Augmenting Reality and Formality of Informal and Non-formal Settings to Enhance Blended Learning

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Abstract—Visits to museums and city tours have been part of higher and secondary education curriculum activities for many years. However these activities are typically considered "less formal" when compared to those carried out in the classroom, mainly because they take place in informal or non-formal settings. Augmented Reality (AR) technologies and smartphones can transform such informal and non-formal settings into digitally augmented learning settings by superimposing "digital" layers of information over physical objects or spaces. At the same time, the formality of these settings increases when connected to formal settings through these digital layers. The right combination of AR and mobile technologies with computer-based educational tools such as Learning Management Systems (LMSs) drives this digital connection, leading to articulated blended learning activities across formal, non-formal and informal settings. This paper contributes to the TEL field with: (1) three blended learning activities illustrating the idea of augmented informal/non-formal settings; (2) results from the cross-analysis of these activities that evidence the impact of technology to enhance blended learning; and (3) a set of lessons learned about the possibilities of NFC/GPS AR technologies and LMSs for blended learning. This work provides insights for the design and implementation of similar technology-enhanced blended learning activities.

Index Terms— Virtual and Augmented Reality, Blended Learning, Smartphones, Learning Management Systems.

1 INTRODUCTION

BORN within graphics, Augmented Reality (AR) was initially a technologically challenging topic and an interaction paradigm alternative (or complementary) to Virtual Reality [14]. The wide adoption of smartphones and availability of AR software has made AR widespread. Novel applications propose forms of interactions that superimpose layers of 'digital' contextualized information over 'physical' settings offering new opportunities for learning experiences [33]. For instance, the iPhone application, Starmap, allows learning about the constellations on a map displayed on its screen "superimposed" onto the real stars being viewed in the sky. Within this context, we refer to AR as the technologies that enable the superimposing of layers of 'digitally' contextualized information over 'physical' settings for enriching or augmenting the real world.

Many researchers seize new opportunities for learning in places other than the classroom using smartphones and AR technologies to bring these digital layers to informal and non-formal settings [15][16][50]. On one hand, the anywhere and anytime capabilities of mobile technologies and the different types of sensors that they incorporate (e.g., cameras, GPS) offer the opportunity of augmenting any setting or object with interactive digital information. Informal settings such as forests or cities, or non-formal such as museums, become digitally augmented spaces with contextual information that scaffolds and supports learning [33]. On the other hand, smartphones have been used to help learners find connections between their daily life and education, bridging the gap between learning in formal, non-formal or informal settings [6][23][49]. The use of smartphones in education has typically been associated with exploratory, informal-type activities because they take place in informal settings and do not follow an organized curricular structure [39]. However this work explores how using combinations of smartphones and AR technologies along with Learning Management Systems (LMS) informal and non-formal settings become augmented settings, enhancing blended learning (BL). In this context, BL is defined as learning through combinations of activities across formal, non-formal and informal settings that are mixed and integrated into the same learning flow or process using combinations of technologies; that is understanding *blend* in a broad sense: blend of activities (including elements of different learning theories or pedagogical approaches), settings and technologies [31].

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To address this challenge, we present three contributions. First, we illustrate the concepts of augmented reality and augmented formality of informal and non-formal settings by giving an overview of three real blended learning activities: *Discovering the Campus 2009* [30], *Discovering the Campus 2010* [7] and *Discovering Barcelona* [31]. Second, we contribute with a cross-analysis of these three learning blended learning activities. All these activities were designed, implemented and evaluated in authentic learning situations in previous work. However, a systematic cross-analysis of the three activities, which are similar interventions in several contexts, facilitates the identification of contrasted evidences about the learning benefits of augmenting reality and formality of informal and non-formal settings. Third, a set of lessons learned about the possibilities of combining mobile, AR technologies and LMSs in blended learning activities/contexts, discussing its advantages and limitations, is presented. Altogether, this paper provides insights about both the design (technological perspective) and application (educational perspective) of AR technologies in informal and non-formal settings with formal learning purposes.

The remainder of the paper is structured as follows. Sec. 2 reviews the literature framing the concepts of augmenting reality and formality of informal and non-formal settings. Then, Sec. 3 presents the three blended learning activities. Sec. 4 introduces the multicase that structures the cross-analysis of the three activities and the methodological approach of the analysis. Sec. 5 follows presenting the findings of the separated cases, the results of the cross analysis and other complementary findings emerging from the analysis. Sec. 6 describes a list of lessons learned from the analysis. Finally, Sec. 7 summarizes the main contributions of this paper and highlights its main conclusions.

2 Background

This section presents an overview of the literature in mobile learning that inspires and sustains the concepts of "augmented reality" and "augmented formality" to frame the terminology adopted throughout this paper.

2.1 Augmented Reality: layers of 'digital' information to support learning

The concept of Augmented Reality (AR) has been associated with several meanings. Some definitions focus on the technological perspective and define AR as "the technology of adding virtual objects to real scenes" [13]. However, the concept of AR has evolved towards another (probably more natural) perspective. These new definitions focus on the idea of "blending" digital with real world information [22] for enriching and supplementing real settings and creating digitally augmented physical settings [33] or (sometimes called) "blended spaces" [2]. As Dunleavy *et al* (2009) [11] state: "AR interfaces enable ubiquitous computing' models in which students carrying mobile wireless devices through real world contexts engage with virtual information superimposed on physical landscapes (…). This type of mediated immersion infuses digital resources throughout the real world, augmenting students' experiences and interactions". Accordingly, we define AR as "the technologies that enable superimposing layers of 'digital' contextualized information over 'physical' settings for enriching or augmenting real world interactions".

Many researchers have experimented with combinations of smartphones and AR technologies for supporting learning. FitzGerald *et al* [15] and Frohberg *et al* [16] offer interesting reviews of the state of art in this field. Most of these experiments propose activities based on socio-constructivist theories, including elements mostly influenced by (somehow interrelated) learning approaches such as: (1) *collaborative learning*, which are "situations in which two or more people learn or attempt to learn something together" [9]; (2) *mobile learning*, "the use of wireless mobile technology to access information and learning materials from anywhere and anytime" [1] or any of its other acceptation [24]; (3) *situated learning* [3], where learning is the product of the activity in a particular context and culture in which it is developed; or (4) *inquiry-based learning*, a "student-centred active learning approach focused on questioning, critical thinking and problem solving" [38]. For the purposes of this article, our literature review focuses only on activity-types based on the above-mentioned pedagogies and using tag-based and GPS-based technologies as the means to interact with the context and to support learning. We classified these activity types into three categories.

(1) Augmented Outdoor Guided Trips: use location-based technologies such as GPS to relate media resources with a specific location. These resources automatically pop up to the user depending on their position. Typically, these are geo-learning experiences that offer information to guide learners through the activity [40] [36], offering contextualized resources about a particular setting/object [35] or recommending materials that best match the students' locations [12].

(2) Augmented Indoor Guided Tours: use tag-based technologies such as NFC, QR codes or AR markers to extend indoor elements/objects with digital information. Usually, these technologies are means for supporting active learning and learning about particular objects in indoor settings such as museums [17], classrooms [42][34] or mixed areas with low GPS signal [30], although AR markers have also been used in open areas for triggering information about projects or videos [25].

(3) Educaching: educaching can use both tag-based and GPS-based technologies to link physical surroundings with digital contents [10]. The main particularity of these activities is that they introduce a strong gamification component.

2.2 Augmented Formality: connecting digital layers to bridge formal and informal settings

Mocker and Spear [27] review formal, non-formal and informal learning and argue that two elements articulate these definitions: (1) the setting where the learning takes place; and (2) the general approach to instruction. Accordingly, they define: (1) formal learning, occurring in traditional settings and whose learning objectives and the means to reach them are decided by someone else besides the learner; (2) non-formal learning, occurring in lifelong learning settings and whose objectives are decided by the learners, but the means are proposed by others; and (3) informal learning, where learners have little or no control at all over the choice of learning objectives, but control the means that can result into learning. In a more recent paper, Sefton-Green [39] defines informal learning in contrast to formal learning taking into account the incorporation of ICT for learning purposes as "two kinds of continuum": organization (a curriculum, or how learning is structured) and setting (where learning takes place). That is, formal learning is structured and organized, while informal learning does not have a clear structure, and is casual or accidental. Setting range from the more formal (such as schools), through intermediate or non-formal (museums or galleries), right to social structures (families and communities).

We adopt a combination of the arguments and definitions by both authors and adapt them to the context of this work. Specifically, we define **formal**, **non-formal** and **informal learning** as a "continuum" between the way **objectives are defined and achieved** and the **setting where the activity takes place**. Accordingly we contend that in formal learning the learning objectives are defined by someone else besides the learner and the means to achieve them is determined by someone other than the learner. In non-formal learning, the learner controls what he wants to learn, but does not control the means to achieve this learning. In informal learning objectives are not defined because learning is casual, but the learner controls the means that can result into learning. In addition, we consider that settings range from formal (classroom), non-formal (museum type) or informal (those that not belong to any educational institution). Consequently, and according to these definitions, we understand that it is possible to find formal learning situations occurring in formal, informal and non-formal settings, informal learning situations taking place in formal, informal and non-formal settings or non-formal situations taking place in formal, non-formal or settings.

Researchers in mobile learning assume that learning flows across locations, time, topics and technologies rather than occurring within a fixed location [40][41]. This mobility across contexts and spaces facilitates and supports exploration and conversation, the fundamental processes by which meaning is sought and attained. Exploration involves physical movements through a setting and conversations are the bridge that connects learning across such settings [40][49]. Both the interaction with the environment and the mobility stimulate and promote active forms of learning [22], augmenting and expanding the learning benefits of traditional activities.

Several studies introduce some of the aspects that support this idea. These approaches benefit from the capabilities of mobile technologies to combine tasks conducted indoors and outdoors including elements of different learning theories into blended learning activities that support learning in context, fostering students' reflection and motivation [43][23][50].

In this frame, this paper focuses on informal and non-formal settings and on how to augment them for explicitly supporting formal activities. Concretely, this work explores how smartphones combined with AR and educational technologies such as LMSs can bridge formal, non-formal and informal settings to build up articulated blended learning activities across them. We argue that technology supports the integration of activities across formal, non-formal and informal settings and at the same time helps augment formality of informal and non-formal settings.

3 THREE BLENDED LEARNING ACTIVITIES

This section presents three BL activities to illustrate how combinations of technologies were used to augment reality and formality of informal/non-formal settings for enhancing blended learning. These activities are *Discovering the Campus 2009* and *2010* editions and *Discovering Barcelona*. All the activities were designed to include elements of learning approaches such as collaborative learning, situated-based learning and mobile learning. Each activity employed different technologies to augment reality and formality of the informal/non-formal setting, offering a different support for social interactions and interactions within the setting. *Discovering the Campus 2009* and *2010* used Radio Frequency Identification/Near Field Communication (RFID/NFC) technologies for augmenting a university campus. *Discovering Barcelona* employed an *ad hoc* software based on GPS technology for enriching tours of the city of Barcelona with digital information. *Discovering the Campus 2009* and *Discovering Barcelona* used Moodle LMS for bridging the connections between formal, non-formal informal settings, whereas *Discovering the Campus 2010* combined .LRN LMS with the use of the IMS Learning Design (IMS LD) specification. All the activities are the result of a participatory design process with practitioners, in which the selection of technologies was driven by their particular educational needs and the limitations imposed by the technological infrastructure available in each educational institution. All activities were enacted with real students and teachers and evaluated in previous research work [7][30][31]. In this work, we cross-analyse these activities from the perspective of how reality and formality of informal/non-formal settings were augmented in each activity to identify contrasted evidences about its learning benefits.

3.1 Discovering the Campus 2009

Discovering the Campus 2009 was included in the compulsory subject "Introduction to Communication and Information Technologies" (ICIT) of the engineering degrees of the Universitat Pompeu Fabra in 2009. The objective of this experience was to facilitate students' first contact with the university campus: its services and community, while at the same time meeting other freshmen. The experience was structured into three phases.

1) Discovering the campus: students had to freely explore 5 selected areas of the campus. For the exploration, students had three different options: (1) accessing the university website; (2) walking around the campus, reading posters fixed on key areas of the campus and asking other students; or (3) participating in an exploratory activity using smartphones. The students could freely choose one out of the three options, or combine two or the three options; no specific option was mandatory.

The campus was digitally augmented with 46 interactive RFID/NFC tags distributed in key physical areas of campus buildings. Students using the third option were provided with NFC-enabled smartphones to interact with the tags and access the videos, pictures and sounds that augmented the information about specific physical areas. This information was extracted from the university website. In this way, students choosing option 1, 2 or 3 had the same information. Students had 20-30 minutes for exploring the campus. The stream of tags accessed by each student and the corresponding timestamps were stored in a log file in the mobile phones. At the end of this phase, all students (in option 1, 2 or 3) filled in a web-based questionnaire in Google Forms about the different areas visited during the exploration and their preferred buildings and services.

2) Explaining the campus: The teacher placed Students into groups of 4 or 5, and each group was assigned as an expert in one of the 5 areas of the campus. Teachers used the log files obtained from the mobile phones via Bluetooth to identify the "building areas" expertise of the students according to the tags they accessed in their interactive visit to campus. For those students performing the activity using the other options (without NFC mobile phones), the information about their campus areas expertise was extracted from the answers to the final questionnaire. The list of groups was published in the institutional Moodle LMS. At home, each group had to prepare a presentation about their assigned area and upload it to Moodle.

3) Reflecting about the campus: this activity was conducted individually. Each student reviewed all the presentations available in Moodle LMS, to fill in a questionnaire of 20 questions about the 5 areas of the campus.

The activity lasted two weeks with the participation of 241 students and 3 teachers. For the exploratory activity 74 of 241 students voluntarily chose to perform the augmented exploratory activity (option 3), and the remaining 167 students one of the other options (108 the university website and 59 chose walking around the campus, reading posters fixed on key areas of the campus and asking other students).

In this activity the university campus was the non-formal setting, which was augmented using RFID/NFC tags. Both the log files registered in the NFC-enabled smartphones and the answers to the questionnaires were employed to organize the groups from one phase to the other to connect activities across the campus, the classroom and home.

3.2 Discovering the Campus 2010

Discovering the Campus 2010 shares with the first edition of the activity (2009) the educational context, the learning objectives and the use of NFC/RFID technologies to augment the campus. The differences with the previous activity stems on the technological system used to integrate the different learning settings. In the 2010 edition, IMS Learning Design (IMS LD) specification was used for supporting the connections across settings. Specifically, a Unit of Learning (UoL) in IMS LD was created to computationally represent the sequence of activities. The UoL was interpreted by the .LRN LMS and complemented with a Generic System Integration (GSI) system [8]. The GSI automatically presented the activities in a sequence to the students and the required resources according to their group. Also, the system facilitated the semi-automatic group formation according to the information gathered from the visit.

As in the previous edition (2009), the activity combined individual and collaborative activities. However, the activity was deployed into a two-hour session for 25 students to allow all the students to have a smartphone for the campus exploration activity. Students followed the flow of activities guided by the computer (.LRN system) instead of receiving the instructions from the teacher or via Moodle. Although, both the campus exploration with the mobile phones and the web were the same than in the 2009 edition, the flow of activities changed slightly with respect to the first version of the experience.

1) Discovering the campus: the flow of activities in IMS LD was presented to the students using the .LRN platform. Learners were divided into two groups. While one group performed the exploration of the digitally augmented campus with the mobile phones, the other group explored the campus via the university website. The groups swapped tasks after 20 minutes. The answers to the questionnaire and the activity log files were automatically analysed by the system, producing .csv file with a summary of the events generated by each student. This .csv file was shown as a spreadsheet to the teacher containing: (1) the number of tags accessed per building; and (2) the building expertise (the building with the maximum number of tags accessed).

2) Explaining the campus: the actions of the students in the previous phase were considered for the distribution of the students in expert groups. This was a semi-automatic process, carried out with the formulae of the spreadsheet, which collected all the information about the exploratory activity. The teacher could manipulate this final distribution directly over the spreadsheet. Once the grouping phase finished and no additional group changes were expected, the teacher marked the activity as finished in the .LRN. This action synchronized the flow with the information in the spreadsheets in a way that .LRN automatically showed each student their expert group and the specific activity they had to complete (i.e., elaborate a presentation of the assigned campus building). All the members of each group had to work together in the presentation and upload it into the .LRN system.

3) Reflecting on the campus: in this final phase the teacher had to press a button in .LRN to automatically send the delivery of the submitted presentations to all the groups. Students had to review all the presentations and to access to the final assessment task.

31 students and 4 teachers participated in this activity. As in the previous edition, the campus was augmented with RFID/NFC tags. However, in this case, a system based on IMS LD and .LRN was in charge of automatically integrating the outcome of the activities across locations.

3.3 Discovering Barcelona

High school teachers designed *Discovering Barcelona* to help their students reflect about the urbanism and socio-geographical characteristics of Barcelona city. The experience combined an exploratory activity in the city and a reflective activity in the classroom. For the exploration, the 32 students, in 6 groups of 5 to 6 people and equipped with a smartphone, visited 1 of the 6 districts of the city. The districts were augmented previously with questions that teachers created and geo-positioned using QuesTInSitu [36]. QuesTInSitu is a web-based application for generating sequences of questions associated to a geographical coordinate. At the time of this experience, QuesTInSitu did not integrate a module for detecting the actual position of the students in real time, and was complemented with MediaScapes, maps with the position of the questions that were installed in the mobile devices for the activity. MediaScapes [45] allows showing users media files associated to a geographical coordinate when passing by this location. The activity was divided into 4 phases:

1) Assigning districts: the students were grouped according to their knowledge and preferences about the districts of Barcelona collected from an individual survey that they answered at home.

2) Discovering the district: each group, equipped with a GPS enabled smartphone with Internet connection, simultaneously explored the district to which they were assigned. During the visit groups had to answer the geo-positioned questions, which had associated feedback that guided the students to the next point and gave them hints about the urban and social characteristics of the area. In addition, students collected pictures and notes about the district.

3) Reflect about your district: students prepared a presentation about the district they visited using the material collected and uploaded to the QuesTInSitu application. Afterwards, students made their presentations to the rest of their classmates via the institutional Moodle of the high school. All the groups presented the conclusions of their visit in class two weeks after the visit to Barcelona.

In this case, the city of Barcelona was the informal setting augmented with questions generated with QuesTInSitu and positioned in MediaScapes maps. Then, the outcomes generated by the students during their visits were the inputs for preparing the presentation in the classroom using Moodle, so as to integrate both activities into a continuous learning flow.

4 CROSS-ANALYSIS OF THE THREE BL ACTIVITIES

To study the learning benefits of augmenting reality and formality of informal settings, we cross-analyze the findings of the three blended learning experiences in a multicase study adjusted to our research purposes. Multicase study is a methodology typically employed by educational researchers to study experiences of cases in real situations [44]. However, multicase studies have been successfully applied in engineering-oriented studies as an instrument for studying the effects of the technology in context [20] or in other disciplines when the evaluation involves human-related real experiences [5].

This paper adapts the multicase methodology according to the proposal by Hernández-Leo *et al* [20] to facilitate the cross-analysis of their findings (See Fig. 1). The strength of using this methodology relies on enriching the understanding of the main research question and providing multiple perspectives of the same proposition for a stronger validation.

As shown in Fig. 1, we structured the multicase start-

Fig. 1. Schema of the multicase study. Research aim, research questions, and issues of the two cases comprising the multicase.

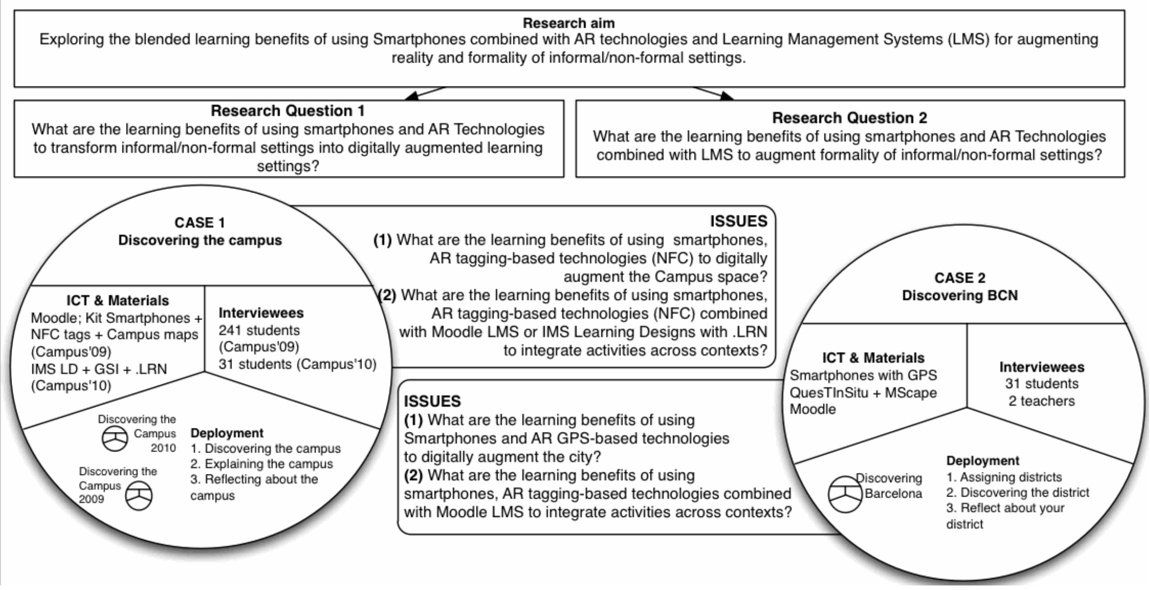

TABLE 1

FINDINGS CASE DISCOVERING THE CAMPUS – ISSUE 1 – WHAT ARE THE LEARNING BENEFITS OF USING SMARTPHONES AND AR TAGGING-BASED TECHNOLOGIES (NFC) TO DIGITALLY AUGMENT THE CAMPUS SPACE?

Findings of separated cases	Partial Results	Selected support data
FCamp1: The activity supported with the smartphones and AR tags facilitates students a more accurate and profound first contact with the campus' services and resources (if compared with reading the information online and/or walking around the campus without smartphones/AR support) **(Campus 09)**.	- The students' marks (when assessing the outcomes of the whole process) indicate that students in the group exploring the NFC tags that augmented campus and completing the other activities in the flow (in class and at home) show better results in average and have developed more original contents for their presentations. - The exploratory activity around the campus using smartphones is a good support for learning non-typical contents about the campus and services. - The students that were physically in contact with the campus show more precise descriptions of the university service's locations that those who only did the exploration via the web. - Students contact with the different services of the university and activities of the department. - The exploration using smartphones is a good support for learning and discovering more about the campus structure and services in comparison with other activities.	- The average score of the students who completed the activity with the mobile phones was of 8.4/10 compared to 7.5/10 of those who did not (only consulting the website or/and walking around without using the smartphones/AR-tags) **([30]; p. 186, Fig. 8)** - "It's a good way of discovering the campus because, when you're a new student, you're lost" [Quest-Experience-eg] **([30]; p. 186).** - "The activity is interactive while the questionnaires can be answered only with the website of the University. In this last case you lose the information of the physical situation of the buildings" [Quest-Reflection-Phase3] **([30]; p. 184).**
FCamp2: Students consider that the activity was useful to learn about the campus services and to locate and orientate themselves among the buildings. Most of them would recommend the activity and would repeat it for learning new aspects of the campus **(Campus 10).**	- Students consider that these types of experiences are useful for learning about the campus environment. The exploratory activity helped them to discover the campus locations and its services, to know how the campus is distributed and to move around the campus and to orientate themselves. - 29 students would recommend the activity to their colleagues and 1 would not (1 student did not answer this question). - Half of the students (16) said that they would repeat the activity.	- "(the activity is useful)… because the activity helps on discovering the campus". [StudentsQuest] **([7]; p. 13)** - "Because in a two-hour session we could learn where to locate everything in the campus" [StudentsQuest] **([7]; p. 13)** - Quantitative results from the [StudentsQuest] **([7]; Table 4)**

ing from the main research aim, which corresponds to what "we seek to understand": *Exploring the blended learning benefits of using smartphones combined with AR technologies and Learning Management Systems (LMS) for augmenting reality and formality of informal and non-formal settings.* The research aim is the umbrella for defining the two research questions that will guide the evaluation and cross-analysis of the cases: *(1) What are the learning benefits of using smartphones and AR Technologies to transform informal/non-formal settings into digitally augmented learning settings?; and (2) What are the learning benefits of using smartphones, AR Technologies combined with LMSs to augment formality of informal/non-formal settings?*

We organized the three blended learning activities under study according to the information they provide about the main research aim. Specifically, we structure the experiences into two case studies depending on: (1) the technology employed to augment the informal/non-formal setting; (2) the learning objectives of the activity; and (3) the informal/non-formal setting where the activity takes place. The two cases are: *CASE 1: Discovering the Campus* and *CASE 2: Discovering Barcelona*. As shown in Fig. 1, the case *Discovering the Campus* comprises the two learning activities *Discovering the Campus* 2009 and 2010. The objective of this case is to understand the learning benefits of using smartphones and tag-based technologies (RFID/NFC) with Moodle or .LRN and IMS LD and to augment reality and formality of the University Campus (a non-formal setting). The case Discovering Barcelona only comprises the activity *Discovering Barcelona*. In this case the objective is to understand the learning benefits of using smartphones and position-based applications (QuesTInSitu and MScape) with Moodle to augment the reality and (learning) formality of the city of Barcelona (an informal setting). The issues under study in each case (as formulated in Fig. 1) are the particularization of the research questions (of the multicase) for each specific case.

To answer the research questions of the multicase, we analysed the data of the different cases from the perspective of the issues. The data were collected using mixed methods combining quantitative and qualitative data gathering techniques [46][21]. The quantitative data are useful for showing trends, while the qualitative provide an in-depth understanding of the learning experience enacted [19]. The quantitative sources of information were closed questions in questionnaires for students and teachers as well as final course grades. The qualitative data were open questions and observations taken by researchers during the experiments. Combining these techniques allow taking into account the contextual issues of each case (characteristics of students and practitioners, achievement of the educational benefits…), particularly important when analysing technologically supported learning practices as authentic situations [26][46]. Then, for analytically contrasting all these data we triangulate qualitative and quantitative data (questionnaires, observations, logs…) to have several confirmations and perspectives of the general tendencies in the use of a technology [18].

5. THE CROSS-ANALYSIS

The first step to carry out a cross-analysis consists in analysing the data of Case 1 and Case 2 separately, guided by its issues, and extracting the findings for each case. In a second step, the findings of each case are organized according to the two research questions to which they provide answers. The findings of a case give the perspective of the research questions from a particular activity and context. Treating all findings together allows extracting contrasted results about the research questions based on evidences, which correspond to the data behind each finding.

TABLE 2

FINDINGS CASE DISCOVERING THE CAMPUS – ISSUE 2: WHAT ARE THE LEARNING BENEFITS OF USING SMARTPHONES, AR TAGGING-BASED TECHNOLOGIES (NFC) COMBINED WITH MOODLE LMS OR IMS LD AND .LRN TO INTEGRATE ACTIVITIES ACROSS FORM., NON-FORM. AND INFOR. SETTINGS?

Findings of separated cases	Partial Results	Selected support data
FCamp3: The data captured by smartphones and tag-based AR technologies provides good mechanisms to integrate exploratory-type of activities taking place in informal settings with activities taking place in formal settings to support learning about the campus and to foster collaboration **(Campus 09)**.	- Log files capturing the interactions of the students with the NFC/RFID tags in combination of online questionnaires are a good technological support for defining expert groups to foster potentially fruitful collaboration. - Log files for storing the actions of the students during the exploratory experience are a good support for the integration of activities taking place in formal and informal settings. - The combination of explorative activities with reflective tasks such as the individual questionnaires reinforces learning.	- The average score of the students who completed the activity with the mobile phones was of 8.4/10 compared to 7.5/10 of those who did not (only consulting the website or/and walking around without using the smartphones/AR-tags) **([30]; p. 186, Fig. 8)** - "The activity is interactive while the questionnaires can be answered only with the website of the university. In this last case you lose the information of the physical situation of the buildings" [Quest-Reflection-Phase3]**([30]; p. 184)** - ''My group helped me because all the members were interested in the same area of the campus (…) " [Quest-Reflection-Phase3] **([30]; p. 187)** - "(…) the logistic was the more demanding issue managing groups (creating groups, informing students about the groups, orchestrating their tasks depending on the groups, managing and analysing their outcome in order to propose them the following tasks, managing their outcomes in order to facilitate the assessment of their learning ,etc.)" [Quest-teachers] **([30]; p. 187)**
FCamp4: Teachers and students consider that integrating activities taking place in formal and non-formal settings enriches the whole experience because of the convergence of media **(Campus 10)**.	- Teachers consider that mixing activities in formal and informal settings enriches the experience because of the "convergence" of different media (Campus 10). - Students consider that mixing activity types is a way to enrich the experience because: (1) it settles down knowledge about the campus and they learn more, (2) have a more varied experience and (3) explore different technological environments.	- "The integration serves to enrich the experience, because most of the students seemed quite motivated to do tasks that are, fundamentally, inane (…)" [TeachersQuest] **([7]; p. 13)** - "Each focusses on a different learning mode to settle down the knowledge acquired." [StudentsQuest] **(Raw data in [7])** - "I feel that an experience such as this allows the students to "converge" different media that they utilize on a daily basis to learn about a place they will visit on a daily basis, allowing them to connect with it in a way that they are comfortable and familiar with.[TeachersQuest] **(Raw data in [7])** - Other results in **[7]; p. 12; Table 7.**
FCamp5: The combination of tools for supporting the enactment of the activity is perceived as an integrated system for both teachers and students that flexibly support and facilitate group formation tasks **(Campus 10)**.	- Teachers perceive that all the activities are well integrated and that the breaks between activities are natural and normal in teaching-learning situations. (Integration). - Teachers do not perceive the system as a set of interconnected tools but as a unique and integrated system. - Although teachers are not used to use spreadsheets for managing groups of students they are familiar with the use of Google Spreadsheets and find it useful and appropriate for hiding the complexity of IMS LD. (Group formation). - Students perceive the whole experience as a set of interrelated and complementary activities.	- "All the activities are inter-related" [Interview] - " I thought that the auto-making of groups is extremely helpful" [Teachers Quest supporting finding 1.II in Table3] **([7]; p. 19; Table 7)** - " There were not a lot of students in the session, therefore we needed to manipulate the groups a bit to be able to have a balance" [Teachers Quest supporting finding 1.II in Table 3] **([7]; p. 19; Table 7)** - "I thought that the auto-making of groups is extremely helpful (…)." [TeachersQuest] **(Raw data in [7])** - Results in **[7]; p. 10; Table 3**.
FCamp6: The technological system implemented supported teachers in following the activity and in the group formation tasks **(Campus 10)**.	- Teachers understood the group formation mechanism integrated into the whole learning process and found it helpful and appropriate to organize the students groups. - Observations and the interview with one teacher indicate that teachers knew what to do and how to follow the activity.	- "I clearly saw the membership of the students in their building-teams (…)" [Interview] **([7]; p. 12)** - "Having the logs and questionnaire responses automatically and instantly in Google spreadsheets is very useful, allowing me to understand the progress of students and know when to complete each activity. I also believe that t having to explicitly say, when to finish the activity using the LMS makes us more aware of the sequence / orchestration of activities." [TeacherQuest] **(Raw data in [7])**

5.1 Findings of the separated cases in the multicase

Tables 1, 2, 3 and 4 show the findings of the two cases for each issue under analysis. Tables 1 and 2 correspond to the findings of the *Case 1: Discovering the Campus* and Tables 3 and 4 to those related with the *Case 2: Discovering Barcelona*. While Table 1 and Table 3 show the findings around the issues related to augmenting reality of informal/non-formal settings (particularization of Research Question 1 for the technologies applied in each case), Table 2 and 4 focus on the findings derived from the issues on augmenting the formality of informal/non-formal settings via its integration with activities in formal settings (particularization of Research Question 2 for each of the cases). The information in these tables is organized as follows.

The first column shows the findings of the case for the issue indicated in the caption of the Table. Each finding is identified with a code written in bold that indicates the number of the finding and the case to which it belongs: FCampX for findings related with Discovering the campus and FBCNX for those related with Discovering Barcelona (where X is the number of finding). We use these codes in the remainder of the paper to refer to the findings. The second column shows the partial results that support each of the findings, which were extracted from the analysis of the row data of each experiment according to the issues in the multicase (see Fig. 1). The third column refers to support data selected for exemplifying the type of information that supports the partial results. Each selected support data points to specific sections/pages of previous publications where additional data are included. The on-line supplementary material of this paper (see Sup. Mat.[1]) provides the comprehensive list of partial results and data sets of the three blended learning activities analysed in the multicase.

5.2 Results of the cross-analysis

Table 5 shows the results of the cross-analysis and indicates the findings from the two cases that support them. The findings are referred in the table using the

[1] http://193.145.50.210:8080/TLT/TLT-ComplementaryData/Index.html

TABLE 3

FINDINGS CASE DISCOVERING BARCELONA ISSUE 1: WHAT ARE THE LEARNING BENEFITS OF USING GPS ENABLED SMARTPHONES AND AR TECHNOLOGIES TO DIGITALLY AUGMENT THE CITY?

Findings	Partial Results	Selected support data
FBCN 1: The experience: (1) promotes students' autonomy and active learning; (2) support learning about more districts than in previous experiences; (3) promotes students' practice of their technological skills; and (4) helps students to pay more attention to their environment and learning easily about the activity contents, spatial locations, urban structure and urban elements.	-Teachers point out that including a technology-enhanced explorative activity: 1) reinforces students' autonomy, 2) allows students technological skills practice, 3) allows learning about more districts of the city and 4) allows students practice their spatial orientation and help them in their understanding of the urban space and its elements. - Students value from the technology-enhanced exploratory activity: 1) their freedom and active participation during the activity, 2) the possibility of learning about how to use a GPS, 3) the dynamism of the activity, which makes it easier to learn and guaranties knowledge acquisition, 4) the facilities for learning and 5) the facility for retaining the details of the main contents. -Both, teacher and students agree with the idea that using mobile phones and the automatic assessment functionalities help students on focusing their attention on the task.	-33/34 (97%) of the students indicated after the whole experience that the activity helped them learn new concepts about the districts **([31], p. 458).** - "They could know more the areas of the city. Working with mobile devices allows arriving to additional learning objectives such as how to locate themselves in a city, explore or have a more personal observation of the environment" [Q-t-route] **(Result I.1 in Table 1 [31], p. 458).**
FBCN 2: Observations and comments by the students and the teachers show that the exploratory activity supported by mobile technology combined with the automatic flow of questions support students in the knowledge acquisition within the environment autonomously.	-Students highlight that the aspects that they liked the most are: to discover new districts and learning about their location, characteristics and history. Besides, observations taken during the route show how students were paying attention to the services and buildings in the area. -Students highlight that using the GPS devices with an automatic assessment questioning mechanism allows them to be directly in contact with the environment and, consequently, to learn more. Moreover, students prefer using the mobile phone instead of a dossier or making an exam because using these devices they can answer observing the environment directly and paying more attention to it. - Students' answers about what they learn during the experience regard to urbanism aspects, to the people living in the neighbourhood and to the infrastructures and services that make one area different to another -Students and teachers perceived using mobile devices as a good mechanism to move around the city autonomously and to learn about how to locate themselves on it. Moreover, teachers highlight that this type of experiences allows analyzing the buildings and other aspects directly.	-Working directly in contact with the environment enhanced students' interactions with people in the city helping them practice their communicative and social skills in situations they are not used to [Observations and result I.2 in Table 1] **([31]; p. 459).** - "What I preferred the most is the activity itself, the way you learn how to locate yourself in the city and the knowledge that I acquired" [Q-st-route]. **(Raw data in [31]).**
FBCN 3: GPS mobile devices complemented by a map and the feedback obtained after answering each question are perceived by the students as a good mechanism to guide them along their way in the route. Besides, the automatic assessment system and the feedback provided are also considered a good mechanism to structure the learning flow in an informal setting. In addition, teachers that highlight using the automatic assessment and feedback systems with mobile devices as an interesting mechanism that helps on structuring and monitoring the activity.	- The GPS enabled smartphones combined with the monitoring functionality included in the QuestInSitu application are, a good support for the teachers to control the evolution of the groups' activity. Observations show that teachers successfully followed the students' activity, their answers and discussed about student's actions. Teachers highlight this functionality as very intuitive and as one of the best features provided by the application. - Observations gathered during the exploration activity evidence that students from the different groups followed the feedback messages during the route. - Unless only half of the students that did not used the GPS during the exploratory experience answered that it had been useful, they experienced some difficulties finding some streets and comment that they would have found useful to use it during the experience.	-[Observations] indicate that teachers could successfully follow what the students were doing on runtime while discussing the answers given by the different groups. **([31]; p. 461).** - 33/34 (97%) students indicated that the feedback helped them to know how to continue in the activity and how was their overall progress. [Q-st-final] **([31]; p. 461).** The use of the GPS and maps complement the guidance provided by the feedback from tby QuesTInSitu [Q-st-route] **([31]; p. 461).**

same codes employed in Tables from 1 to 4 highlighted in bold.

First column in Table 5 shows the results regarding the research question 1 *What are the learning benefits of using smartphones and AR technologies to transform informal/non-formal settings into digitally augmented learning settings?* The results in this column evidence that NFC/GPS enabled smartphones and AR technologies are a good mechanism for digitally augmenting an informal/non-formal setting with educational purposes to support activities with learning benefits.

The first result **1.I indicates that combining NFC/GPS enabled smartphones with AR technologies such as NFC tags or QuesTInSitu for creating geo-positioned routes of questions supports situated learning**. Findings *FCamp1* and *FBCN1* show that the students learn better about a particular object, area or location *in situ*. Adding digital information over the reality facilitates students' ability to contextualize information from different sources (Internet, school books…) and focus on concrete aspects, obtaining a better understanding of the object/area under study. Finding *FCamp1* of the *Case 1: Discovering the Campus* especially supports this result. Partial results of this finding indicate that students voluntarily participating in the activity supported by smartphones and AR tags performed better compared with those who did not (doing the activity online or exploring the campus without technological support), demonstrating a more accurate and profound knowledge about the campus' services and resources in the related assessment task. Besides, partial results of *FBCN1* of the Case 1: *Discovering Barcelona* point out that using GPS enabled smartphones as the mediating artefact to answer questions about the city *in situ* help students focus their attention on the task and retain the contents and details of the areas under study.

The result **1.II indicates that although NFC/GPS enabled smartphones interactively guide the students along the space where the activity takes place, this guidance is not enough**. Partial results of finding *FBCN3* of the Case 2 *Discovering Barcelona* support this statement, indicating that other complementary elements are needed to support students' exploration. On the one hand, students feel comfortable with the guidance provided by the smartphones and the GPS-based technologies, although they also find it useful to complement the activity with a physical map. In addition, findings *FCamp2* and *FBCN1* indicate that, while smartphones allow students to move freely, the information facilitated through the NFC tags (about the different point in the campus) or GPS applications (showing the situation of the student all the time) provide the necessary guideline to locate themselves, supporting learners in the practice of orientation skills. Partial results of *FBCN1* indicates that using smartphones and AR GPS-based technologies promotes students' autonomy and active learning, while enabling students to practice their orientation and technological skills and to understand the urban space and their elements. In addition, partial results of *FCamp2* show that both teachers and students perceived the combination of Smartphones and AR NFC-based technologies as a helpful and useful approach for learning about how the campus space is organized, locating the different buildings and services.

On the other hand, teachers highlighted the importance of the feedback as a way to structure the activity. Feedback can be composed by hints (designed by the teachers) to guide students along the learning flow; and help them focus on the relevant aspects of the activity in situ (where they do not have the support of the teacher) (*FBCN3)*.

The second column in Table 5 shows the results regarding the research question *What are the learning benefits of using smartphones and AR technologies combined with LMSs to augment the formality of informal/non-formal settings?* The results related with this research question indicate that the use of NFC/GPS enabled smartphones and AR technologies combined with LMSs is a good mechanism to build up digital connecting layers across formal and informal/non-formal settings. These digital layers integrate the activities taking place in formal and informal/non-formal settings into a continuous and articulated learning flow. A learning flow in which settings of informal/non-formal nature augment their formality, since they support formal activities that generate outcomes which have a direct impact on follow-up in-class activities.

Finding **2.I** in Table 5 **indicates that these combinations of technologies support students to apply the contents learned in class to other contexts**. This is supported by the partial results of finding *FBCN4*, *FCamp3* and *FCamp4*. First, partial results of *FBCN4* show that in activities in which students have been physically in contact with the element under study, reflection is promoted by supporting with ICT the collection evidences to bring them back to the classroom. In the case "Discovering Barcelona", the outcomes from the visit were collected with QuesTInSitu question/answer system in combination with Moodle, to compile and share the main outcomes and discuss them in class. Teachers value the outdoor technology-supported activity because students reinforce concepts and ideas worked in class. Besides, finding *FCamp4* shows that a variety of technologies also facilitate the inclusion of a variety of media that enriches the students' learning experience. For the teachers participating in the 2009 edition of *Discovering the Campus*, using different technologies also means having contact with several technological environments and types of content. For the students, this variety enriches the learning experience, while helps them settle down the concepts learned in the different contexts.

However, and as indicated by partial results of *FCamp3*, using smartphones and AR technologies for interactively collecting information is not enough to have an articulated and integrated activity across settings. This integration requires technologies driving the connections along digital layers for capturing the interactions in one setting and to send them to the other. In the case of *Discovering the Campus* this was done capturing the students' intentionality during the campus exploratory activity into log files. Then, this information was sent with Moodle in the first edition and .LRN/ IMS LD for the second one, and the information was used to form groups for the next activities. These grouping policy fostered students' collaboration. Similar results have been observed in other studies such as Myartspace [48], in which evidences collected in a museum were the input for a further reflective activity in the classroom.

Finally, result **2.II indicates that complementing NFC/GPS smartphones with LMSs and Log files systems do not only scaffold students along the blended learning activity, but also support teachers in its orchestration across settings**. This is especially noticeable since it is supported by multiple partial results of findings *FCamp5, FCamp6* and *FBCN4*. *FCamp5* indicate that combining smartphones, AR NFC technologies and IMSLD/.LRN systems teachers and students perceived the activities taking place in the campus, home and the classroom as a continuous articulated learning flow that enriches the learning experience because of the variety of contents and technology-enhanced tasks.

Complementary to these results, partial results of finding *FCamp6* indicate that this combination of technologies proposed supported teachers in defining the

TABLE 4

FINDINGS CASE DISCOVERING BARCELONA ISSUE 2: WHAT ARE THE LEARNING BENEFITS OF USING GPS ENABLED SMARTPHONES, AR TECHNOLOGIES WITH MOODLE LMS TO INTEGRATE ACTIVITES ACROSS FORMAL, NON-FORMAL AND INFORMAL SETTINGS?

Findings	Partial Results	Selected support data
FBCN4: Combining exploratory activities with activities in the classroom promotes students' reflection and application of the concepts learnt. Teachers also consider this integration necessary to provide a complete evaluation of the activity.	- Students highlight that some of the aspects that they have learnt and have been useful for them in the exploratory activity is to apply the contents worked in the classroom. - Teacher stress that these types of activities complement the contents worked in class at a more concrete level that they can analyze directly. - Teachers see the exploratory activity and the presentation activity as complementary activities that, integrated into a wider learning process, allow providing a complete evaluation of the activity. - Observations from the presentations evidence that the students have been looking for information using other sources for complementing the ideas they gathered during the route or worked in class.	- "(Integrating activities across settings enable students to) … apply in a concrete way the contents explained in class" [Q-t-route] **([31], p. 460).** - "The score of the test would be a complementary mark for the evaluation" **([31], Supporting data of Finding I.5, Table 1).**

grouping policies taking into account the students' performances in the different settings. RFID/NFC and smartphones technologies were in the case *Discovering the Campus* the means for capturing students' interaction into log files and defining digital representations of their personal experience with the campus. These representations were the input for defining roles or profiles for further activities. Also, partial results of this finding point out that the teachers successfully followed students' activity across settings. It is noticeable that both *FCamp5* and *FCamp6* are findings related with the 2010 edition of *Discovering the Campus,* in which the learning flow was structured using an integrated set of technologies in which most of the orchestration processes along the learning flow were automatic. Besides, partial results of finding *FBCN4* points out that teachers highlight the importance of using a technological bridge connecting formal and informal settings for facilitating a more comprehensive evaluation of the activity that took place in the informal setting.

5.3 Other complementary findings

In addition to the results in Sec. 5.2, other relevant issues were detected during the cross analysis.

Data in both the cases of *Discovering the Campus* and of *Discovering Barcelona* indicate that students enjoyed and valued the initiative of incorporating technologies as a learning support. Students' comments highlight that they appreciated the interactive and mobility possibilities offered by the smartphones because they felt having the "control" and being the main actors of the activity. Moreover, students appreciate working in groups because this is something helpful and different compared with other similar activities. For instance, one student from the case *Discovering Barcelona* said: "*This activity is better and more fun compared to other activities (such as going to a museum). Moreover, this activity allows us to work in groups in a very fun way*" [Q-st-final] ([30] p. 460). Further, in both cases students' and teachers' comments describe the activity using adjectives such as "innovative", "dynamic", "interesting", "fun" and "enriching".

Data in the case *Discovering Barcelona* indicate that the teachers attribute partly the students' motivation as intrinsic to the use of ICT in school activities. In order to exclude the Hawthorne effect [29], we investigated other aspects as identified in Pintrich's framework [32]. Pintrich' framework identifies several aspects that should be taken into account when designing activities for increasing students' motivation: efficacy, control, interest, values and goals. According to Pintrich's principles, we identified the following aspects influencing motivation in the activities under study: (1) the variety of contents and technology-enhanced tasks (FCamp4 & FCamp5, FBCN4); (2) the value of the activity to learn about aspects worked in class and needed by the students (FCamp1, FCamp2, FBCN4); (3) the collaborative component of the activities (FCamp4); (4) the feeling of choice and control (FCamp5, FBCN3); and (5) the self-efficacy and competence components based on feedback and adaptation of the activities (FCamp5, FCamp6, FBCN3).

All these results indicate that, although both teachers and students are not used to these technology-based activities, they quickly adopted the technology as a support for learning, highlighting its benefits and advantages over other more traditional situations.

6 Lessons Learned

For a deeper understanding and discussion of the results, we study and compare the technological combination employed in each case and its implications. The comparison results on a list of lessons learned that offers the research community some insights about how to augment reality and formality of informal/non-formal settings for enhancing blended learning.

(1) Use tag-based technologies for digitally augmenting closed non-formal settings such as museums or informal open settings such as a city in which the objects/areas under study are close to each other to support situated and active learning [1.I in Table 5]. In most mobile devices, GPS technologies do not work and lose precision in short distances smaller than 2 meters. Besides, GPS cannot be used indoors. In these cases, tag-based technologies are the most appropriate solution. Several studies demonstrate the suitability of NFC Technologies for controlling the students going to the class in an educational centre [42], transforming the classroom into an interactive setting. These technologies can, for example, support scenarios in which the sound of the mobile phones is set off when students enter the class or in which promoting active learning is achieved when students

TABLE 5
RESULTS OF THE CROSS-ANALYSIS

Research Q1: ***What are the learning benefits of using NFC/GPS enabled smartphones and AR Technologies to transform informal/non-formal settings into digitally augmented learning settings?***	**Research Q2:** ***What are the learning benefits of using NFC/GPS enabled smartphones and AR Technologies combined with LMS to augment formality of informal/non-formal settings?***
1.I. NFC/GPS enabled Smartphones and AR technologies transform non-formal and informal settings into digitally augmented learning settings that support students in (1) learning about objects or areas of particular locations in context; and (2) focusing their attention on a concrete area or object **(FCamp1, FBCN1, FBCN2)** **1.II.** NFC/GPS enabled Smartphones and AR technologies complemented with maps and automatic feedback, structure and guide exploratory-type of activities in informal settings where students do not have teacher support. Students learn how to orientate in a location, are more autonomous doing their tasks and participate in the activity more actively **(FCamp2, FBCN1, FBCN3)**.	**2.I.** Combining the use of Smartphones with NFC/GPS AR technologies with computer-based tooling such as LMSs support students in connecting concepts learned in different contexts, promoting reflection about these concepts and facilitating a more complete evaluation by the teachers. In addition, this combination of technologies enriches students' learning experiences because of the variety of media to which they have access to during the activity. However, smartphones and AR technologies are not enough for connecting activities taking place in formal and informal settings. Log files and LMS such as Moodle or IMS-based .LRN are complementary tools for supporting this connection across settings. **(FCamp3, FCamp4, FBCN4)** **2.II.** LMSs and Log file systems are a good complement of NFC/GPS enabled smartphones and AR technologies because they support teachers' tasks around structuring, organizing and evaluating collaborative activities in blended learning experiences. In cases of complex blended learning activities, automatic mechanisms facilitate teachers' organizational tasks **(FCamp5, FCamp6, FBCN4)**

are asked to interact with a NFC-augmented blackboard for answering questions [34]. This is also the case of *Discovering the Campus*, in which the campus mixed closed areas (the library) and opened areas (campus courtyard) where the GPS connectivity and precision was very low.

(2) Capture students' interests and profiles in non-guided exploratory learning situations [2.I in Table 5]. Tag-based technologies require the active participation of the students to get the digital information superimposed to an augmented object. Registering students' deliberate interaction with an object is a mirror of their interests in such object or area. In a learning situation with a high amount of information available but a limited time, the interactions with the tags represent the students' preferences towards the particular environment. This is the strategy used in the case *Discovering the Campus* in which the aim was to capture the students' interests regarding particular campus areas and consider this information to shape the following activity (in this case as the parameter for the group formation policy). With GPS-based technologies it would be possible to have a similar effect if, when displaying content to the students at a concrete position, they could chose to read or not read such information. Then, the profile of the students would be defined according to those information points accessed.

(3) Use GPS-based technologies in guided exploratory learning situations in which students have to follow determined routes [1.II in Table 5]. GPS technologies allow positioning digital information into a particular geographical coordinate. Applications such as QuesTInSitu use this GPS functionality to trigger automatically contextual questions to the students when passing by a concrete location. In this case, receiving contextual information is not a voluntary action. Students will always receive the information and then choose if they want to read it or reject it. For this reason, these technologies are interesting for promoting serendipitous learning [47]. In addition, GPS-based technologies are useful when guiding the students along a particular route. In the *Discovering Barcelona* case, the GPS helped students advance in their exploration along the city.

(4) Combine tag-based and GPS-based applications with paper maps or appropriate feedback systems to structure and guide exploratory activities [1.II in Table 5]. Using paper maps provide students with an overview of the complete augmented learning setting. If using tag-based technological approaches the maps will help students to find the interactive information points. If using GPS-based applications, the maps will be especially useful in case of low GPS signal. Moreover, similar experiments combining both types of maps show that paper maps provide the students with a global view of the whole area to be explored, while digital maps are used to be focus in a particular sub-area [37].

Offering feedback to students in particular locations can support the guidance too, at the same time that the feedback allows highlighting important learning aspects of the activity. Moreover, providing feedback (clarifying the result of the question and indicating what the correct answer is) can serve as reward to the students, having positive effects in their motivation [32][35].

(5) Integration of technologies for augmenting formality [2.I., 2.II, 2.III in Table 5]. Creating augmented BL activities requires a seamless and articulated integration between the data generated in learning activities taking place in formal, non-formal and informal settings. As stated by Vavoula *et al* in [49] "A successful learning activity should be integrated with other learning events, building on them and contributing to their outcomes".

Currently, there are several educational tools specifically developed to drive blended learning activities data flows across settings. For example, the nQuire [28] toolkit for supporting inquiry based learning between settings such as home and the classroom, or Myartspace systems [48], which provides both Web and mobile applications to support inquiry learning between classrooms and museums. Both proposals provide a technological solution to send the data generated in one setting to influence a further activity taking place at another different setting. Usually, these technologies are *ad-hoc* monolithic solutions designed in collaboration with technologist and educational experts to support this data flow between settings for a particular learning purpose/scenario.

However, not all the educational institutions or teachers can afford these *ad hoc* developments. In these scenarios, educators should select from existing technologies for supporting BL across settings (e.g., mobile applications for informal settings, Learning Management Systems for formal settings) and integrate the data generated in each to articulate the learning flow. Selecting these technologies has to be driven by both the educational design of the activity and by the technologies available in their institutions (see [49] for a guideline on what to consider for selecting the appropriate technology in each activity). But, in BL activities that require integrating data generated in different settings, the selected technologies have also an implication on how the data flow across settings is produced [31].

There are BL situations across settings in which it is sufficiently satisfactory to combine the use of several existing technologies suitable for each setting to get an articulated data flow between activities. This is what happened in the case of *Discovering Barcelona*, in which the combination of *QuesTInSitu* and Moodle articulated the flow of the data generated in the city to the classroom. The data collected during the trip in the informal setting was the input for preparing the final presentations in the classroom. Both teachers and students were in charge of moving the data collected during the trip with QuesTInSitu (pictures and other evidences) to Moodle for sharing it with the rest of their colleagues. This process was done manually. Manual integration is an affordable and easy-to-adopt solution for augmenting formality for those institutions that do not have resources to develop a tooling *ad hoc.* Many educational institutions already use LMSs that practitioners could combine with other technologies such as Layar to articulate the data flows between formal, non-formal and informal settings, augmenting their formality.

However, this type of integration entails some limitations. First, technologies available for the teachers have a limited set of functionalities that may not match with the teachers' interest and needs, forcing practitioners to re-define their activity according to what the tool offers. Second, manually recovering the data generated in one setting to use it in another setting requires a control from the teacher side, which can be unfeasible in complex activity designs or in situations with massive number of students. In these situations, this type of integration can be very inefficient, hindering the adoption of these BL activities as daily school practices.

This is what happened in the 2009 edition of *Discovering the Campus*. In this edition of the activity, teachers manually processed the log files of the students' interaction with the Campus to organize them in groups. Teachers used Moodle to create the different groups and assign them their corresponding tasks according to their profile. But adapting the group formation, supporting transitions between activities and artefacts across locations using diverse technologies, displaying the appropriate tools to students depending on their group, or assigning the correct task to each group was very demanding and complex, entailing lot of difficulties for the practitioners.

To alleviate this complexity we proposed for the 2010 edition an integration of technologies based on the use of a learning technology specification for automatizing these tasks. Concretely, we proposed using a Unit of Learning (UoL) codified in an extended IMS LD and running in the .LRN LMS to structure the learning flow. In this case, the .LRN LMS and a complementary system compliant with the IMS LD specification [7][8] were in charge of interpreting the conditions computationally represented in the learning flow to automatically generate the groups of students according to the information collected in the log files and to automatically show to each group its corresponding activity. The result was an articulated blended learning flow that teachers could easily orchestrate and monitor, having an overview of how the data generated in one setting flowed to the other setting.

Therefore, although in both 2009 and 2010 editions the activity was the same, the results of the cross-analysis shows that using computational representations of the learning flow facilitated the integration of data generated across settings, making the activity more feasible and easy-to-adopt by the teachers. Moreover, using automatic systems for transferring data from one setting to the other alleviates some orchestration tasks, facilitating the adoption of these BL activities in real educational contexts.

7 Conclusions and Future Work

This paper shows that smartphones combined with the right AR technologies and educational tooling such as LMSs enable augmenting informal/non-formal settings for increasing the natural continuity between learning across settings. The contribution of the paper provides insights both about the design (technological perspective) and application (educational perspective) of AR technologies in informal/non-formal settings with formal learning purposes.

A cross-analysis of three authentic blended learning activities organized in a multicase study involving two cases, *Discovering the Campus* and *Discovering Barcelona* illustrates this idea. Each case proposes a combination of technologies that result in an integration of formal with informal/non-formal settings that allows transferring the data from one to the other enhancing BL activities. First, using NFC/GPS enabled smartphones and AR technologies to augment an informal/non-formal setting is a good mechanism to support learning in context, transform traditional trip field activities into interactive and structured activities and foster students and teachers' motivation and interest in technology. Second, when combining these technologies with LMSs and log files or other *ad hoc* software for capturing students' interaction within the informal setting foster students' reflection, enrich experiences combining different media and help teachers orchestrate the activity. The findings supporting these results evidence that using technology in blended learning activities facilitates the data flow between formal, non-formal and informal settings, producing a stronger connection between activities taking place in these settings and leading to an augment of formality. Finally, these results are sketched as a set of lessons learned about the possibilities of these technologies in two different activities/contexts.

The results and the lessons learned in this work do not only point out the encouraging possibilities of specific combinations of technologies, but they also identify directions for advancing the technology and design of activities for informal and non-formal settings to enhance blended learning. Within these directions, we identified several research avenues that could be pursued in future work.

From a technological perspective, one of these directions is the development of tools or services incorporating the elements that have shown benefits to enhance BL activities across formal and informal settings. For example, giving feedback to guide the activity, providing monitoring or learning analytics features to see how students' progress in the activity or to automate concrete workflow aspects related with task distribution among students and across settings. In this line, it would be interesting to explore the learning benefits of combining feedback functionalities with gamification techniques, from two perspectives, as a way of fostering their interest in the activity and as a means supporting students in advancing along the activity flow.

From a more pedagogical perspective, another line for future work would be to develop authoring features providing BL gamified activity patterns, such as the augmented treasure hunts type games or guided trips identified in the literature. This functionality would support practitioners in the design and deployment of BL activities based on GPS technologies or tag-based technologies, promoting their adoption in real scenarios. Tools such as the "QR Treasure Hunt Generator"[2], which provides an automatic solution for generating treasure hunting activities based on QR codes with multiple choice questions, is a first approach towards this line.

Finally, derived from the complementary findings obtained from the cross-analysis, it would also be of interest

[2] http://www.classtools.net/QR/

to explore, experiment and evaluate how to incorporate in these activity patterns factors that can potentially enhance students' motivation, such as those defined by Pintrich [32] or other related motivational models or tools such as the IMI and EMI models used in the work by Buckworth *et al* [4].

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REFERENCES

[1] M. Ally (Ed.), "Mobile learning: Transforming the delivery of education and training," Athabasca University Press, 2009.

[2] D. Benyon, O. Mival and S. Ayan, "Designing blended spaces," *Proceedings of the 26th Annual BCS Interaction Specialist Group*, pp. 398-403, 2012.

[3] J. S. Brown, A. Collins and P. Duguid, "Situated Cognition and the Culture of Learning," *Education Researcher*, vol. 18, no. 1, pp. 32-42, 1989.

[4] J. Buckworth, R. E. Lee, R. Gail, L. K. Schneider, C. C. DiClemente, "Decomposing intrinsic and extrinsic motivation for exercise: Application to stages of motivational readiness", *Psychology of Sport and Exercise,* vol. 8, no. 4, pp. 441-461.

[5] P. Cairns and A. L. Cox, *Research methods for human-computer interaction*. NY: Cambridge University Press New York, 2008.

[6] J. Cook, N. Pachler and C. Bradley, "Bridging the gap? Mobile phones at the interface between informal and formal learning," *Journal of the Research Center for Educational Technology*, vol. 4, no. 1, pp. 3-18, 2009.

[7] L. de-la-Fuente-Valentín, M. Pérez-Sanagustín, P. Santos, D. Hernández-Leo, A. Pardo, C. Delgado Kloos and J. Blat, "Technological support for the enactment of collaborative scripted learning activities across multiple spatial locations," *Future Generation Computer Systems,* vol. 31, pp. 223-237, 2014.

[8] L. de-la-Fuente-Valentín, A. Pardo and C. Delgado Kloos, "Generic service integration in adaptive learning experiences using IMS learning design," *Computers & Education*, vol. 57, no. 1, pp. 1160-1170, 2011.

[9] P. Dillenbourg, "What do you mean by collaborative learning?," *Collaborative-learning: Cognitive and Computational Approaches*, P. Dillenbourg, ed., Oxford: Elsevier, pp.1-19, 1999.

[10] S. M. Dobyns, M. S. Dobyns, M. S. and E. E. Connell, "EDUCACHING: Capturing the spirit of the hunt for learning," *D. C.: National Association for Gifted Children*, http://www.nagc.org/index.aspx?id=1844, 2013.

[11] M. Dunleavy, C. Dede and R. Mitchell, "Affordances and Limitations of Inmersive Participatory Augmented Reality Simulations for Teaching and Learning," *J Sci Educ Technol*, vol. 18, pp. 7-22, 2009.

[12] M. M. El-Bishouty, H. Ogata and Y. Yano, "PERKAM: personalized knowledge awareness map for computer supported ubiquitous learning," *Educational Technology & Society*, vol. 10, no. 3, pp. 122-134, 2007.

[13] N.A.M. El Sayed, H.H. Zayed and M.I. Sharawy, "ARSC: Augmented reality student card," *Computers and Education*, vol. 56, no. 4, pp.1045-1061, 2011.

[14] S. Feiner, B. Macintyre and D. Seligmann, "Knowledge-based augmented reality," *Communications of the ACM*, vol. 36, no. 7, pp. 53-62, 1993.

[15] E. FitzGerald, A. Adams, R. Ferguson, M. Gaved, Y. Mor, T. Rhodri, "Augmented reality and mobile learning: the state of the art," *Proc. World Conference on Mobile and Contextual Learning*, pp. 62–69, Oct. 2012.

[16] D. Frohberg, C. Goth and G. Schwabe, "Mobile learning projects: a critical analysis of the state of the art," *Journal of Computer Assisted Learning*, vol. 25, no. 4, pp. 307-331, 2009.

[17] G. Ghiani, F. Paternò, C. Santoro and L.D. Spano, "UbiCicero: A location-aware, multi-device museum guide," *Interacting with Computers*, vol. 21, no. 4, pp. 288-303, 2009.

[18] E. G. Guba, "Criteria for assessing the trustworthiness of naturalistic inquiries," *Educational Technology Research and Development*, vol. 29, no. 2, pp. 75–91, 1981.

[19] E. G. Guba and Y. S. Lincoln, "Competing paradigms in qualitative research," *Handbook of qualitative research*, N. K. Denzin & Y. S. Lincoln, eds. , New Delhi: Sage Publications, Inc., pp. 163–194, 1994.

[20] D. Hernández-Leo, I. Jorrín-Abellán, E. D. Villasclaras-Fernández, J. I. Asensio-Pérez and Y. Dimitriadis, "A multicase study for the evaluation of a pattern-based visual design process for collaborative learning," *Journal of Visual Languages & Computing*, vol. 21, no. 6, pp. 313-331, 2010.

[21] R. B., Johnson, A. J. Onwuegbuzie and L. A. Turner, "Toward a definition of mixed methods research," *Journal of Mixed Methods Research*, vol. 1, no. 2, pp. 112–133, 2007.

[22] L. Johnson, R. Smith, H. Willis, A. Levine and K. Haywood, *The 2011 Horizon Report*. The New Media Consortium, Austin: Texas, 2011.

[23] A. Kurti, D. Spikol and M. Milrad, "Bridging outdoors and indoors educational activities in schools with the support of mobile and positioning technologies," *International Journal of Mobile Learning and Organisation*, vol. 2, no. 2, pp. 166-186, 2008.

[24] Y. Laouris and N. Eteokleous, N., "We need an educationally relevant definition of mobile learning," *Proceedings of mLearn*, vol. 2005, 2005.

[25] T.Y. Liu, T. H. Tan and Y. L. Chu, "2D barcode and augmented reality supported English learning system," *IEEE/ACIS International Conference on Computer and Information Science (ICIS '07)*, pp. 5-10, Jul. 2007.

[26] A. Martínez-Monés, Y. Dimitriadis, E. Gómez-Sánchez, B. Rubia-Avi, I. Jorrín-Abellán and J. A. Marcos, "Studying participation networks in collaboration using mixed methods," *International Journal of Computer-Supported Collaborative Learning*, vol. 1, no. 3, pp. 383–408, 2006.

[27] D. W. Mocker and G.E. Spear, "Lifelong Learning: Formal, Non-formal, Informal, and Self-directed," *The ERIC Publications Clearinghouse on Adult, Career, and Vocational Education*, no. 241, 1982.

[28] P. Mulholland, S. Anastopoulou, T. Collins, M. Feisst, M. Gaved, L. Kerawalla and M. Wright, "nQuire: technological support for personal inquiry learning," *IEEE Transactions Learning Technologies*, vol. 5, no. 2, pp. 157-169, 2012.

[29] R. Gillespie, "Manufacturing knowledge: a history of the Hawthorne experiments," Cambridge University Press, 1993.

[30] M. Pérez-Sanagustín, G. Ramírez-Gonzalez, D. Hernández-Leo, M. Muñoz-Organero, P. Santos, J. Blat, and C. Delgado Kloos, "Discovering the Campus Together: a mobile and computer-based learning experience," *Journal of Network and Computer Applications*, vol. 35, no. 1, pp. 176–188, 2011.

[31] M. Pérez-Sanagustín, P. Santos, D. Hernández-Leo and J. Blat, "4SPPIces: A case study of factors in a scripted collaborative-learning blended course across spatial locations," *International Journal of Computer Supported Collaborative Learning*, vol. 7, no. 3, pp. 443-465, 2012.

[32] P. R. Pintrich and E. V. De Groot, "Motivational and self-regulated learning components of classroom academic performance," *Journal of Educational Psychology*, vol. 82, no. 1, pp. 33-40, 1990.

[33] S. Price and Y. Rogers, "Let's get physical: the learning benefits of interacting in digitally augmented physical spaces," *Computers & Educa-*

tion, vol. 43, no. 1-2, pp. 137-151, 2004.

[34] G. Ramírez, M. Muñoz and C. Delgado Kloos, "Exploring NFC for supporting Mobility in Learning Scenarios," *Proc. IADIS International Conference on Mobile Learning (mLearn '08)*, pp.11-13, Apr. 2008.

[35] P. Santos, M. Balestrini, V. Righi, J. Blat and D. Hernández-Leo, "Not interested in ICT? A Case Study to Explore How a Meaningful m-Learning Activity Fosters Engagement among Older Users," *Proc. European Conference on Technology Enhanced Learning* (ECTEL '13), vol. 8095 pp. 328-342, 2013.

[36] P. Santos, M. Pérez-Sanagustín, D. Hernández-Leo and J. Blat, "QuesTInSitu: From tests to routes for assessment in situ activities," *Computers & Education*, vol. 57, no. 4, pp. 2517-2534, 2011.

[37] P. Santos, D. Hernández-Leo and J. Blat, "To be or not to be in situ outdoors, and other implications for design and implementation, in geolocated mobile learning", *Pervasive and Mobile Computing*, available online, 2014.

[38] J. R. Savery, "Overview of problem-based learning: Definitions and distinctions", *Interdisciplinary Journal of Problem-based Learning*, vol. 1, no. 1, pp. 9-20, 2006.

[39] J. Sefton-Green, "Literature Review in Informal Learning: with Technology Outside School," *Futurlab Series*, Report 7, pp. 1-39, 2004.

[40] M. Sharples, I. Arnedillo-Sanchez, M. Milrad, G. Vavoula and G. Balacheff, "MobileLearning: Small Devices, Big Issues," *Technology Enhanced Learning: Principles and Products*, Ludvigsen, N., Jong, S., Lazonder, T. and Barnes, S., eds., Springer: Netherlands, pp. 2-14, 2009.

[41] M. Sharples, J. Taylor and G. Vavoula, "A Theory of Learning for the Mobile Age. Learning through Conversation and Exploration Across Contexts," *Medienbildungin neuen Kulturräumen*, Bachmair, B., ed., Springer: Verlag, 2010.

[42] C. W. Shen, Y. C. J. Wu and T. C. Lee, "Developing a NFC-equipped smart classroom: Effects on attitudes toward computer science," *Computers in Human Behavior*, 2013. (Pending publication)

[43] D. Spikol and M. Milrad, "Combining physical activities and mobile games to promote novel learning practices," *IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, Beijing, China, pp. 31–38, Mar. 2008.

[44] R. Stake, *Multiple case study analysis*, The Guilford Press New York: NY, 2006.

[45] S. P. Stenton, R. Hull, P. M. Goddi, J. Reid, B. Clayton, T. Melamed, "Mediascapes: context-aware multimedia experiences," *IEEE Multimedia*, vol. 14, no. 3, pp. 98–105, 2007

[46] A. Tashakkori and C. Teddlie, *Handbook of mixed methods in social and behavioral research*. Thousand Oaks: Sage Publications, Inc., vol. 1, pp. 241–272, 2003.

[47] N. Vavoula and M. Sharples, "KLeOS: A personal, mobile, Knowledge and Learning Organization System," *Proc. IEEE International Workshop on Wireless and Mobile Technologies in Education*, pp. 152-156, Aug. 2002.

[48] N. Vavoula, M. Sharples, P. Rudman, J. Meek and P. Lonsdale, "Myartspace: Design and evaluation of support for learning with multimedia phones between classrooms and museums," *Computers & Education*, vol. 53, no. 4, pp. 286-299, 2009.

[49] G. Vavoula, M. Sharples, P. Rudman, P. Lonsdale and J. Meek, "Learning Bridges: a role for mobile technologies in education," *Educational Technology*, vol. 47, pp. 33-36, 2007.

[50] N. Winters, "What is mobile learning?," *Big issues in mobile learning: Report of a workshop by the Kaleidoscope Network of Excellence Mobile Learning Initiative*, M. Sharples, ed., University of Nottingham: UK, pp. 7-12, 2006.

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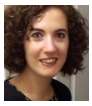

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