds in across-spaces learning situations"; Educational Technology & Society, (in press)

[Okada et al. 2001] Okada, M., Tarumi, H., Yoshimura, T., and Moriya, K.: "Collaborative environmental education using distributed virtual environment accessible from real and virtual worlds"; SIGAPP Applied Computing Review, 9, 1 (2001), 15-21.

[Orlikowski and Baroudi 1991] Orlikowski, W.J. and Baroudi, J.J.: "Studying Information Technology in Organizations: Research Approaches and Assumptions"; Information Systems Research, 2, 1 (1991), 1-28.

[Peña-Rios et al. 2013] Peña-Rios, A., Callaghan, V., Gardner, M., and Alhaddad, M.J.: "xReality interactions within an immersive blended reality learning space"; 3rd European Immersive Education Summit (EiED'13), London, UK (2013), 26-35.

[Pérez-Sanagustín et al. 2011] Pérez-Sanagustín, M., Ramirez-Gonzalez, G., Hernández-Leo, D., Muñoz-Organero, M., Santos, P., Blat, J., and Delgado Kloos, C.: "Discovering the campus together: A mobile and computer-based learning experience"; Journal of Network and Computer Applications, 35, 1 (2011), 167-188.

[Pourmirza and Gardner 2013] Pourmirza, S. and Gardner, M.: "Integrating a Facebook Group with the Open Wonderland Environment"; 3rd European Immersive Education Summit (EiED'13), London, UK (2013), 17-22.

[Prieto et al. 2011] Prieto, L.P., Dlab, M.H., Gutiérrez, I., Abdulwahed, M., and Balid, W.: "Orchestrating technology enhanced learning: a literature review and a conceptual framework"; International Journal of Technology Enhanced Learning, 3, 6 (2011), 583-598.

[Rakshit and Ogneva-Himmelberger 2008] Rakshit, R. and Ogneva-Himmelberger, Y.: "Application of Virtual Globes in Education"; Geography Compass, 2, 6 (2008), 1995-2010.

[Santos et al. 2011] Santos, P., Pérez-Sanagustín, M., Hernández-Leo, D., and Blat, J.: "QuesTInSitu: From tests to routes for assessment in situ activities"; Computers & Education, 57, 4 (2011), 2517-2534.

[Schaf et al. 2012] Schaf, F.M., Paladini, S., and Pereira, C.E.: "3D AutoSysLab Prototype - A Social, Immersive and Mixed Reality Approach for Collaborative Learning Environments"; International Journal of Engineering Pedagogy, 2, 2 (2012), 15-22.

[Sharples 2013] Sharples, M.: "Shared orchestration within and beyond the classroom"; Computers & Education, 69, 0 (2013), 504-506.

[Spikol and Eliasson 2010] Spikol, D. and Eliasson, J.: "Lessons from Designing Geometry Learning Activities that Combine Mobile and 3D Tools"; Proceedings of the 6th IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE), Kaohsiung, Taiwan (2010), 137-141.

[Stake 2004] Stake, R.E.: "Standards-Based and Responsive Evaluation"; SAGE Publications Inc. (2004)

[Ternier et al. 2012] Ternier, S., Klemke, R., Kalz, M., van Ulzen, P., and Specht, M.: "ARLearn: augmented reality meets augmented virtuality"; Journal of Universal Computer Science, 18, 15 (2012), 2143-2164.

[Villasclaras-Fernández et al. 2013] Villasclaras-Fernández, E., Hernández-Leo, D., Asensio-Pérez, J.I., and Dimitriadis, Y.: "Web Collage: An implementation of support for assessment design in CSCL macro-scripts"; Computers & Education, 67, 0 (2013), 79-97.

[Vlahakis et al. 2002] Vlahakis, V., Ioannidis, N., Karigiannis, J., Tsotros, M., Gounaris, M., Stricker, D., Gleue, T., Daehne, P., and Almeida, L.: "Archeoguide: an augmented reality guide for archaeological sites"; Computer Graphics and Applications, IEEE, 22, 5 (2002), 52-60.

[Warburton 2009] Warburton, S.: "Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching"; British Journal of Educational Technology, 40, 3 (2009), 414-426.

[Wu et al. 2013] Wu, H.-K., Lee, S.W.-Y., Chang, H.-Y., and Liang, J.-C.: "Current status, opportunities and challenges of augmented reality in education"; Computers & Education, 62, (2013), 41-49.

[Zurita et al. 2014] Zurita, G., Baloian, N., and Frez, J.: "Using the cloud to develop applications supporting geo-collaborative Situated Learning"; Future Generation Computer Systems, 34, 0 (2014), 124-137.