Design and implementation techniques for location-based learning games

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A mis padres y hermanos

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Abstract

Over the past few years the use of computer-supported games for learning purposes has reported many educational benefits in terms of students' motivation and engagement towards learning. However, the comprehensive integration of Game-Based Learning (GBL) environments in formal learning settings is still a challenge that shapes several interdisciplinary research problems in the domain of GBL. A main problem is that for games to be relevant in formal education they need to be aligned with the curriculum and adapted to teachers' requirements depending on their particular educational situations. An approach to face this problem is to formulate GBL technologies that enable teachers to design meaningful games for their scenarios. This thesis contributes to this approach in GBL.

In particular, the thesis focuses on location-based learning games. These games are relevant to create contextualized learning activities in which physical objects and spaces are virtually augmented with interactive digital objects. The thesis' standpoint is that for teachers to be involved in the definition of location-based games, their constituting design elements need to be of feasible customization by teachers while, at the same time, enable rich learning activities. From the premise that the structural design of location-based learning games is often inspired by board games, the thesis proposes a puzzle board metaphor and a template based on the metaphor as techniques for the design of location-based learning games. The thesis also contributes with a model for the computational representation of the games and a set of implementation guidelines. The design and implementation techniques are applied and evaluated in a set of case studies at different scales involving a total of 36 teachers and 253 students.

Resumen

A lo largo de los últimos años, el uso de juegos computacionales para el aprendizaje ha aportado diversos beneficios educativos relacionados, principalmente, con la motivación y el interés de los estudiantes hacia el aprendizaje. Sin embargo, la adopción de entornos de aprendizaje basados en juegos (también conocidos como *Game-Based Learning* ó *GBL* en inglés) en contextos educativos formales todavía es un reto que conlleva varios problemas de investigación interdisciplinares dentro del dominio del GBL. Uno de los problemas principales es que para que los juegos sean relevantes en la educación formal, tienen que estar alineados con el curriculum y adaptados a los requisitos de los profesores dependiendo de sus situaciones educativas particulares. Una solución para afrontar este problema consiste en el desarrollo de tecnologías basadas en el GBL que permitan a los profesores diseñar juegos significativos para sus escenarios. Esta tesis contribuye a este enfoque en el GBL.

En particular, esta tesis se centra en los juegos de aprendizaje ubicuos. Estos juegos son relevantes porque permiten crear actividades de aprendizaje contextualizadas en las que objetos y espacios físicos son virtualmente aumentados con objetos digitales interactivos. El punto de partida de esta tesis considera que, para que los profesores se involucren en el diseño de juegos de aprendizaje ubicuos, los elementos de diseño que componen este tipo de juegos tienen que poder ser personalizados por los profesores mientras que, al mismo tiempo, deben permitir la creación de actividades de aprendizaje enriquecidas. Considerando la premisa de que el diseño estructural de juegos de aprendizaje ubicuos a menudo está inspirado en “juegos de tablero”, esta tesis propone una metáfora de “tablero de puzzles” junto con un conjunto de plantillas basadas en dicha metáfora como técnicas para el diseño de juegos de aprendizaje ubicuos. Esta tesis, además, contribuye con un modelo para la representación computacional de estos juegos y una serie de guías de implementación. Tanto las técnicas de diseño como las de implementación se han utilizado y evaluado en un conjunto de estudios de caso a diferentes escalas en los que han participado un total de 35 profesores y 253 estudiantes.

Resum

Al llarg dels últims anys, l'ús de jocs computacionals per a l'aprenentatge ha aportat diversos beneficis educatius relacionats, principalment, amb la motivació i l'interès dels estudiants cap a l'aprenentatge. No obstant això, la adopció d'entorns d'aprenentatge basats en jocs (també coneguts com *Game-Based Learning* o *GBL* en anglès) en contextos educatius formals encara és un repte que comporta diversos problemes de recerca interdisciplinaris dins del domini del GBL. Un dels problemes principals és que perquè els jocs siguin rellevants en l'educació formal, han d'estar alineats amb el currículum i adaptats als requisits dels professors depenent de les seves situacions educatives particulars. Una solució per afrontar aquest problema consisteix en el desenvolupament de tecnologies basades en el GBL que permetin als professors dissenyar jocs significatius per als seus escenaris. Aquesta tesi contribueix a aquest enfocament en el GBL.

En particular, aquesta tesi se centra en els jocs d'aprenentatge ubics. Aquests jocs són rellevants perquè permeten crear activitats d'aprenentatges contextualitzades en les quals objectes i espais físics són virtualment augmentats amb objectes digitals interactius. El punt de partida d'aquesta tesi considera que, perquè els professors s'involucrin en el disseny de jocs d'aprenentatge ubics, els elements de disseny que componen aquest tipus de jocs han de poder ser personalitzats pels professors mentre que, al mateix temps, permetre la creació d'activitats d'aprenentatge enriquides. Considerant la premissa que el disseny estructural de jocs d'aprenentatge ubics sovint està inspirat en "jocs de tauler", aquesta tesi proposa una metàfora de "tauler de puzles" juntament amb un conjunt de plantilles basades en aquesta metàfora com a tècniques per al disseny de jocs d'aprenentatge ubics. Aquesta tesi, a més, contribueix amb un model per a la representació computacional d'aquests jocs i una sèrie de guies d'implementació. Tant les tècniques de disseny com les d'implementació s'han utilitzat i avaluat en un conjunt d'estudis de cas a diverses escales en els quals han participat un total de 35 professors i 253 estudiants.

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CHAPTER 1
INTRODUCTION

This chapter describes the research context and main problems in Game-based Learning, particularly in designing location-based learning games. Besides, the chapter formulates the research objectives, the obtained contributions, and the applied methodology. Finally, the chapter ends with an outline of the remainder of the dissertation.

1.1 Introduction

Playing games as a means of facilitating learning is not new in education. Some research efforts have been done to classify the diverse variety of games in specific taxonomies (Adams & Rollings, 2007; Gros, 2007; Prensky, 2001; Whitton, 2010). Mainly, the following types of games are identified: adventure, platform, puzzle, role-play, shooters, sports, strategy, vehicles-simulations, and construction-and-management simulations. Besides, within Technology Enhanced Learning (TEL) (Goodyear & Retalis, 2010), researchers argue that educational games are a powerful medium that should be used for worthy learning outcomes (Prensky, 2001). Computer-supported educational games are essential to address the learning requirements of the modern 'digital' generation of students who are different from previous generations since they are growing up immersed in digital technology (Prensky, 2001). Building on this foundation, this dissertation is framed in the domain of Game-based Learning, which is focused on supporting learning methods that better correspond with current students' requirements and habits and, as a consequence, engage students in the learning process (Lee & Chen, 2009).

One of the primary advantages and uses of games with educational purposes is that they can provide intrinsically motivating learning environments (Sedig, 2008). According to Ke (2008), frequently-cited arguments held by researchers indicate that computer games can engage learners in meaningful and enjoyable learning, encourage active learning, can be effective tools for enhancing learning and understanding of complex subject matter, and can promote collaboration among learners. Also, games can be conceived as potential approaches that can engage students in the subject topics, while at the same time foster students' problem solving, analytical and memory skills (Bottino, Ott, & Tavella, 2008; Huang, Cheng, & Chan, 2007). Besides, educational computer games can become powerful learning environments since they have many attributes that are associated with how people learn (Oblinger, 2004). More specifically, these attributes are: considering prior learning to advance forward, promoting exploration of information, providing feedback and assessment to progress along the learning activities, allowing experiential scenarios to test hypotheses, and being contextualized in social environments.

However, despite the potential benefits of educational computer games, one concern associated to this research domain is that teachers do not broadly adopt game-based learning environments in formal learning settings (Williamson, 2009). The main reasons behind the low adoption include that the available games do not often fulfil the requirements of particular educational situations, and that teachers do not have advanced technological skills to create or adapt games in formal educational contexts (Frossard, 2013; Tornero, J., Moreno-Ger, & Fernández-Manjón, 2010; Yang, 2005). Diverse research efforts are being devoted to provide easy-to-use game editors, such as <e-Adventure> (Torrente, del Blanco, Marchiori, Moreno-Ger, & Fernández-Manjón, 2010), Alice (Conway, Audia, Burnette, Cosgrove, & Christiansen, 2000), Squeak (Ingalls, Kaehler, Maloney, Wallace, & Kay, 1997), and GameMaker (Overmars, 2004). These authoring tools have been mainly developed to allow teachers to design educational games. Unfortunately, these tools can be still too complex for some instructors, hard to adapt to individual courses, require too many resources and too much time for development (Frossard, 2013; Tornero et al., 2010; Yang, 2005). Consequently, this dissertation aims to contribute to facilitate teachers' design and implementation of educational games.

Considering the diverse variety of educational games, we focus on puzzle board games as an approach to facilitate teachers the design and implementation of game-based learning environments. The nature of puzzle board games seems relevant to consider as educational strategy to feasibly involve teachers as game designers

(Crawford, 1982; Huang et al., 2007). Furthermore, puzzle board games can cover a wide range of implementations. In this regard, most of the computer educational games are completely digital, allowing students to interact with virtual representations of concepts that are difficult to access in the real world. Different types of digital games can be distinguished (Ulicksak & Williamson, 2011): electronic games, video games, computer games, online games, and mobile games. However, not only digital games but also new types of games considering pervasive computing and physical objects (with tangible interfaces or embedding sensing technologies) have emerged to address specific educational needs (e.g., manipulation of physical objects vs. symbolic representations, physical interaction for particular therapies, etc.) (Li, Fontijn, & Markopoulos, 2008). Focusing on puzzle board games, existing research has already been done in terms of implementing completely digital (Battocchi et al., 2010) or physical (Bohn, 2004) puzzle board games, and a combination of both virtual and physical objects (Lee & Chen, 2009; Scarlatos, 2002). Moreover, board games have also been considered for implementing pervasive games (Björk, Falk, Hansson, & Ljungstrand, 2001; Magerkurth, Cheok, Mandryk, & Nilsen, 2005; Nicklas, Pfisterer, & Mitschang, 2001; Schlieder, Kiefer, & Matyas, 2006).

Considering the different types of implementations, we particularly focus our research on pervasive mobile learning environments. There is a special interest in pervasive mobile learning environments because of their potential educational benefits that relate to the possibility of creating contextualized learning activities that take place in physical spaces (Jeng, Wu, Huang, Tan, & Yang, 2010; Vinu, Sherimon, & Krishnan, 2011). In the context of game-based learning, location-based games are those approaches based on pervasive mobile learning that support contextualized learning (Avouris & Yiannoutsou, 2012). Then, location-based games bring possibilities to enrich learning experiences by extending the learning beyond traditional classrooms and interacting with physical items by adding virtual layers of information. Research studies have identified design considerations when mapping board games as location-based games (Nicklas et al., 2001; Schlieder et al., 2006). Nevertheless, there is a gap regarding the involvement of teachers when designing location-based learning games that consider board games elements. Therefore, this dissertation further analyses the use of puzzle board games as an approach to model and implement fruitful pervasive m-learning activities, and to facilitate teachers the design of these types of approaches.

Focus of the Dissertation

This PhD thesis proposes and evaluates techniques considering the use of puzzle board games elements for the design and implementation of location-based learning games.

1.2 Objectives

According to the issues identified in this dissertation, and presented in the previous section, the global objective of this dissertation is:

MAIN OBJECTIVE: To support the design and implementation of location-based learning games by considering computer-supported puzzle board games elements including virtual and physical objects.

The context, both main and partial objectives, the expected contributions, as well as the evaluation carried out in this dissertation are depicted in Figure 1. Furthermore, this global objective is stated as three partial objectives.

OBJECTIVE 1: To model and computationally represent computer-supported puzzle board games including virtual and physical objects.

To face this objective, first of all, it is necessary to carry out a review of the existing literature. The review aims to understand the current situation in game-based learning domain, identifying the most relevant elements when designing educational games. In particular, considering the context stated in the Introduction, we focus on puzzle board games as a strategy to be applied for designing and implementing location-based learning games. Part of this literature review is compiled in the following conference and journal papers (Melero, Hernández-Leo, & Blat, 2011a, 2012a).

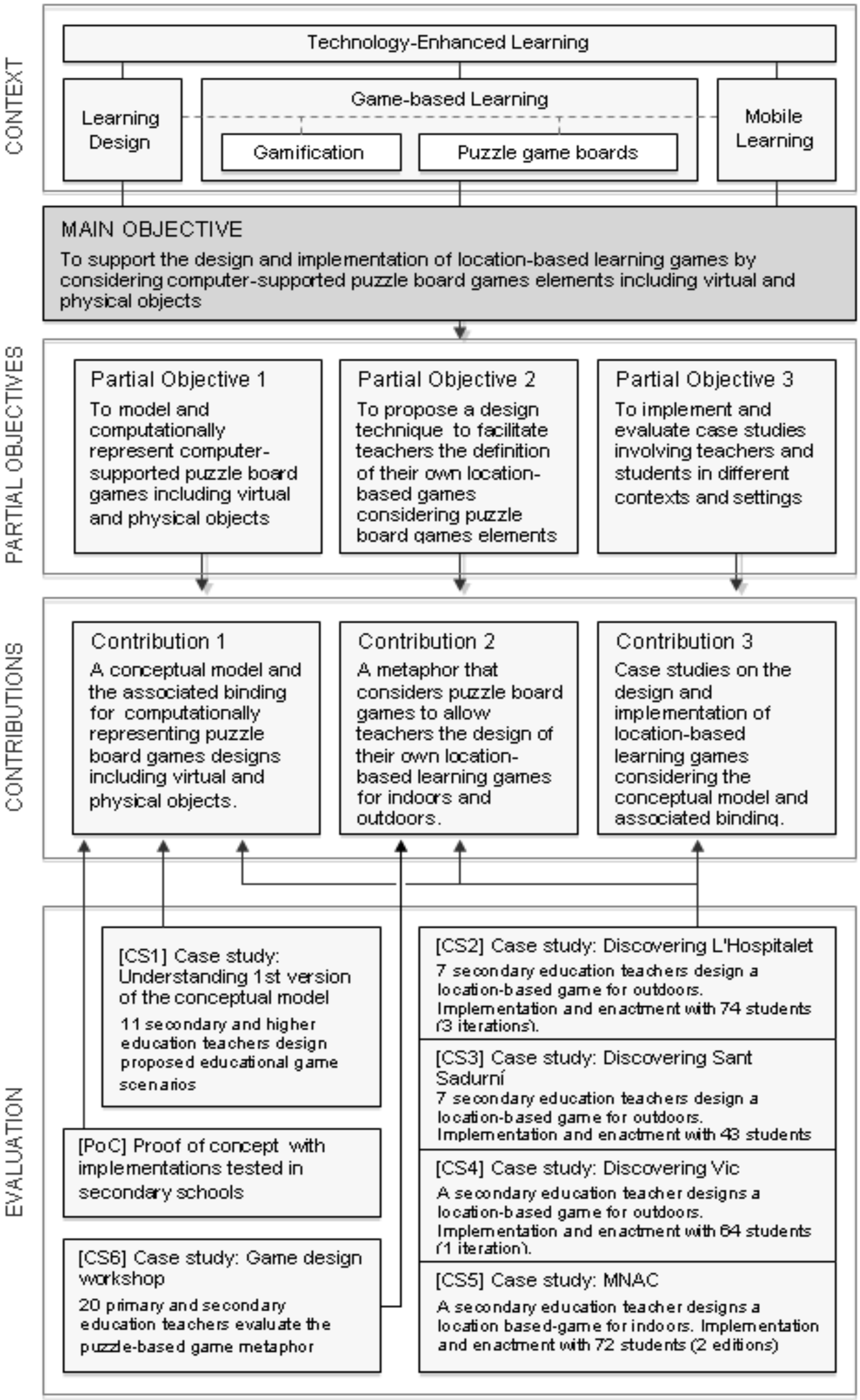

Figure 1. General schema of the research context, main objectives, contributions and evaluation

Building on the identified design elements in the literature review, one of our objectives is to contribute with the proposal of a conceptual model for facilitating the design and implementation of computer-supported puzzle board games including virtual and physical objects. Besides, we aim to show the expressiveness of the model with several cases to illustrate that the model covers a wide range of significant puzzle board games. Also, we aim to evaluate the understanding of the conceptual model with teachers (see [CS1] in Figure 1). This contribution is reflected in (Melero & Hernández-Leo, in press).

In parallel to the definition of the conceptual model, we propose the associated XML binding for the computational representation of puzzle board game designs (Melero & Hernández-Leo, in press). The deployment of this XML binding resulted in the creation and evaluation of several prototypes [PoC] and "QuesTInSitu: The Game", a mobile application to support the creation of gamified routes of location-based learning activities designed by teachers [CS2; CS3; CS4; CS5]. These results are published in (Melero, Santos, Hernández-Leo, & Blat, 2013; Melero, Hernández-Leo, & Blat, submitted).

OBJECTIVE 2: To propose a design technique to facilitate teachers the definition of their own location-based games considering puzzle board games elements.

As mentioned in section 1.1, among the different types of implementations, we focus on educational games based on pervasive computing. This leads us to work around location-based learning games. More specifically, we consider research studies focused on defining the main considerations to map traditional board games in location-based games. Also, we take benefit of previous expertise in location-based m-learning field acquired in the Interactive Technologies Group (GTI), particularly, in the work carried out by (Santos, 2011).

In this second objective, we claim that involving teachers in the design of their own learning games is necessary in order to create fruitful game-based learning environments that fulfil teachers' requirements for their particular learning situations. For this reason, this dissertation is also particularly focused on proposing a technique to design location-based learning games. In particular, we propose a metaphor, based on elements of puzzle board games, that simplifies the complexity of the proposed conceptual model (Melero & Hernández-Leo, in press). Then, we analyse the feasibility of involving teachers in their own designs by using the proposed metaphor in different learning contexts [CS2; CS3; CS4; CS5; CS6]. The contributions related to this objective are compiled in different conference and journal papers (Melero et al., 2013; Melero, Sun, Hernández-Leo, Santos, & Blat, conditionally accepted).

OBJECTIVE 3: To implement and evaluate case studies involving teachers and students in different contexts and settings.

The final aim of designing location-based learning games is to implement them in order to analyse whether students engage in the proposed designs. Then, we aim to evaluate not only teachers' designs but also the implementations using "QuesTInSitu: The Game" in real pervasive m-learning scenarios. "QuesTInSitu: The Game" has been evaluated in the different contexts involving 4 high schools and a total of 253 secondary education students. Besides, the implementations consider outdoor [CS2; CS3; CS4] and indoor [CS5] settings.

This partial objective is also complemented with two particular cases. The first case is focused on the importance of teachers' inquiry in their own designs in order to identify the elements that should be revised and improved. As a contribution to this objective we engage teachers from one of the cases studies [CS2] to inquire into their design (Melero, Sun, et al., conditionally accepted). Specifically, we study the use of visualizations to support students' self-assessment and teachers' inquiry of the designed location-based game. The visualizations were discussed with the teachers as a learning analytics approach to consider when redesigning, if needed, the learning activity. Besides, the study shows that the visualizations led students to make a better diagnose of their own activity performance. The second case [CS5] analyses not only the overall enactment of teacher's design for a location-based game for indoors, but also students' performance when using the proposed approach of puzzle board games (Melero, Hernández-Leo, et al., submitted).

1.3 Research methodology

The research of this dissertation is framed in a multidisciplinary problem domain that requires tackling issues belonging to the (computer-supported) location-based games and learning design domains. We aim to contribute to the Technology-Enhanced Learning field by proposing a new educational approach to design and implement location-based learning activities. Since the nature of this research involves different participants in a continuous design, development and evaluative process, it was decided to ground the methodology for this project in the theoretical framework of Design-Based Research (Brown, 1992). In fact, in Design-Based Research there is continual interaction between practitioners and researchers throughout the entire research process (Cotton, Lockyer, & Brickell, 2009). Besides, Design-Based Research focuses on solving broad based, complex, real world problems that are critical to education, while at the same time maintaining a commitment to theory construction and explanation (Reeves, Herrington, & Oliver, 2005). Overall, this research methodology involves a continuous cycle of design, enactment, analysis, and redesign. The cycle of the design-based research methodology involves revisions to test and refine a proposed innovative learning approach. This iterative process permits not only to validate the findings of the analysis phase, but also to reflect on how these findings alter the outcomes of the other phases (Barab & Squire, 2004; DBRC, 2003). Particularly, the four distinct Design-Based Research phases proposed in (Reeves, 2000) provided the basis for the research approach used in this dissertation as they encapsulate the planning, designing, developing, testing and refining nature of the project (see Figure 2).

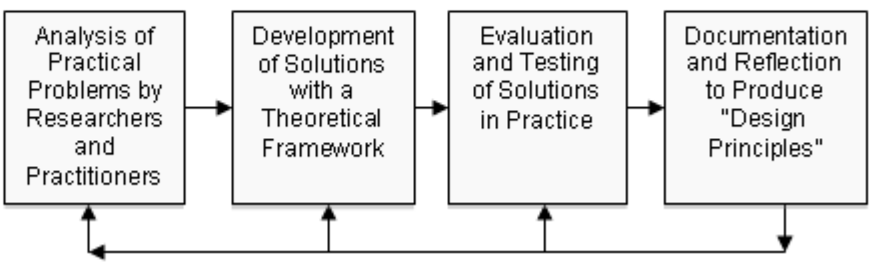

Figure 2. Development Research (Design-Based Research) by Reeve’s (2000)

Considering the evaluation and testing phase, we use different data gathering techniques that allow supporting or refusing the proposals. To evaluate teachers' designs we use questionnaires and observations; while to evaluate students' performance and their opinions we make use of questionnaires, log files, observations. Then, a mixed evaluation method (Cairns & Cox, 2008; Creswell, 2003) has been used to analyse the data resulted from the different experiments that we carry out. In fact, this method has been selected due the characteristics of the educational scenarios, involving teachers and students in real contexts. The method states that qualitative and quantitative data have to be collected. In particular, quantitative data is used to detect tendencies, while qualitative data is intended to confirm or reject these tendencies.

1.3.1 Methodological stages

In order to adapt these four phases and the cyclic nature of the original Design-Based Research model, this dissertation is conducted in six stages. Figure 3 shows how these stages relate to Reeves' development research model. The aim of Stage 1 is to select and identify the most relevant information in game-based learning environments, and detect possible literature gaps in this context. The following tasks are done:

- A first revision and analysis of the research literature regarding the design and implementation of game-based learning environments. In particular, the review is concentrated mainly in following topics: (a) an overview of the current situation of game-based learning environments; (b) the use of puzzles and game elements in the specific case of location-based games; and (c) the main considerations to support the teachers when designing their own location-based games.
- Participation in the Spanish Ministry of Science and Innovation Learn3 project (TIN2008-05163/TSI).
- Participation in Game Based Learning Summer School 2011, the 5th European Conference on Games Based Learning (Melero et al., 2011a), and the International Conference on Computer Science Applications (Melero, Hernández-Leo, & Blat, 2011b) These participations provide the opportunity to contact people in the TEL community with special interest in the game based learning research domain.

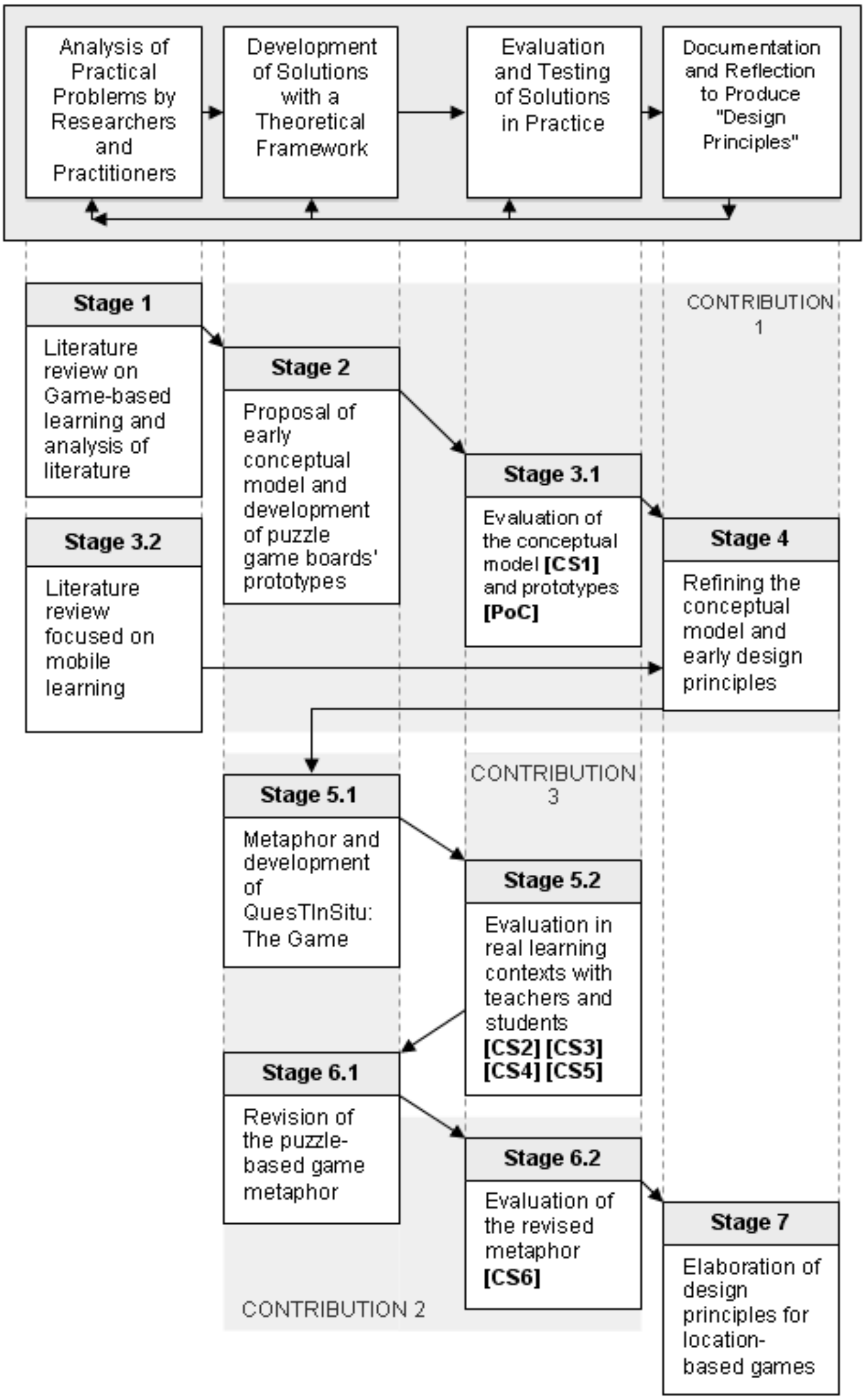

Figure 3. Outline of the research methodology following Reeves' (2000) original Design-Based Research model

In Stage 2, we propose an early version of the conceptual model (Melero et al., 2011b) Also, we focus on the development of puzzle board games prototypes. In particular, we propose solutions related to the identified information collected in the literature review phase.

The design and implementation of the prototypes is followed by an evaluation of the prototypes in Stage 3.1. Here, different prototype implementations have been evaluated to identify drawbacks, limitations and considerations that require further research [CS1; PoC]. Specifically, in (Melero, Hernández-Leo, & Blat, 2012b), we present the design of three different game-based learning environments providing hints for puzzle solving different tasks within the area of computer architecture, programming fundamentals, and computing networks. Findings obtained in an evaluation carried out with secondary and higher education students provide further considerations regarding the design of hints, score, and supportive learning material that should be taken into account when creating such kind of games. These stages result in the participation of the 12th International Conference on Advanced Learning Technologies (Melero et al., 2012b; Hjert-Bernardi, Melero, & Hernández-Leo, 2012).

Concurrently with Stage 3.1, we refine the revision of the literature in Stage 3.2. We narrow the type of technologies to m-learning. Particularly, we identify the most relevant literature dealing with integrating game elements in location-based learning. Besides, we take benefit of the expertise of this field previously studied by (Santos, 2011), also a member of the GTI group. Also, the participation in the ongoing work at the EEE Project (TIN2011-28308-C03-03) brings us the opportunity to discuss the work with experts in the field.

The Stage 4 analyses the proposed puzzle board games prototypes and the research literature carried out in Stages 3.1 and 3.2, respectively. These analyses result on a redefinition of both the puzzle board games conceptual model and the associated binding (Melero & Hernández-Leo, in press). Besides, these two stages also result in the participation of the 7th European Conference on Games Based Learning (Melero et al., 2013).

Considering the refined conceptual model, Stage 5.1 proposes the associated metaphor to facilitate the teachers' designs of their own location-based games. Also, the implementation of the extended version of "QuesTInSitu" is carried out in this phase. The evaluation of both the metaphor and "QuesTInSitu: The Game" is done in Stage 5.2. Specifically, a first iteration of using the puzzle board metaphor is carried out in four real learning scenarios for designing and implementing location-based games [CS2; CS3; CS4; CS5]. Evaluation results show that despite some identified difficulties, the teachers are able of using the metaphor to design potentially fruitful location-based games according to their educational objectives (Melero, Hernández-Leo, & Blat, accepted-b).

A second iteration of the proposed puzzle board metaphor has been carried out considering the drawbacks found in the aforementioned learning experiments. Then, we revise the proposed puzzle board metaphor (Stage 6.1.) and evaluate it with teachers of primary and secondary education (Stage 6.2) [CS6]. These two stages are reflected in (Melero, Hernández-Leo, & Blat, accepted-a). In particular, we evaluate both the changes made to the definitions of the metaphor's elements and the dynamics of the proposed game design task in a workshop session with 20 primary and secondary education teachers.

Finally, Stage 7 was devoted to elaborate design considerations taking into account the lessons learnt from the previous stages.

1.4 Structure of the dissertation

The remainder of this dissertation is structured as follows:

- Chapter 2: Location-based games design. This chapter starts with an overview of game-based learning research field and environments. Further, a focus on mobile learning and location-based learning games design is also discussed. Finally, we expose the problem of involving teachers in the design of these approaches.
- Chapter 3: A model and computational representation of puzzle board games. This chapter presents the model (conceptual model and information binding) to support the creation of

puzzle board games including virtual and physical objects. Particularly, the chapter describes the main elements defined in this model that are the result of an analysis of the literature review and the evaluation of an early version of the conceptual model with some prototype implementations.

- Chapter 4: Design of location-based learning games. This chapter describes a metaphor based on the conceptual model for puzzle board game designs to simplify the complexity of understanding the model, and facilitating the teachers' designs of their own location-based games. Besides, the metaphor is evaluated in a first iteration in four real learning contexts for secondary education. From the lessons learnt in these cases, the chapter also presents a second iteration of the metaphor involving teachers of different educational levels.
- Chapter 5: Implementation of location-based learning games. The implementations of the teachers design are described in this chapter. Also, the main findings from the enactment with students are reported to gain insights about the elements to take in consideration when designing gamified location-based learning activities. Particular cases studies are also reported in terms of supporting teachers' inquiry of their own designs, and evaluating students' performance.
- Chapter 6: Conclusions and future work. As its name implies, this chapter discusses the main conclusions and summarizes the main contributions and the future work derived from this dissertation.

CHAPTER 2
LOCATION-BASED LEARNING GAMES DESIGN

The aim of this chapter is to present the domain problem and the research field that motivates this PhD thesis, putting into focus the specific challenges that it undertakes. Particularly, we expose the problem when considering teachers as designers of their own location-based learning games. We introduce the field of Game-based Learning, as well as the design factors and models to consider when designing educational games. Besides, we specifically focus on location-based games and stress the main considerations when designing and implementing this type of approaches.

2.1 Introduction

According to (Bourgonjon, Valcke, Soetaert, & Schellens, 2010), many authors believe that the current generation of students is different from former generations due to the changes in their media consumption patterns: students grow up with hypertexts, social networking programs and video games. These students have gained specific technical skills, new ways of thinking, and different learning preferences, which require a new educational approach (Prensky, 2003). These new educational approaches are required to be in correspondence with these students (Bourgonjon et al., 2010; Oblinger & Oblinger, 2005; Prensky, 2003). In this context, educational games are being backed up in the Technology-Enhanced Learning domain as strategies that can lead to worthy learning outcomes. Besides, from the perspective of successful learning, motivation is an indispensable condition and games just happen to provide such a condition (Prensky, 2001). Also, computer-supported games increase the learning effects, making learning meaningful to students and creating a learning culture which is more in correspondence with students' interests (Lee & Chen, 2009). In fact, computer games are often considered as embodiments of this new educational approach: games situate learning in meaningful contexts, empower students to become self-regulated; present students with ill-structured problems; integrate several knowledge domains; promote inquiry-based and discovery learning (Bourgonjon et al., 2010).

Despite the positive effects of game-based learning environments, one of the main issues in this research domain is that teachers do not broadly adopt educational games in their educational settings (Williamson, 2009). In fact, several researchers have identified a number of issues and challenges derived from the low integration of games in formal educational settings (Gros, 2007; Kirriemuir & McFarlane, 2004; Klopfer, Osterweil, & Salen, 2009; Tornero et al., 2010; Ulicksak & Williamson, 2011; van Rosmalen, Klemke, & Westera, 2011; Yang, 2005). Most mainstream games are difficult to set up so they fit into the educational process and the accomplishment of the pursued learning objectives. Besides, most teachers do not have programming nor game development skills to create their own educational games. Furthermore, the support by teachers in technology enhanced learning environments is not straightforward, and the limited availability and experience of teachers severely reduces the amount and quality of feedback a learner might receive, as well as the design of support is complex and time consuming.

This chapter analyses the current state of the art of game-based learning, and particularly, how to facilitate teachers the design of their own educational games. Therefore, accordingly to the research methodology followed (see section 1.3), this chapter is focused on reporting the results of Stages 1 and 3.2, intended to complete a literature review in game-based learning design. Then, the remainder of this chapter is structured as follows. First, we start explaining the positive effect of game-based learning and the reasons why we focus on puzzle board games. Next, we emphasise the use of mobile learning, and how puzzle board games can be mapped to design pervasive computing environments. This leads to describe location-based learning games and different existing implementations that show the variety of these approaches. In order to properly design these types of games, next section is intended to analyse the most relevant design elements in game-based learning and, particularly, those games that considers the physical space. Finally, we expose the current situation of authoring tools that facilitate the creation of game-based learning environments, and particularly, location-based learning games.

2.2 Game-based learning

There is abundant empirical evidence supporting the positive effects of computer games as instructional tools. The evidences indicate that games implementing pedagogical designs can strengthen and support school achievement, cognitive abilities, motivation towards learning, reflection, attention and concentration, and learners appear to be behaviourally active while playing games (Amory & Seagram, 2003; Bottino, Ferlino, Ott, & Tavella, 2007; Jenkins, 2002; Lee & Chen, 2009; McFarlane, Sparrowhawk, & Heald, 2002). Moreover, as mentioned in the Introduction, frequently-cited arguments held by researchers for using serious games in education are: (a) they can invoke intense engagement in learners (Rieber, 1996), (b) they can encourage active learning (Garris, Ahlers, & Driskell, 2002), (c) empirical evidence shows that games can be effective tools for enhancing learning and understanding of complex subject matter, and (d) computers games can foster collaboration among learners (Kaptelinin & Cole, 2002). Besides, games that encompass educational objectives and subject matter are believed to hold the potential to render learning of academic subjects more learner-centred, easier, more enjoyable, more interesting, and, thus, more effective (Malone, 1981; Papastergiou, 2009). However, as stated in Chapter 1, the integration of games in formal settings is not broadly adopted (Kirriemuir & McFarlane, 2004; Klopfer et al., 2009; Ulicksak & Williamson, 2011). We believe that providing with flexible and customizable approaches to involve teachers as designers of their own educational games can make a significant difference to foster an enhanced comprehensive integration of game-based learning environments in formal learning settings.

With the aim of contributing to facilitate teachers' design of their educational games, we have to focus on what type of games is relevant or more suitable to this purpose. The nature of educational games is very varied (Mitchell & Savill-Smith, 2004), and because of the fast evolution of the game market it is becoming difficult to establish stable categories of games (Gros, 2009). However, considering digital games, some authors have produced different types of taxonomies (Adams & Rollings, 2007; Gros, 2007; Prensky, 2001; Whitton, 2010). Following types of digital games have been differentiated: action, adventure, platform, fighting, puzzle, role-playing, shooter, simulations, sports and strategy.

Furthermore, in addition to digital games, novel types of games, based on pervasive computing, have recently emerged. Mobile technology is one of the technologies that support pervasive computing, providing opportunities to interact with virtual and physical objects. In this context, puzzles, and more general board games, also become relevant as being considered approaches that allow the possibility of not only implementing digital computer games but also pervasive learning environments, bringing the possibility to extending the interactions beyond classroom. In this line, (Nicklas et al., 2001; Schlieder et al., 2006) describe how game concepts from existing board and computer games can be mapped for designing location-based games.

Puzzle board games

In this dissertation we focus on puzzle board games. Most of the existing games for learning purposes are quizzes, board, puzzles and problem solving staging (Batson & Feinberg, 2006; Bontchev & Vassileva, 2010; Ferreira, Pereira, Anacleto, Carvalho, & Carelli, 2008). Indeed, it is becoming a tendency that authors consider to present quizzes in map or board approach, where knowledge from course material is taught in a safe navigation (Bontchev, Gabarev, & Pavlov, 2002; Bontchev & Vassileva, 2010). Besides, board games permit the integration of not only quizzes but also puzzles or mini-games, adding extra value to educational scenarios (Schlieder et al., 2006). Furthermore, board games can cover a wide range of implementations, from purely digital or physical approaches to blended environments that can combine both virtual and physical objects. In particular, we redefined board games as puzzles. Indeed, puzzles' characteristics provide potential opportunities to involve teachers in the design of this approaches: puzzles are based on simple rules that requires interrelating pieces over a given board (Huang et al., 2007); rules can be defined independently from content and clues (Crawford, 1982) and, therefore, they can be applied to multiple subject matters.

Therefore, within the game-based learning domain, this Doctoral dissertation focuses on computer-supported puzzle board games to define different techniques to facilitate the design and implementation of location-based learning games (Figure 4).

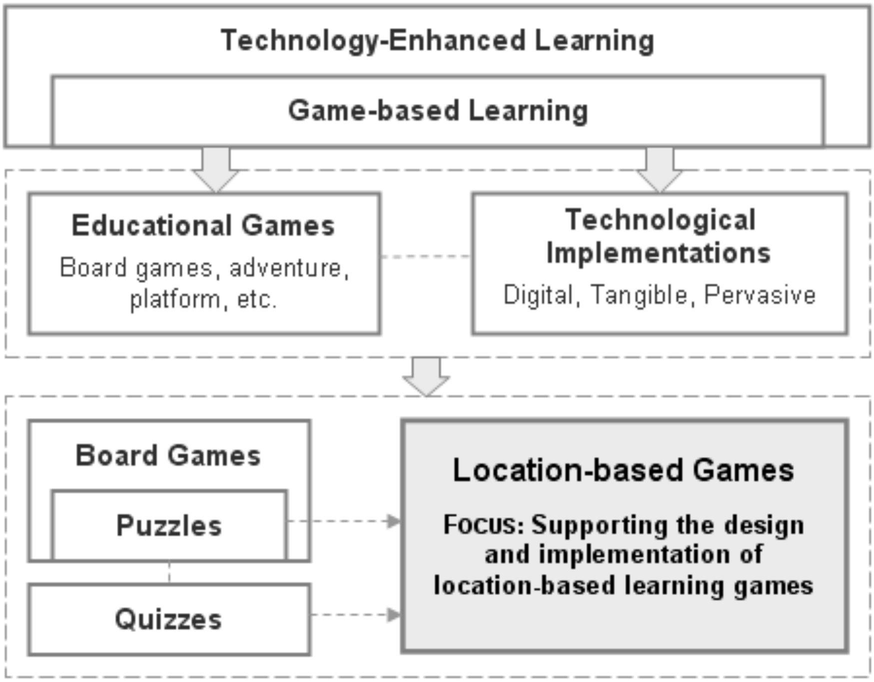

Figure 4. Scheme of concepts developed in Chapter 2

2.2.1 Location-based games

This dissertation focuses mainly on those games supported by mobile technology that allows the interaction of virtual and physical objects. Mobile learning is an emerging field of educational research that it is starting to attract the interest of practitioners in all phases of education to facilitate informal learning in formal contexts (Bachmair, Cook, & Kress, 2010). Besides, key aspects of such interests are the growing significance of mobile devices in learners' everyday lives (Vinu et al., 2011), and the increasing portability of these technologies, as well as the reduction in their cost and services. Besides, these approaches facilitate contextualized learning (Avouris & Yiannoutsou, 2012). In this context, the use of mobile technology in education has led to a new educational paradigm in which students can learn anytime and anywhere (Jones & Jo, 2004; Vinu et al., 2011). Considering the research domain of Game-based Learning, mobile learning brings the possibility of creating location-based games (Davis, 2002; Jeng et al., 2010).

Location-based games represent a new and emerging type of game that draws on the technological resources described as pervasive and ubiquitous computing. Pervasive computing goes beyond the realm of personal computers: technology is moving beyond the personal computer to everyday devices with embedded technology and connectivity as computing devices become progressively smaller and more powerful. Besides, location-based games bring possibilities to: enrich learning experiences by extending the learning beyond traditional classrooms and interacting with physical items by adding virtual layers of information; create fruitful learning experiences that involve exploration and cooperation (Hwang, Tsai, & Yang, 2008); access to contextualized information, communication, analysis and interrelation of real place (Roschelle, 2003); be entertaining and stimulating (Cabrera et al., 2005; Davis, 2002); an opportunity to focus and pay attention to the contextualized physical objects; and effective in terms of increasing the motivation to learn and to acquire a deeper understanding of the exhibits (Yatani, Onuma, Sugimoto, & Kusunoki, 2004).

<u>Location-based learning games</u>

This PhD thesis particularly focuses on the implementation of location-based learning games. Key game elements to consider in location-based games are constituted by (Nicklas et al., 2001): Players' positions (tracked typically by GPS or wireless local area network); Players moving around in the real world and interacting with the game by changing their position and visiting certain places that are of interest to the game; Players' interactions using various standard input devices; and opportunities to facilitate learning experiences by embedding abstract concepts in their contexts of actual use (Kurti, Milrad, & Spikol, 2007). Considering these elements, a great variety of location-based games for indoors and outdoors have been created. Besides, in the context of our work, some research works have identified design considerations when mapping traditional board games as location-based games (Magerkurth et al., 2005; Nicklas et al., 2001; Schlieder et al., 2006). However, only limited research focuses on how teachers can be involved in their design.

Furthermore, to the best of our knowledge, there is not research evidence on how puzzle board games can be computationally represented for its interpretation by software systems. Thus, it deserves further research to describe and identify the elements involved when mapping board games to location-based games in order to propose feasible techniques to facilitate the design and implementation of this type of games. On the other hand, it will be interesting to further research how implementations of the location-based games designs have an effect in student's engagement and outcomes.

Examples of location-based learning games

Within the field of location-based games, (Bohannon, 2010) identify the most relevant location-based games for outdoors (see Table 1).

Table 1. Examples of location-based games for outdoors

Name	Subject matter	Collaboration	Devices
Environmental Detectives	Science	Group-internal collaboration	PDA/GPS
Mad City Mystery	Science, argumentation/reasoning	Group-internal collaboration	PDS/GPS
Savannah	Ecological systems	Group-internal collaboration, negotiation	PDA/GPS, Wi-Fi
Alien Contact!	Math, language arts, and scientific literacy skills	Collaboration	Handheld computer, GPS
Relieving revolution	Historical thinking and inquiry	Group-internal collaboration	PDA/GPS, Wi-Fi
Frequency1550	History	Internal collaboration & cooperation, external competition	Smartphone, GPS, UMTS, PC

In *Environmental Detectives* (Klopfer, Squire, & Jenkins, 2002), students work in small teams playing the roles of environmental engineers who are called in to investigate a simulated chemical spill on a college campus. Information needed during the game is incorporated into digital content and in the form of supporting documents, interviews with location experts and witnesses. GPS is used to take and report virtual samples, and to help players navigate the campus and indicate their position. In *Mad City Mystery* (Squire & Jan, 2007) middle school students investigate an untimely death caused by murder, suicide or the combination of several interacting toxic chemicals that are commonly found in the region. Virtual media is triggered by location, determined by GPS. In *Reliving the Revolution* (Schrier, 2006) players try to find out who fired the first shot at the Battle of Lexington aiming to teach historical thinking and inquiry skill. Students use GPS enabled PDAs to receive information at certain hot spots as they walk around Lexington Square. In the game *Savannah* (Facer et al., 2004), children interact outdoors, through PDAs with GPS, with a virtual Savannah and explore the opportunities and risks to being lions. *Alien Contact!* (Dunleavy, Dede, & Mitchell, 2009) is intended to teach math, language arts, and scientific literacy skills. Students, playing collaboratively assume different roles within their teams, work to explore the augmented reality world, interview virtual characters, solve math problems, scientific literacy and language arts puzzles in order to determine why the aliens have landed. The mobile city game called *Frequency 1550* (Huizenga, Admiraal, Akkerman, & ten Dam, 2009) helps students playfully acquire historical knowledge of medieval Amsterdam.

On the other hand, different learning technology settings have been proposed to create location-based games for indoors such museums (see Table 2).

Table 2. Examples of location-based games for indoors

Name	Type of museum	Collaboration	Devices
Blåtannkoden	Museum of telecommunications	Internal-group collaboration	Mobile phone, Bluetooth, QR-Codes
UbiCicero	No museum specific	Internal-group collaboration, cooperation	RFID, PDA, mobile phones
Kurio	Museum of history	Internal-group collaboration	Tabletop display, tangible computing devices, PDA
Mystery in the museum	Museum with cultural and historical educational content	Internal-group collaboration	Mobile devices
Musex	Science museum	Internal-group collaboration	PDA

Some examples include: *Blåtannkoden*, a mobile application that uses QR-codes to create a treasure hunt game that involves solving different riddles related to the topics of a museum of telecommunications (Ceipidor, Medaglia, Perrone, De Marsico, & Di Romano, 2009); *UbiCicero*, location-aware game for mobile phones and personal digital assistants that use of RFID technology to propose gamified activities, such as quizzes, associations games, memory games, related to the associated museum's artworks (Ghiani, Paterno, Santoro, & Spano, 2007); *Kurio*, a game-learning approach based on challenges that is composed of a tabletop display, several independent tangibles, and a PDA, intended to engage family members to find historical information while visiting a museum (Wakkary et al., 2009); *Mystery in the Museum*, the use of mobile devices (Cabrera et al., 2005) to allow the students to solve collaboratively a set of puzzle activities (related to the exhibits of the museum) for a traditional museum with a culturally and historically rich educational content; *Musex* and the use of PDAs (Yatani et al., 2004) to solve different questions related to the science museum's exhibits by pairs of students.

These examples have shown a diverse variety of location-based games for outdoors and indoors. As we can see, these games can address different learning purposes (e.g.: science, math, or history) and be implemented for diverse types of handheld devices (e.g.: PDAs, tangible computing devices, or mobile phones). Besides, these initiatives have been using technologies such as GPS, Near Field Communication (NFC) or Quick Response (QR) codes to augment spaces and propose location-based learning scenarios in which learners' experience is enhanced. Also, collaboration seems to be a relevant factor when playing educational games. In this line, group-internal collaboration is the most common approach followed by these systems (i.e. several participants working as a group and collaborating by using a handheld device).

2.3 Design of game-based learning environments

Apart from focusing on the most relevant aspects of location-based learning games, it is important to pay attention to main factors involved in the design of this type of approaches. Overall, according to (Coller & Scott, 2009), the learning principles embedded in good digital games have a direct correspondence to constructivist theories of learning, active learning and metacognition. Besides, in (Squire & Jenkins, 2003) several learning factors embedded in games have been identified: a) the goals of the game have to be clear; b) feedback has to be immediate, abundant, and unambiguous; c) the game has to progressively increase the level of challenge to keep players at the edge of their abilities; d) games should encourage active and critical learning, and knowledge and skills are discovered through direct experiences, in a cyclic process of probing, reflecting, hypothesizing, and testing; e) information has to be available to players at just the time they will be able to make sense of it and to use it. In line with this, (Jones, 1998) proposes a set of characteristics on how to design engaging learning experiences: a) learners have to be able to complete and concentrate on the tasks; b) tasks should have clear goals, provide immediate feedback and deep but effortless involvement; c) games have to provide to the students a sense of control over their actions and self reflection after flow activity.

According to (Kirriemuir & McFarlane, 2004), it might be worth to take into account some analyses that describe the pleasures of games play as a ‘flow’ experience instead of focusing on making learning fun to motivate students and the belief that learning by doing in games offers a powerful learning tool. Malone describes the following conditions to induce the flow state (Malone, 1981): a) to structure the activity in such a way that the player can increase or decrease the level of challenges in order to match exactly personal skills with the requirements for action; b) to isolate the activity from other external or internal stimuli that might interfere with involvement in the activity; c) to develop a clear criteria for performance in order to allow a player evaluate their actions; d) to provide concrete feedback in the performance of the activities; e) the activity ought to have a broad range of challenges, and possibly several qualitatively different ranges of challenge, so that the player may obtain increasingly complex information about different aspects of her/himself.

On the other hand, taking in consideration that the problem with the design of most games is related to either the time required by learners interacting within games or to show improvement in achievement related to formal learning outcomes (Jones & Warren, 2008), a key point in game-based learning is to consider the design of appropriate help, feedback and hint structures to assist and scaffold students in their learning experience (Fisch, 2005). As a part of a literature review we conducted in (Melero et al., 2012a), we differentiated diverse types of scaffolding to support students' learning processes. A first differentiation is associated to a granularity perspective:

- Macro-scaffolding denotes pedagogical methods or teachers' strategies defining flows of coarse-grained activities that provide guidance on how to approach different learning tasks or problems. In that way, some constructivist learning methods can be considered as scaffolding techniques. These learning methods define the activity workflow that must be followed by learners in order to achieve the defined learning outcomes (Abe et al., 2004; Hadjerrouit, 2005; Harrer, Malzahn, & Roth, 2006; Hernández-Leo, Asensio, & Dimitriadis, 2006; Regueras et al., 2009).
- On the contrary, micro-scaffolding is intended to provide scaffolds for solving detailed actions that enable the resolution of specific activities. Micro-scaffolding may be implemented, for instance, using automatically-generated hints (Muñoz-Merino & Delgado Kloos, 2009); or offered by instructors coachers (Chan, 2007) or mediators (Moreno, Gonzalez, Castilla, Gonzalez, & Sigut, 2007a, 2007b).

Considering the actual implementation of the guidance offered to the learners, we differentiate between:

- Social-guidance scaffolding, when teachers or more knowledge peers are responsible for supporting the learning process either by guiding students (Chenard, Zilic, & Prokic, 2008), assisting students (Abe et al., 2004; Kim & Jeon, 2009), or acting as a mediator (Moreno et al., 2007a, 2007b);
- and system-guidance scaffolding, when technological approaches or environments support students during the different learning processes by means of, for instance, videogames (Papastergiou, 2009), learning management systems (Baturay & Bay, 2010; Garcia-Robles, Diaz-del-Rio, Vicente-Diaz, & Linares-Barranco, 2009; Moreno et al., 2007a, 2007b), modelling tools or simulators (Grigoriadou, Kanidis, & Gogoulou, 2006).

When system-guidance scaffolding is applied during the learning process, we notice that two different implementation approaches have been followed:

- On the one hand, we use the term tool-embedded scaffolding, when ICT-devoted tools, such as simulators, implement macro- or micro- scaffolding techniques with the aim of supporting learners to achieve the expected learning objectives (Harrer et al., 2006; Hazeyama, Ogame, & Miura, 2005; Kordaki, 2010; Muñoz-Merino & Delgado Kloos, 2009; Murray, Ryan, & Pahl, 2003).
- On the other hand, when generic tooling, such as Learning Management Systems (e.g. Moodle), is used as a part of the whole learning process and integrates specific ICT-devoted tools intended to scaffold specific actions within this learning process, we use the term tool-enveloped scaffolding (Regueras et al., 2009).

Taking into account this classification, location-based learning games designed as puzzle boards can consider different types of scaffolding. This type of games can be implemented as an ICT-devoted tool integrating tool-embedded scaffolding. Then, the game itself can be considered as a system-guidance scaffolding approach that guides students during a gamified activity (e.g. using feedback-oriented game design elements). Of course, depending on the context, teachers might act as an additional social-guidance scaffolding to support students when needed, and guide them to overcome specific problems. Finally, location-based games can integrate micro-scaffolding elements, as hints, designed to support students when solving specific actions within the game.

<u>Main factors for designing digital games</u>

Therefore, in order to design fruitful game-based learning environments, the above-mentioned elements described in this section can be summarized as follows:

- Games should be based on either constructivist learning theories or strategies that promote active learning and metacognition.
- Games have to clearly define the learning goals.
- Games have to be challenging and progressively increase the level of difficulty.

- Tasks and activities have to be clearly identified within the game.
- Immediate feedback has to be provided in regards with players' actions.
- Supportive learning material has to be provided to players when performing a specific task.
- Help and hint structures should be provided to assist players within the learning process in the game to allow them complete correctly a specific task.

2.3.1 Design of location-based games

Focusing on location-based games designs, it is important to focus on identifying relevant elements when designing this type of games. In this context, the representation of physical and virtual objects and the context where the game takes place are key aspects to consider. On the other hand, when designing educational games, teachers do not consider the educational games as a stand-alone activity, but as part of a learning package of activities (Frossard, 2013; Whitton, 2010). Indeed, in regards to location-based learning games, and particularly, the use of mobile technology, it seems to make sense to consider mobile learning and games-based learning not as distinct experiences, but as experiences that could fruitfully be combined (Facer et al., 2004).

After analysing the literature review, we found a limited research on supporting the modelling of this type of approaches. Particularly, a broadly recognized useful approach is the 4-dimension framework proposed by (de Freitas & Oliver, 2006) that considers contextual information as a key aspect. Besides, this framework aims at helping teachers to evaluate the potential of using games- and simulation-based learning (Figure 5). We adopt this framework to analyse and extract the main characteristics to consider when supporting teachers in the design of location-based learning games that are mapped as puzzle board games.

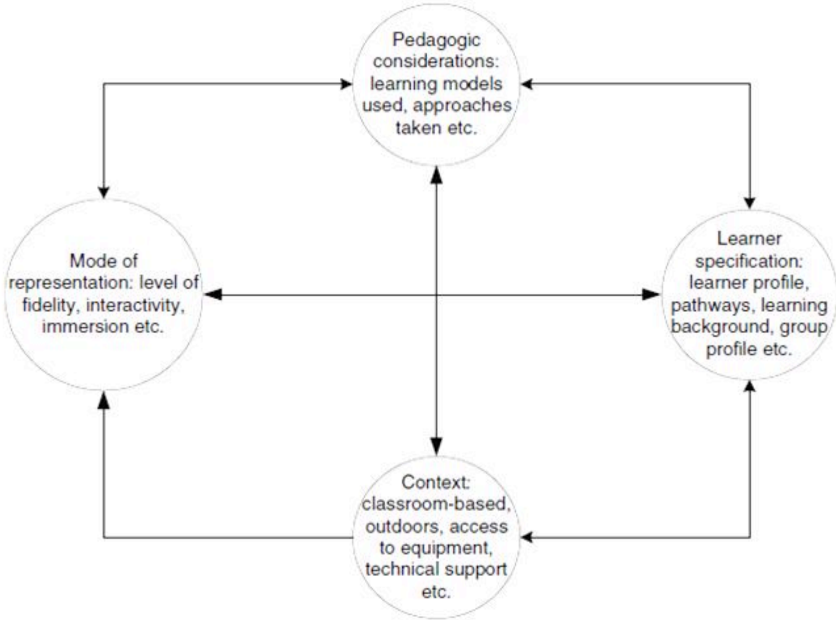

Figure 5. Framework for evaluation educational games (de Freitas & Oliver, 2006)

Dimension 1: Context

The first dimension of this framework focuses upon the particular context where play/learning takes place. In that sense, mobile technologies make possible to extend the learning environment far beyond classroom walls and school schedules (Liu, 2007) Also, mobile learning enhances traditional educational methodologies with greater portability and flexibility (Chang & Sheu, 2002). That means mobile games provide a way for learning activities that requires physical motion, problem solving, inquiry and collaboration (Avouris & Yiannoutsou, 2012; Spikol & Milrad, 2008). Besides, according to (Nicklas et al., 2001), when converting a board game to a location-based game, the game board must be mapped into the real world. In particular, (Nicklas et al., 2001) proposes three ways to map a typical game board, consisting of a set of discrete locations, into the physical world:

- Stick to discrete locations, meaning that each game location is associated with a geographical zone in the real world. Then, players are only allowed to move between these locations according to the game's rules.

- No discrete locations, just a predefined path that corresponds with the game flow. Players can move freely along the path, but are not allowed to take shortcuts.
- No restrictions allowing players to move around the real world freely, but the game can still require players to visit certain locations (for instance to pick up virtual game objects).

Dimension 2: Learner Profile

The second dimension focuses upon attributes of the particular learner or group. This may include the age and educational level, as well as specific components of how students learn including their learning background, styles and preferences. Considering location-based games mapped from traditional board games, players themselves are subject to the game's rules (Nicklas et al., 2001).

Dimension 3: Mode of Representation

The third dimension focuses upon the internal representational world of the game (i.e.: the mode of presentation, the interactivity, the levels of immersion and fidelity used in the game). In this line, we differentiate between virtual and physical objects to represent both the different pieces and boards of a puzzle game. Interacting with virtual representations allow students to comprehend and manipulate abstract concepts that cannot be accessed in real world. On the other hand, there are learning situations in which physical representations have clear benefits: physical objects can be more easily understood than more symbolic ones, it is easier to demonstrate knowledge with physical actions, and solving problems with concrete objects can be easier than using symbolic representations (Li et al., 2008; O'Malley & Stanton-Fraser, 2004). Then, game items in board games come in all shapes and sizes – cards, wooden pieces, and even small statues. While it is possible to carry and display such physical objects in a location-based game, it is inconvenient (Nicklas et al., 2001). Virtual game objects are not only more convenient, but also more flexible. Virtual objects can be made visible even to remote players and it is possible to transfer them to another player that is not in the vicinity. Furthermore, virtual objects can appear and disappear dynamically under the game's control.

Dimension 4: Pedagogic Considerations

The fourth dimension promotes the practitioners' reflection upon methods, theories, models and frameworks used to support learning practice. Several models have been used to describe the activities' flow of educational games. One example is the Game Achievement Model (Amory & Seagram, 2003) that takes in consideration the learning objectives for the game and the storyline that encompasses these objectives and is defined as actions or activities. Also, Educational Modelling Languages have been studied for creating educational digital games, and particularly, for analysing how aspects of gaming and learning could be combined with educational standards. In that sense, IMS Learning Design (Koper & Olivier, 2004), a specification for describing sequences of activities associated to user roles, has been proposed as an option for designing educational games (Kelle, Klemke, Gruber, & Specht, 2011). Besides, considering e-learning standards also becomes relevant to enable the integration of games into broader learning scenarios and to facilitate the interoperability and reuse of game-based learning implementations.

During the last years, there is a research line investigating how games can be integrated into broader learning scenarios (Tornero et al., 2010) and as an interlaced element throughout a learning experience (Burgos, Moreno-Ger, Sierra, Fernández-Manjón, & Koper, 2007; Burgos, Tattersall, & Koper, 2007). Some studies have shown the potential benefits of integrating educational games within broader learning process instead of remaining as an isolated stand-alone resource (Gee, 2005). Mainly, working in a closer integration would allow for pedagogical improvements as well as a better contextualised learning paths (Burgos, Tattersall, et al., 2007; Richards, 2005). In this context, it becomes relevant to consider e-learning standards to facilitate the interoperability and reuse of game-based learning implementations. Particularly, it deserves to be mentioned the work done in communicating <e-Adventure> with IMS LD (Burgos et al., 2008). This communication is regulated using adaptation and assessment rules, which can also be described using XML documents. Considering the related work carried out by (Vogten et al., 2006), the communication between IMS LD and <e-Adventure> has been implemented by adding a new game-based adaptive service to the IMS-LD engine. This service facilitates the communication between the IMS-LD engine and the diverse Web services required to support the different learning activities.

Considerations when mapping
location-based games as puzzle board games

Therefore, several aspects have to be considered when modelling the designs of location-based learning games:

- The context where the game takes place. This means that the resources available in physical places can take part of the game, as well as the players' position. In this sense, it is important to consider the available technology (e.g. QR-codes, GPS or RFID) to model this aspect.
- The representation of the elements involved in the game. Since physical and virtual objects can be represented in these types of games, it becomes important how to model the design of these objects. Particularly, since we consider puzzle board games to be mapped as location-based games, we have to define the representation of virtual and physical puzzle pieces and boards
- The modelling of learning flows within location-based games. In this case, it seems relevant to consider research works on educational modelling languages to increase the interoperability and reuse of location-based learning games.

Thus, after analysing the main design factors for designing educational games, next section is focused on current works around authoring tools for supporting teachers in the creation of educational games.

2.4 Authoring tools for game-based learning environments

With the aim of facilitating teachers the creation of their own educational games, diverse research efforts have being devoted in game-based learning field to provide easy-to-use game editors.

In general, <e-Adventure> (http://e-adventure.e-ucm.es/) is one of the most representative tools in game-based learning for allowing teachers the development of purely-digital educational games. Specifically, <e-Adventure> is an authoring tool for educational game development that is focused on point-and-click adventure games (Torrente et al., 2010). Particularly, <e-Adventure> is a research project aiming to apply a documental approach to the authoring of educational point-and-click adventure games (Sierra, Fernández-Manjón, Fernández-Valmayor, & Navarro, 2005; Sierra, Fernández-Valmayor, Fernández-Manjón, & Navarro, 2004; Sierra, Navarro, Fernández-Manjón, & Fernández-Valmayor, 2005). Also, <e-Adventure> is supported by a language based on XML, a graphical authoring tool, and an engine supporting the interpretation and execution of the game (Burgos et al., 2008). Essentially, the key objective of this project is to allow an author without a strong technical background to produce and maintain an entire game as a document using an easy-to-understand language, which is interpreted by an engine that produces a fully functional game (Burgos, Moreno-Ger, et al., 2007). On the other hand, another example of authoring tool is Jclic (http://clic.xtec.cat/en/jclic/), an environment intended to create, carry out and assess multimedia educational activities. It enables teachers to design different types of activities, some of them game-like (e.g. memory games, puzzles and crosswords). Activities are not presented alone, but packed as one or more sequences of activities. However, the activities created with Jclic cannot be considered as proper games (Frossard, 2013).

Furthermore, there are other examples focused on facilitating students the creation of their own games. These tools are intended to engage students in game design tasks while engage them in learning specific topics. Particularly, Alice (http://www.alice.org) is a 3D programming environment designed for undergraduates with no 3D graphics or programming experience (Conway et al., 2000). Specifically, this environment is designed as a tool to learn object-oriented programming by creating animations for telling a story, playing an interactive game, or a video to share on the web. Also, GameMaker: Studio (https://www.yoyogames.com/studio) is a rapid-application-development tool used by young people to create two-dimensional and isometric games (Overmars, 2004). Finally, Squeak (http://www.squeak.org/) is an open implementation in Smalltalk used to enhance and amplify learning by utilizing new ways to teach students powerful ideas about math and science (Ingalls et al., 1997).

Focusing on supporting the creation of computer-supported board games, there some representative works. “ELG” is an adaptive authoring tool that enables teachers to customize computer-supported board games. The game requires players to answer questions and is intended to foster students’ creativity, problem-solving skills, and imagination (Retalis, 2008). “Joyce” is a computer-based board game that encourages players to practice fractions by answering specific quizzes. When players obtain specific amount of points they are sent to other areas in which they have to practice other abilities in learning fractions (Feng, Chang, Lai, & Chan, 2005). Besides, Bontchev & Vassileva (2010) present a multimedia-rich and problem-oriented quiz game by means of board game instruments. The approach permits a facile and rapid construction of rich multimedia games by means of quiz and puzzle games. Besides, the authors argue that this type of games allow the presentation of a wide range of e-learning activities such as: visiting a virtual museum and shooting pictures of some pieces of arts, collecting or selecting objects of given type residing specific locations, discovering a specific object on a map, etc. However, all these tools are intended for creating purely-digital board games, and do not consider the interaction with physical objects or spaces.

Finally, some implementations have been carried out around facilitating teachers the creation of their own location-based games. “Treasure-HIT” is a system that aims to support teachers’ designs of their own location-based games for outdoors (Kohen-Vacs, Ronen, & Cohen, 2012). Teachers have to define specific geolocation points and associate clues and activities. Specifically, teachers can define different types of items including: plain text, Web pages, pictures and multiple-choice questions. “ARLearn” is a platform for educators and learners supporting different phases and activities during a field trip (Ternier, Klemke, Kalz, van Ulzen, & Specht, 2012). The system permits the creation of different types of objects: narrator item, audio object, video object, YouTube object, scan tag, single- and multiple-choice questions, that can be interrelate “Mobilogue” is a tool to support educators and students in authoring and developing mobile applications integrating quizzes and location guidance for diverse informal learning environments (e.g. museums, zoos, or other outdoor settings like cultural or historic heritage places) (Giemza & Hoppe, 2013).

However, the design elements that can be customized by teachers in those tools are limited. For example, none of these tools considers the customization of score mechanisms. Particularly, despite different type of quizzes can be associated to the location-based learning games, no points can be defined to the different (correct and incorrect) options associated to questions. In fact, none of these applications rely on an overall score reflecting the students' activity performance. Finally, there is not the possibility of creating levels of difficulty (i.e. creating a sequence of routes within the same game). We claim that these limitations may constrain teachers aiming at accommodating activity's formal purposes when designing location-based games.

Issues with current authoring tools

Even though some research works have been done for supporting teachers on the development of digital educational games, still some of the authoring tools, such as <e-Adventure>, are hard to adapt to individual courses, require much time for development, or require technical skills that are beyond the level of most instructors (Frossard, 2013; Tornero et al., 2010; Yang, 2005). Besides, other tools, such as Alice, Squeak or GameMaker are more focused on students so that they can learn programming concepts rather than supporting teachers in the creation of game-based learning environments. On the other hand, despite other tools, such as ELG or Joyce, are focused on computer-supported board games, they are not intended to be mapped to physical environments. Finally, some research works have been done to support the development of location-based learning games. However, current tools do not allow the customisation of elements, such as scores, that can be relevant to formal learning contexts. Also, considering the design elements identified in section 2.3., existing tools do not contemplate the creation of levels within the games. Besides, these studies have not reported evaluations with teachers yet. Thus, one of our aims is to make contributions to the research community by proposing a feasible approach to involve teachers as designers of their own location-based games.

2.5 Discussion and conclusions

This chapter has introduced the research domain of this dissertation focused on game-based learning design. In particular, within the game-based learning research field, we encompass the specific challenges around supporting the design of location-based learning games. The chapter has presented the current situation of game-based learning, focusing on the issue of supporting teachers the creation of educational games. Specifically, we particularly describe the main considerations when designing and implementing location-based game approaches considering computer-supported puzzle board games.

The main reasons behind considering puzzles are that these approaches are potential tools to involve teachers as game designers. Puzzle board games have simple rules around the basis of a challenge that requires interrelating pieces over a given board (Huang et al., 2007). Their rules can be defined independently from content and clues (Crawford, 1982) and, therefore, they can be applied to multiple subject matters. Besides, board games can be implemented with a wide range of technologies.

Considering different types of technological implementations, pervasive computing for mobile environments emerge as relevant approaches for educational contexts because of the influence of handheld devices in students' everyday lives, the portability of these technologies, and low-cost services. Particularly, in the context of game-based learning, location-based games are those applications that make use of contextual information to provide task-relevant functionalities. Besides, in order to design and implement location-based learning games we consider related research studies focused on mapping this type of games as traditional puzzles and board games.

Different factors have been identified to design good educational games. In particular, for the case of location-based games, key aspects to consider are: a) contextual information, that means where the game takes place, b) players' information, c) representation of virtual and physical objects, and d) pedagogical approach to support learning practices. Besides, in order to foster the implementation and interoperability of location-based games in broader learning scenarios, it seems relevant to consider educational modelling languages.

Finally, some efforts have been devoted around supporting teachers in the creation of their own computer-supported educational games. However, existing authoring tools are still complex for some instructors, hard to adapt to their specific educational situations, and require too much time for development. Therefore, next chapters tackle the issues of supporting the design and implementation of location-based games, considering puzzle board games.

CHAPTER 3

A MODEL AND COMPUTATIONAL REPRESENTATION OF PUZZLE BOARD GAMES

This chapter presents the contribution that addresses the research objective of proposing a solution for modelling and computationally representing computer-supported puzzle board games including virtual and physical objects. Particularly, the conceptual model and the associated binding are presented. Several third-party examples and different prototypes show the relevance of the proposed conceptual model. On the one hand, different puzzle board games compliant with the conceptual model are described to show the feasibility of using the conceptual model. On the other hand, these examples cover different subject matters to illustrate the applicability of puzzle board games in different educational levels and areas. Besides, we report the results of an exploratory user study to explore teachers' understanding of the model. The main contributions have been published in (Melero et al., 2011b, 2012b) and accepted in (Melero & Hernández-Leo, in press).

3.1 Introduction

In the previous chapter we review the literature in relation to the design of the main elements and frameworks when designing game-based learning environments. In particular, we focus on pervasive computing for mobile technology to implement location-based learning games' designs. Besides, in order to support the design of location-based learning games we consider puzzle board games as a suitable approach: board games are widespread in educational settings, they have been studied as feasible approaches to map in location-based games, and puzzle board games have been reported as feasible strategies to involve teachers as game designers.

The design factors and elements discussed in section 2.3 are used as a basis for defining a model that enables teachers to design their own puzzle board games according to the educational needs. In this context, the objective of any puzzle board game is the arrangement of a set of given pieces into a single, well-fitting structure (Williams, 1997). Puzzles also are interesting because its result is not immediately intuitive; they can foster students' problem solving, analytical and memory skills (Huang et al., 2007). According to Kahn, puzzle games have also shown pedagogical importance since they lead a player step by step where the designer wants to go, and players have the feeling of control over the game (Kahn, 1999). There are several reasons that make puzzle board games interesting approaches to involve teachers as designers. Puzzles usually have simple game rules (simplicity); their rules can be defined independently from content and therefore they can be applied in a wide range of subject matters (generality, independence); and their nature and duration is typically equivalent to other types of learning activities for the classroom or field trips (Falkner, Sooriamurthi, & Michalewicz, 2010; Michalewicz & Michalewicz, 2008).

Therefore, this chapter focuses on the first contribution of this dissertation intended to model computer-supported puzzle board games (see Figure 6).

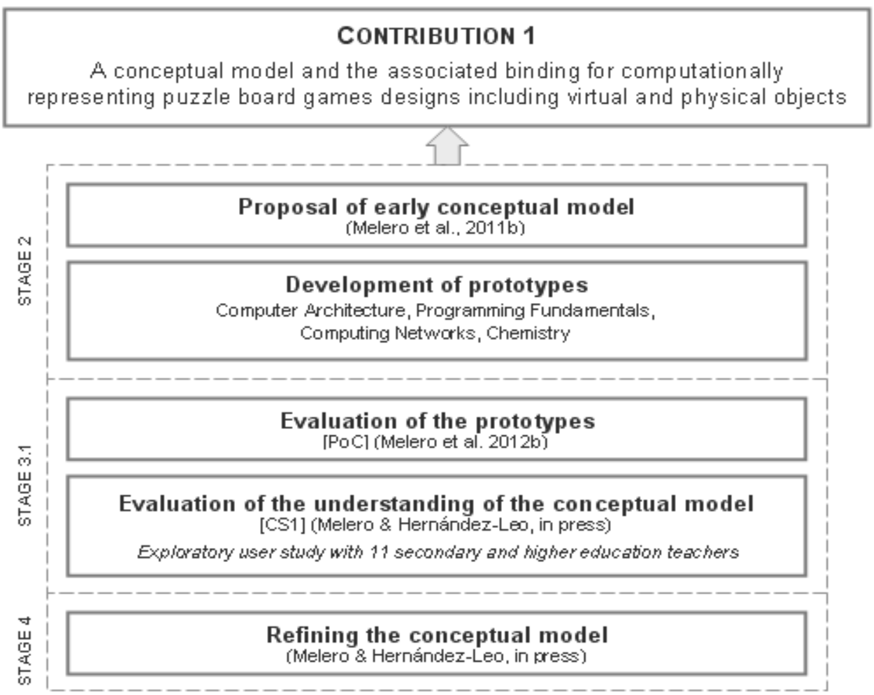

Figure 6. Overview of the tasks performed in relation to the first contribution

Specifically, we report the work down in stages 2 (i.e. Proposal of early conceptual model and development of prototypes), 3.1 (i.e. Evaluation of the conceptual model and the prototypes), and 4 (i.e. Refining the conceptual model).

The remainder of the chapter is structured as follows: First, we present the foundations of the conceptual model and the associated binding. Then, describe different examples of game board games to show the expressiveness of the conceptual model. Following section describes an exploratory user study with secondary and higher education teachers to evaluate the understanding of the conceptual model. Finally, we indicate some implementation guidelines for educational games compliant with the proposed model.

3.2 Conceptual model for puzzle board games design

Aligned with the factors and characteristics of games and puzzle boards designs, discussed in Chapter 2, Figure 7 adapts the (de Freitas & Oliver, 2006) framework to describe an overview of our model. The resulted conceptual model also considers a first iteration presented in (Melero et al., 2011b).

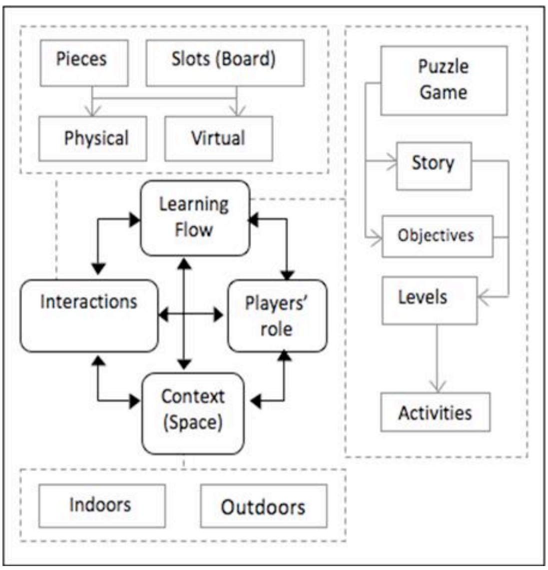

Figure 7. Overview of the conceptual model

Overall, this conceptual model defines the learning flow of the whole game, the context where the game takes places as well as the puzzles associated to each activity. In particular, the learning flow consists of a story structured by levels that have associated a single activity or a group of activities to be performed indoors or outdoors. Each activity includes a puzzle that has to be solved. In this sense, each puzzle is represented by relating pieces among them or by relating pieces with specific positions (i.e. slots) of a board. Additionally, different game elements, including scoring mechanisms, feedback and hints, can be associated to the activities and puzzles in order to scaffold the learning process and guide students to the correct expected solutions.

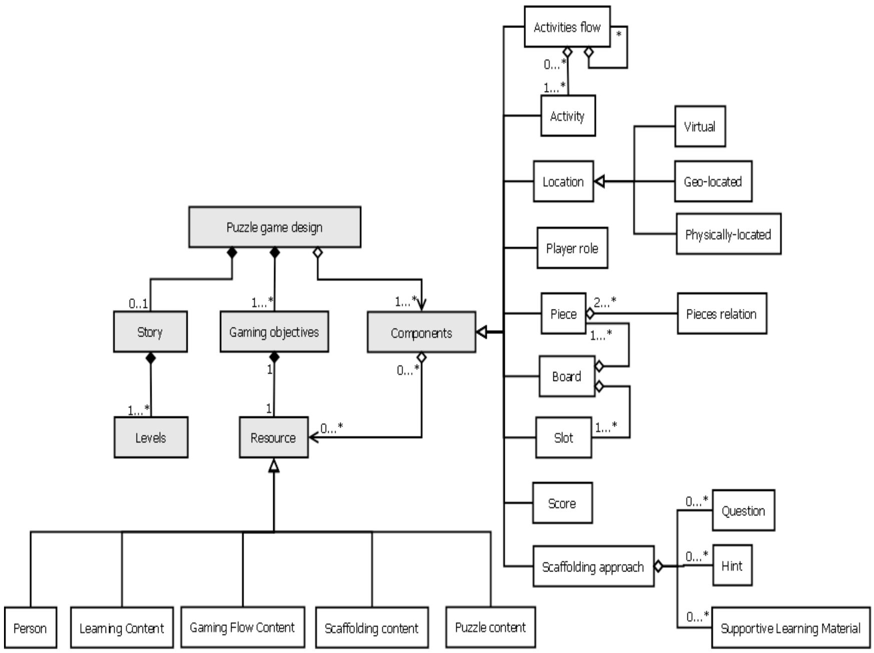

Figure 8. Semantic aggregation levels in the puzzle board game specification

The entities depicted in Figure 7 can be conceptualized in a set of elements and their relationships. Figure 8 represents the aggregation relationships and the specializations of abstract classes of the conceptual model for designing puzzle games represented by virtual and physical objects. The model shows that a puzzle game design provides a semantic view of a collection of resources on the one hand, and on the other hand it integrates a story, specifying the dynamic aspects of the puzzle game design. The model shows three levels of semantic aggregation: The semantically highest level is the puzzle game design; it aggregates a collection of components, gaming objectives, and a story. The lowest level of aggregation is the resources, and levels of the game. The resources are aggregated into components and gaming objectives. The levels of the game are aggregated into the story. A component can be one of the nine different types: activities flow, activity, location, player role, piece, board, slot, score and scaffolding approach. A resource can be one of the four different types: person, learning content, gaming flow content, scaffolding content and puzzle content.

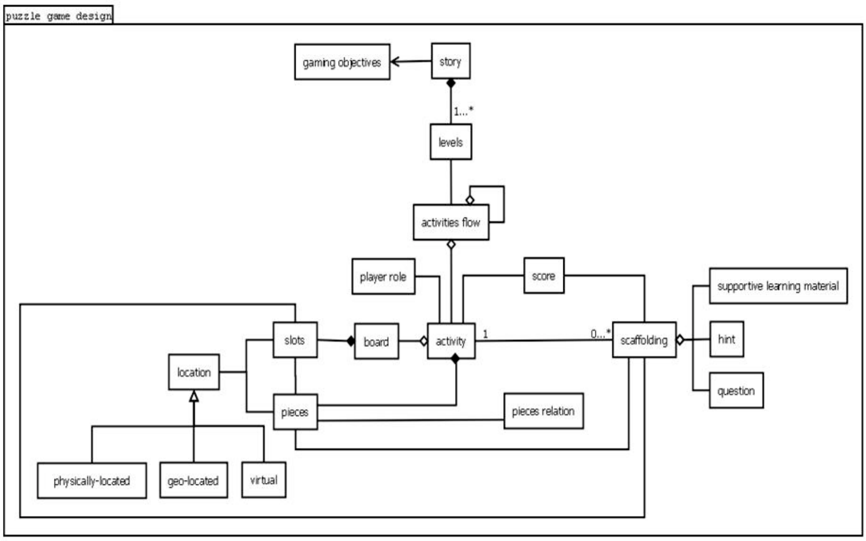

Figure 9. Conceptual model of puzzle board game design

The core of the puzzle game design can be summarised as follows. The story of the game specifies which role has to perform which activity and at what moment in the gaming process. For a player role, outcomes are stated as gaming objectives. These outcomes are achieved by performing learning activities, within the levels of the game, with the help of hints that scaffold the learning process if needed. In order to solve the learning activities, a set of (virtual or physical) pieces is provided to the players to propose their own solutions. Pieces and their relations could provide mechanisms, such as hints, questions or supportive learning material, to scaffold the gaming process as well. Besides, pieces could be part of a board in which players should relate each piece with its corresponding slot. Otherwise, players should relate pieces between them to propose the solutions. Depending on the puzzle game design (e.g.: a virtual puzzle game, a puzzle game for a museum, a puzzle game designed to be played in a city), either pieces or slots could have associated virtual, tagged or geo-located positions. Figure 9 emphasises the functional relationships between the different classes.

3.3 Information binding

The conceptual model previously explained can be computationally represented by an XML binding as shown in Figure 10.

```
puzzle-game-design
        title
        gaming-objectives
        story
                levels
                        level
                                player-role-ref
                                activities-ref
        components
                player-roles
                        player-role
                activities
                        activity
                                scaffolding-ref
                                puzzle-ref
                        activity-flow
                                learning-activity-refs
                puzzles
                        puzzle
                                metadata
                scaffoldings
                        scaffolding
                                metadata
        metadata
```

Figure 10. Main elements of a puzzle game design

More specifically, the computational representation for a puzzle board game design includes:

- The title for a puzzle game design as well as the game objectives.
- The story of the game that contains the levels to be carried out sequentially.
- Each level defines who has to perform which activity or set of activities. That means, levels link each player-role to a specific activity or activity flow (i.e. group of activities).

- Activities appear as single activities or they could be grouped in an activities flow. The activity provides a description about the problem that has to be solved by a player performing a concrete role. An activity also contains a reference to metadata that defines the puzzle intended to solve the proposed problem. Each activity also can provide different scaffolding mechanisms to assist the player during the game as well.
- Puzzles are used when a player performs a concrete activity, but they do not form part of the activity description itself. Thus, each puzzle is linked to each activity of the game.
- Scaffolding is used by player roles when asking for some type of help while performing an activity. Scaffolding does not form part of the activity description itself neither.

The different puzzles associated to each activity are also defined by its corresponding XML document in order to be computationally represented as well (Figure 11).

```
puzzle
        rels-between-pieces
                piece
                        name
                        type
                        location
                        scaffolding-ref
                rel-between-pieces
                        piece-id-ref
                        feedback
                        score
        rels-pieces-slots
                board
                piece
                        name
                        type
                        location
                        scaffolding-ref
                slot
                        type
                        information
                        location
                        scaffolding-ref
                rel-piece-slot
                        piece-id-ref
                        slot-id-ref
                        feedback
                        score
```

Figure 11. Main elements of a single puzzle associated to an activity

We differentiate two types of relations within a puzzle: First, those relations in which the puzzle is not contained into a board. They

define only the relations that can be made between the different pieces that form the puzzle (rels-between-pieces). Second, the relations that has to be defined for relating the different puzzle pieces with the slots of the board in which the puzzle is contained (rels-pieces-slot).
A piece includes its name, the type of piece depending on its representation (i.e. virtual or physical), and scaffolding mechanisms (i.e. hint, question prompt, or supportive learning material).

A slot is defined by its type depending on its representation (i.e. virtual or physical), information to describe the slot, location (defined by coordinates {x, y, z} for virtual representations; or a geo-located coordinate, for location-based interactions), and scaffolding mechanisms (i.e. hint, question prompt, or supportive learning material).

Each relation, for puzzles that only consider the relations between pieces (rel-between-pieces), is defined by the reference of the different pieces forming the specific relation, a feedback provided to the player depending on whether the relation is correct or not, and a score consisting on positive (correct relationships) or negative (incorrect relationships) points.

Each relation, for puzzles that consider the pieces and the slots of a board (rel-pieces-slot), is defined by a reference of the piece and the slot forming the relation itself, a feedback provided to the player in order to inform whether the relation is correct or not, and a score consisting in positive points for correct relations, and negative points for incorrect ones.

To show the expressiveness of the model, next section discusses different examples covering a wide range of puzzle board games.

3.4 Expressiveness of the conceptual model

The examples described in this section include diverse virtual and physical objects' (as pieces or slots) combinations. In particular, we describe several illustrative learning scenarios that consider the proposed conceptual model, as well as third-party examples proposed by other researchers. Reporting not only our examples, but also external ones, adds a stronger validation of the model expressiveness and shows how the model can be applied to a diverse variety of educational contexts.

3.4.1 Examples of puzzle board games including virtual pieces and virtual slots

We developed several puzzle board games (available in the attached CD-ROM), following the early version of the proposed conceptual model. In particular, the games (see Figure 12) aim at learning computer architecture, programming fundamentals, computing networks (Melero et al., 2012b) and chemistry (Hjert-Bernardi et al., 2012).

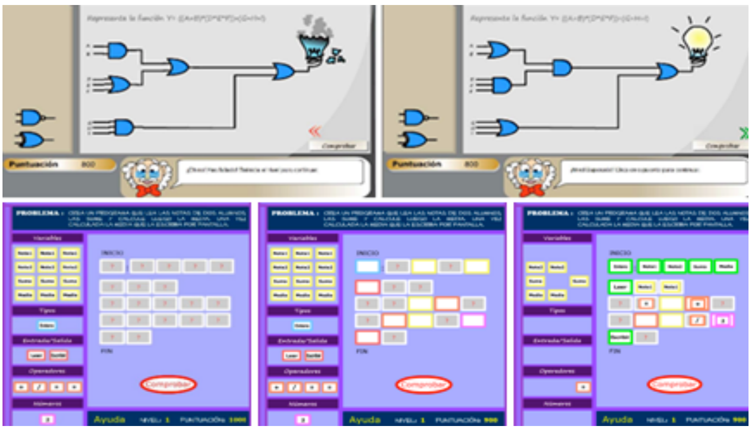

Figure 12. Some screenshots of puzzle board games prototypes

Each game contains different levels that have associated different supportive learning material to solve the proposed problems, and different hint mechanisms to assist players in reaching a correct solution. Besides, a set of puzzle pieces provided to the players to solve the problems (see Figure 13): a) blocks of programming instructions designed as specific puzzle pieces that students must join each other to reach a solution for a proposed program (Programming Fundamentals), b) puzzle pieces becomes different logic gates, CPUs, Control Units, Arithmetic Logic Units, Memories, etc. to learn about Boolean logic or von Neumann architecture (Computer Architecture), c) puzzle pieces designed as different devices, such as modems, routers, firewalls, etc. (Computing Networks), and d) pieces as the periodic table of elements (Chemistry). As an example, Figure 13 depicts a chunk of the XML binding for computationally representing the programming fundamentals game. In particular, virtual pieces correspond to blocks of concrete programming instructions that are mapped using the tag “<piece>”. The board is formed by empty grey spaces, which are mapped in the tag “<slot>”, intended to put the different pieces. Finally, correct and incorrect relations between pieces and slots are mapped using the tag “<rel-piece-slot>”.

```
<puzzle id="puzzle_programming_lv1">
    <rels-pieces-slots id="relations_programming_lv1">
        <board id="board_puzzle_logic_gates">
            <board-file>#9933cc</board-file>
        </board>
        <piece id="piece_TYPE_INTEGER_1">
            <name>Integer</name>
            <type>virtual</type>
            <location>
                <pos_x>20</pos_x>
                <pos_y>45</pos_y>
            </location>
            <file-ref>/type_integer.png</file-ref>
        </piece>
        ...
        <slot id="slot_TYPE_INTEGER">
            <type>virtual</type>
            <information>Slot reserved for a type integer</information>
            <location>
                <pos_x>75</pos_x>
                <pos_y>134</pos_y>
            </location>
        </slot>
        ...
        <rel-piece-slot id="rel_piece_slot_TYPE_INTEGER">
            <piece-id-ref>piece_TYPE_INTEGER_1</piece-id-ref>
            <slot-id-ref>slot_TYPE_INTEGER</slot-id-ref>
            <feedback>Correct!</feedback>
            <score>250</score>
        </rel-piece-slot>
        ...
    </rels-pieces-slots>
</puzzle>
```

Each virtual piece corresponds to a chunk of code (it could have associated an static image)

Each virtual slot has a predefined location in which the player has to associate a piece

Tag "rel-piece-slot" defines whether a piece has been correctly (or incorrectly) associated to a slot.

Figure 13. Example of using the XML binding for representing the digital puzzle board game for programming fundamentals

A third-party example in this context is “The Collaborative Puzzle Game” (Battocchi et al., 2010). This example consists in a puzzle board game that can be expressed with the proposed model. This game has been designed to capitalise on the strengths of children with Autism Spectrum Disorder while taking into account their needs and limitations. It aims at providing an environment that supports the need for consistency and sameness while motivating social communication interactions. Results from an evaluation show benefits concerning collaborative behaviours and social skills. The game supports two players working together on the same horizontal display surface. Children can drag pictures that are presented as digital objects (pictures) on a screen in order to assemble them as required by the puzzle board (solution area with invisible cells, equal to the total number of pieces; the target picture to achieve assembling the pieces is available as a hint). From the description of this game, it is intuitive to see how their characteristics can be represented with the elements of the model (game objective, pieces, board, and relations between pieces and board).

3.4.2 Example of a puzzle board game including virtual pieces and physical slots

Lee & Chen (2009) propose a mathematical educational game for young children in an Augmented Reality environment to practice with the concept of addition and subtraction. This could be an example of a puzzle game in which virtual pieces and physical slots work together. The player has three dice (two numbered dice and one operator dice) that have to roll and calculate the outcome. Then, the player moves a piece on the board according to the outcome. The player who arrives at the finishing point first wins the game. The board is made of markers and pieces are augmented as 3D models. The players can select different boards and the 3D models player’s pieces would change as on the selected board. The representation of the game with the model would specify each board and its corresponding pieces as a different puzzle in the game. Each of the board’s markers would correspond to a physical slot, and the augmented pieces would be mapped as virtual pieces of the model. Thus, different “rel-piece-slot” elements would be defined to specify the possible relations that can be established between each piece and slot.

3.4.3 Example of puzzle board games including physical pieces and virtual slots

Two functional prototypes of puzzle board games using physical pieces and virtual slots have been implemented in (Cardona-Serra, 2012; Ponz-Adán, 2012). These games (available in the attached CD-ROM), compliant with the conceptual model, reflect contents of computer architecture and programming fundamentals. Puzzle pieces were implemented using the ReacTIVision technology (Kaltenbrunner & Bencina, 2007), an open-source toolkit for developing tangible multi-touch surfaces. Particularly, the games consisted in matching the physical pieces, representing different computer science concepts, with their corresponding virtual slots.

```
<puzzle id="puzzle_logic_gates">
    <rels-pieces-slots id="relations_puzzle_logic_gates">
        <board id="board_puzzle_logic_gates">
            <board-file>/board_game.jpg</board-file>
        </board>
        <piece id="fiducial_AND">
            <name>AND</name>
            <type>physical</type>
        </piece>
        ...
        <slot id="slot_AND">
            <type>virtual</type>
            <information>Slot reserved for a logic gate</information>
            <location>
                <pos_x>-100</pos_x>
                <pos_y>78</pos_y>
            </location>
        </slot>
        ...
        <rel-piece-slot id="rel_fiducial_slot_AND">
            <piece-id-ref>fiducial_AND</piece-id-ref>
            <slot-id-ref>slot_AND</slot-id-ref>
            <feedback>Correct!</feedback>
            <score>100</score>
        </rel-piece-slot>
        ...
    </rels-pieces-slots>
</puzzle>
```

Each piece (<piece>) is associated to a concrete physical fidutial. Each fidutial id is mapped in <name>

The slots are the virtual empty spaces where the pieces have to be placed

Each <rel-piece-slot> indicates whether a relation "piece-slot" is correct or not.

Figure 14. Example of using the XML binding for representing the tangible puzzle board game for computer architecture concepts

Figure 14 depicts a chunk of the XML binding for the tangible puzzle board game intended to learn computer architecture concepts. Fiducial markers (recognize computationally by the ReacTIVision technology) are virtually represented using the tag “<piece>”. Each “<piece>” has to be placed in a concrete virtual slot (displayed in the tabletop interface), and the relationships between pieces and slots are mapped using the tag “<rel-piece-slot>”.

Another example, in this context, is “TICLE” (Scarlatos, 2002), a third party implementation in which pieces are physical and they correspond to the Tangram’s pieces, and slots are virtually represented in a tabletop interface. Specifically, the game consists in a prototype tangible interface for the Tangram, an old Chinese geometric puzzle. Computer vision techniques track the puzzle pieces as they are moved about, and the system responds the player’s actions with audio, graphics, and animation. A colour graphics monitor located near the game provides the visual feedback. TICLE allows students to focus on the task at hand without having to worry about how to give instructions to a machine. According to the conceptual model, the board would contain virtual slots, each one of them with its corresponding location, indicating the correct position of a given piece. The player should match each tagged piece with its corresponding virtual slot. The “rel-piece-slot” element would define whether the matching is correct or not.

3.4.4 Example of a puzzle board game including physical pieces and physical slots

“The Smart Jigsaw Puzzle Assistant” (Bohn, 2004) is a computer application that operates with a physical jigsaw puzzle game that uses miniature RFID tags and a palm-sized RFID scanner to technologically support the interactions with both physical pieces and slots. The application is executed on a computer and monitors the current status of the physical jigsaw puzzle. Whenever the player chooses a new piece of the physical jigsaw game to be added to the previously combined pieces on the table, he or she scans it with a handy RFID reader connected to the computer. The application then automatically recognizes the added piece and updates the status of the jigsaw game on the computer screen. Both piece and slot elements would be specified as physical (setting the attribute type to “tag”) to comply with the conceptual model. The application would recognize the added physical piece and check, using the “rel-piece-slot” element, whether the piece has been placed in a correct position.

3.5 Understanding of the conceptual model

Once different examples have been described to illustrate meaningful educational context using the proposed approach, it is import ant to evaluate whether teachers understand the elements of the model. Then, we carried out an exploratory study in which different teachers have to solve a proposed design task. Before discussing the results, we describe the proposed design tasks and the methodology applied in the study.

3.5.1 Methodology and design task

Teachers were recruited to participate upon an open invitation. Invitations were sent by email to two secondary education schools and one higher education (university) department. A total of 11 teachers replied positively to the invitation and agreed to participate in the user study (see Figure 15)

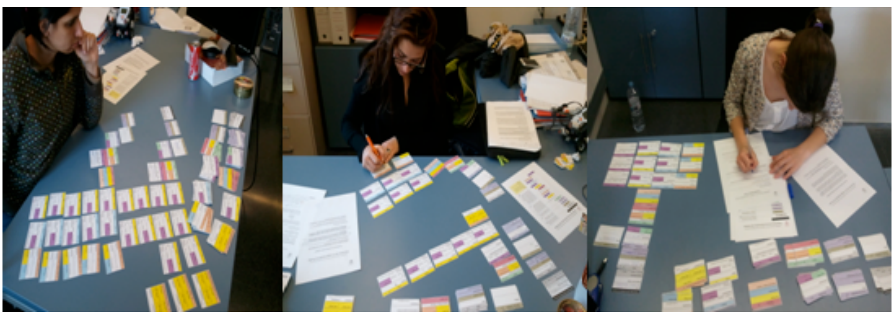

Figure 15. Pictures of the exploratory user study

As done in (Derntl, Neumann, Griffiths, & Oberhuemer, 2012), this study was organized as paper-based sessions. Participants used paper snippets representing the elements of the conceptual model to solve the design task. In particular, the sessions were structured as:

- Pre-test for gathering contextual information and the teachers' background using technology or educational games in their learning approach (10 minutes).
- Introduction about game-based learning and the key elements of the model needed to build a puzzle game. Some examples using the elements of the model were shown as well (15 minutes).
- Paper-snippets introduction. Every participant received an envelope with paper snippets (see Figure 16), each representing one instance of an element of the conceptual model. Each paper snippet was divided into boxes that represent information about the element in conformance with the model. Besides, each element had its own unique colour in order to guide participants in placing connections between elements (5 minutes).

Figure 16. Sample of snippets (i.e. piece, slot, relation between pieces, and relation between piece-slot)

- Puzzle board game design task. After the introduction, every participant had the task of representing one scenario (two narratives of puzzle board game scenarios were defined and randomly offered to participants) (50 minutes). The resulting designs created with the snippets were collected, once the participants finished the design task.
- Post-task survey. Participants were asked to fill out a post-task survey, which aimed to collect additional information about what caused them more problems during the task (10 minutes).

As a task protocol, participants were not offered any help or guidance during the task other than (a) provision of a cheat sheet with a tabular overview of the elements of the conceptual model and (b) personal answers to questions for clarification.

Prototype solutions for each of the two proposed scenarios were created by decomposing the overall task into solution items. Each solution item consisted of an action that needed to be performed with an individual element of the model, or a small group of elements, in order to obtain a correct solution. Each solution proposed by the participants was individually analysed and matched with the prototype solution. Table 3 lists the scenarios and includes sample snippets. The complete collection of snippets composing the specification of the games described in the scenarios is available in a CD-ROM attached at the end of the dissertation.

Table 3. Scenarios proposed in the design task

Scenarios
1. Imagine a non-native English student wants to improve his/her English vocabulary related to shopping. The first level aims at learning English words for different clothes [s1-1]. Each activity, in this level, consists in forming words of different type of clothes that are shown in pictures. The player, using different letters, has to construct the specific name of clothes shown in the picture [s1-2]. The next level consists in an activity for learning specific shop departments (dressing room, counter, etc.) [s1-3]. To this end, a map of the shop containing different empty spaces is presented to the player. Then, the player has a set of given words to place in a specific area of the map [s1-4]. The purpose is to match each word with its correct empty space in the map. During the game different hints can be provided to the player indicating for instance, the first letter of a word, the last letter, etc.
2. Using a Smartphone, a student has to find some contemporary pictures in a museum [s2-1]. The Smartphone shows, on one hand, the museum's map and, on the other hand, a set of pieces that represent specific parts of concrete pictures [s2-2]. The museum's map also contains different highlighted locations that correspond to specific pictures in the museum. Students have to match each piece with its corresponding picture/location. Each picture in the museum has associated a physical card (e.g.: NFC tags, QR-Code, etc.) [s2-3]. The player has to read the physical card to indicate that he/she has reached a specific location. Then, once the player arrives to a concrete location and read the physical card, he/she can select which of the virtual piece correspond to the concrete the picture [s2-4]. Each virtual piece may contain some hints indicating the area of the museum where the student can find the related picture.

To analyze to what extent teachers were able to complete the specification of the games and identify the missed elements of the resulting designs, we use a chart taking into account the aforementioned decomposition of the overall tasks into solution items. Thus, Table 4 summarizes the different data sources considered in the evaluation.

Table 4. Data sources for the evaluation of the exploratory study

Data source	Type of data	Labels
Pre-test	Quantitative ratings and qualitative opinions by the different participants	[Pretest-all] and [Pretest-X] Where X is the number of the user, from 1 to 11
Participants Solutions	Proposed solutions by the different participants using the snippets	[Sol-ScX-Y] Where X is the number of the scenario (1 or 2) Where Y is the number of the user, from 1 to 11
Post-test	Quantitative ratings and qualitative opinions by the different participants	[Postest-all] and [Postest-X] Where X is the number of the user, from 1 to 11
Observations	Record of direct observations during the experience by 2 researchers.	[Observer1] [Observer2]

3.5.2 Teachers' profiles, opinions and previous experiences with educational games

Participants' average teaching experience is 5 years, in different subject areas. Half of them have a technical background. 75% of teachers teach in secondary education; the rest teaches in higher education. All the participants use technology in their classes, with YouTube (63%), Moodle (45%) and Facebook (36%) the most used tools. All participants rated with 4 or more (in a scale from 1 to 6) the need of using technology in education to enrich the students' learning experiences.

Using a scale from 1 to 6, 70% of the teachers rated with 4 or more the interest of using games in education. Also, 80% of the teachers rated with 4 or more the usefulness of games in education. In this regard, some comments were: "*Educational games can be a complement to the students' learning in other to motivate them*" [Pretest-2], "*Learning by means of games stimulates and motivates students, but designing appropriate games can be difficult for a* *teacher*" [Pretest-5]. These data indicate that teachers perceive educational games as important approaches to support their lessons because technology and gaming motivate students. However, the teachers also recognize that its design is time consuming and they do not have enough resources to easily create their own games. It seems that for this reason teachers tend to adopt mainstream games in their lessons.

Half of participants had adopted or made some variations from existing games. These games were "*collaborative games, avoiding competitiveness, intended to work on retention capacity and strategy*" [Pretest-2], "*games such as memories or scattergories*" [Pretest-4], and "*games to form sentences using cards, to guess famous people*" [Pretest-11]. The other half of participants do not use educational games because "*the devoting time; I prioritize to explain my lessons*" [Pretest-2], "*There are not games covering the topics of my subject*" [Pretest-8] and "*I don't know the technology or the means to include games in my teaching*" [Pretest-6].

3.5.3 Results: Outputs from the design task

The resulting designs created by the teachers were compared to the solutions prototyped for each scenario. The different teachers' profiles did not seem to influence the results of the experiment since their outcomes and opinions were overall quite aligned. Then, the data were aggregately analysed, and it was just indicated the teachers' profiles when appropriate. The comparisons are captured in Tables 5 (scenario 1) and 6 (scenario 2). Each table shows whether the participants used correctly the elements of the conceptual model for designing the puzzle board games.

The percentage of conformity in the total sample for the results of the scenario 1 is 76%, whereby only 1 out of 4 solutions was rated at less than 50%. Despite final solutions, such as [Sol-Sc1-5], were simpler than expected; all participants were able to use and correctly relate the different elements of the conceptual model. Activities' flow was the more problematic element. In order to include several puzzles in a level, it is necessary to include the element activities flow that contains as many activities as puzzles are designed for the level (one activity per puzzle). However, [Sol-

Sc1-2] specified the references of the different activities in the attribute "activity reference" (instead of using the activities flow element), [Sol-Sc1-4] specified for a single activity a group of puzzles instead of creating a puzzle per activity, and [Sol-Sc1-9] used the activities' flow snipped to directly relate the different puzzles for a level, instead of specifying the single activities included within the activities' flow and related each single activity to a puzzle.

Table 5. Participants' solutions' conformity with the prototype solution of scenario 1 (Notation according Table 4)

Scenario 1	Elements	Sol-Sc1-2	Sol-Sc1-4	Sol-Sc1-5	Sol-Sc1-8	Sol-Sc1-9
[s1-1]	*Puzzle game design*	✔	✔	✕	✔	✔
	Level	✔	✔	✔	✔	✔
	Player role	✔	✔	✔	✔	✕
[s1-2]	*Activities flow*	✕	✕	✔	✔	✕
	Activity	✔	✔	✔	✔	✕
	Puzzle	✔	✔	✔	✔	✔
	Piece	✔	✔	✔	✔	✔
	Rel. between pieces	✔	✔	✔	✔	✔
[s1-3]	*Level*	✕	✔	✔	✔	✔
	Activity	✕	✔	✔	✔	✔
[s1-4]	*Puzzle*	✕	✕	✔	✔	✔
	Board	✕	✕	✔	✔	✔
	Piece	✕	✕	✔	✔	✔
	Slot	✕	✕	✔	✔	✔
	Rel. piece-slot	✕	✕	✔	✔	✔
	Use of hints?	No	Yes	Yes	Yes	Yes
Conformity (%)		47%	60%	93%	100%	80%

The percentage of conformity was also affected by the time devoted to design the proposed scenario; participants [Sol-Sc1-2] and [Sol-Sc1-4] (from secondary education schools) did not have enough time to finish their solutions. Two isolated mistakes referred to not using the puzzle board game design snipped to indicate the title, objectives and levels of the games [Sol-Sc1-5]; and duplicate the same player role to different levels of the game [Sol-Sc1-9].

Table 6. Participants' solutions' conformity with the prototype solution of scenario 2 (Notation according Table 4)

Scenario 2	Elements	Sol-Sc2-1	Sol-Sc2-3	Sol-Sc2-6	Sol-Sc2-7	Sol-Sc2-10	Sol-Sc2-11
[s2-1]	*Puzzle game design*	✔	✔	✔	✔	✔	✔
	Level	✔	✔	✔	✔	✔	✔
	Player role	✔	✔	✔	✔	✔	✔
[s2-2]	*Activity*	✔	✔	✔	✔	✔	✔
	Puzzle	✔	✔	✔	✔	✔	✕
	Piece	✕	✔	✔	✕	✔	✕
	Board	✔	✔	✕	✔	✔	✔
[s2-3]	*Slot*	✔	✕	✕	✕	✔	✔
[s2-4]	*Rel. piece-slot*	✔	✔	✔	✔	✔	✔
	Use of hints?	Yes	Yes	Yes	Yes	Yes	Yes
Conformity (%)		89%	89%	78%	78%	100%	78%

The results for scenario 2 show that there is a generally high conformity of the teachers' solutions with the prototype solution. The percentage of conformity in the total sample is 85%. Despite final solutions were simpler than expected, all participants were able to properly use the different elements of the conceptual model. There was only an exception, [Sol-Sc2-6], in which the proposed solution was not satisfactory. The participant associated tag pieces for the pictures of the museum, and virtual pieces for showing chunks of some pictures of the museum. The expected solution was using a board with slots (i.e. QR-codes for pictures of the museum) and pieces (i.e. virtual pieces showing chunks of some pictures of the museum). For this reason, the solution was not considered correct since the participant did not use the expected elements. Besides, the attributes 'virtual' and 'tag', for the pieces (i.e. [Sol-Sc2-1], [Sol-Sc2-7], [Sol-Sc2-11]) and slots (i.e. [Sol-Sc2-3], [Sol-Sc2-6], [Sol-Sc2-7]), were not correctly used in some cases. A concrete error was the [Sol-Sc2-11] that specified both "relation between pieces" and "relation pieces – slots", when only "relation pieces –slots" was correct. However, this specific error seemed to be more related with the graphical design of the snipped than with the formulation of the model elements.

3.5.4 Results: On the design process

Participants encountered some difficulties in the design process in regards to: a) the creation of groups of activities for designing different puzzles for a concrete level of a game, b) referencing the different snippets, and c) the design of the task protocol.

8 out of the 11 participants thought that they correctly understood the elements for the design of the game. However, participants have troubles with understanding some of the elements. The most problematic element was the activity flow [Postest-4-5-7-9-10-11]. In fact, as showed in the previous section, participants [Sol-Sc1-2], [Sol-Sc1-4] and [Sol-Sc1-9] failed at creating activity flows. For instance, some participants indicated "*I considered the activity about clothes as a one activity with various puzzles instead of an activity flow*" [Sol-Sc1-5], and "*I don't distinguish between activity and activity flow*" [Observer 1]. Other problematic elements were the pieces and slots [Postest-2-6-8]. In particular, some participants did not correctly understand the attributes 'virtual' and 'tag' for these two elements [Sol-Sc2-1-3-7]. These misunderstandings were mostly derived from the terminology: "*I don't understand the meaning of some concepts because they are unfamiliar*" [Postest-1], "*what is the difference between puzzle and board?*" [Observer 1].

10 out of the 11 participants understood how to relate the different elements. Participants appreciated the examples showed in the introduction [Postest-4-8], and the use of different colours helps the participants to correctly design the games [Postest-1-5]: "*The colours of the snippets were useful to design the game*" [Observer 1]. However, the participants [Sol-Sc1-2], [Sol-Sc1-4] and [Sol-Sc1-6] had troubles when indicating the 'id' for each snippet. For instance, participant 9 pointed out: "*what does 'id' mean in the different targets?*" [Observer 2].

Task protocol induced some issues to the participants during the design process. Participants felt lost because we did not offered any guidance during the task: "*at the beginning I did not understand anything*" [Postest-3], "*I have some problems to start designing the game, I wasn't sure what to put in each snipped*" [Postest-2], "*I understand the scenario of the game but now, which targets do I take?*" [Observer 1]. However, after some clarifications, all of the participants agreed that they were able to propose a solution: "*once you understand the mechanics, it is easier*" [Postest-4], "*the process is through repetitions, so one can easily become familiar with the process*" [Postest-5], "*It presents a clear structure*" [Postest-9].

Finally, all participants agreed that they would like to design their own games and test them with their students. Besides, when asking the participants how much they would devote to designing their own puzzle board games according to our conceptual model, the average was half a day [Postest-all]. Some comments were: "*If it is effective, I would devoted as much time as it was necessary*" [Postest-4], "*I don't care, I would expend as much time as I need*" [Postest-11].

3.6 Implementation guidelines and authoring tool prototype

Finally, this section aims to propose implementation guidelines to create game-based learning environments compliant with the proposed model, as well as gain insights about the development of an authoring tool. In this line, an authoring tool prototype (see Figure 17) has been created to generate the XMLs compliant with the information model for designing puzzle games (Carreño-Cid, 2012). The tool is implemented as a wizard.

Figure 17. Some screenshots of the authoring tool

First, the teacher specifies the title of the puzzle and the learning goals expected to be achieved by playing the game. Next, the teacher introduces the information associated to the levels for the game. For each level, at least, an activity with its associated puzzle has to be defined. In order to create the puzzle, the teacher selects between creating a puzzle of “relation between pieces” or “relation between pieces and slots”. Depending on this selection, the teacher specifies the demanding information, for instance, the content for the different pieces, slots, hints and the relationships between them. At the end, the different XML documents are automatically generated by the authoring tool.

3.6.1 Exploratory study with teachers

5 teachers from higher education evaluated the authoring tool. For such evaluation we involved the teachers in a game design task. The aim was to test the usability of the authoring tool. In particular, two different scenarios were proposed to the teachers in order to design the game by using the tool:

- “Let's go shopping!”: In this scenario the teacher has to create a game that consists of two levels. The first level is about an activity that shows concrete clothing and the player has to use a set of letters (A-Z) to form the correct name of garment. The second level is an activity that shows, on the one hand, a map of a store that contains some spaces (i.e. slots); and on the other hand, a collection of words. Then the player has to put each word in the correct space. Some resources provided for this scenario are showed in Figure 18.

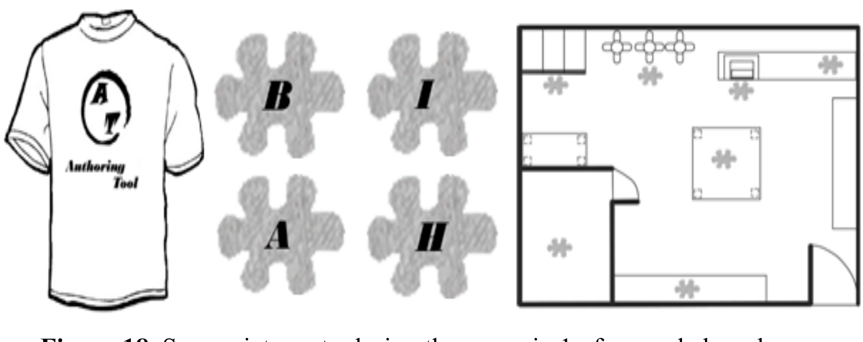

Figure 18. Some pictures to design the scenario 1 of a puzzle board game

- "Visit the Museum of Contemporary Art". In this scenario the teacher has to create a puzzle game that consists on a single level. The level consists in showing a museum map in a handheld device. Different spaces are marked in the map that corresponds to some pictures of the museum. In addition, the game has to show chunks of pictures (each chuck metaphorically corresponds to a piece within the puzzle game). Then, the student has to go to each indicated space in the map. Once there, the student will find a QR-Code to indicate that has find a specific slot of the map and has to select from the collection of chucks of pictures, which one corresponds to the specific slot. Figure 19 shows some resources provided for this scenario.

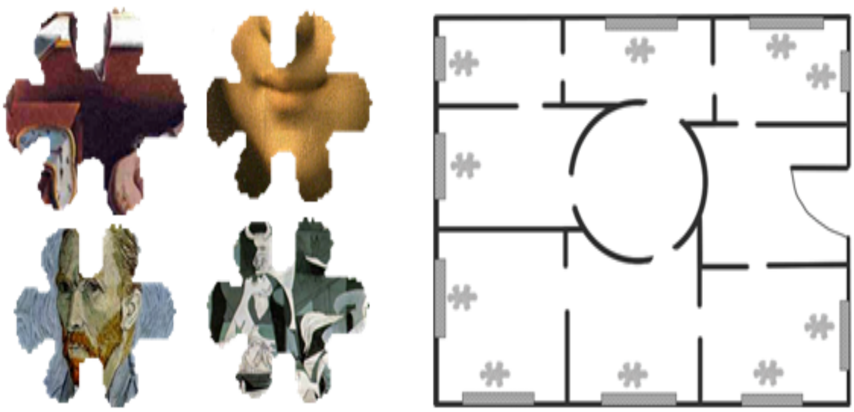

Figure 19. Some pictures to design the scenario 2 of a puzzle board game

After finishing the game design task, the teachers filled out a questionnaire. Results showed that teachers misunderstood some of the concepts associated to the conceptual model that were involved in design the scenario. Specifically, some problems were identified, especially differentiating the attribute "tag", "virtual", and "geolocalized" of both pieces and slots. Besides, although the game design was not found complex and the time invested in creating the puzzle game was the expected, we detected the three main problems:

- The first problem was about adding hints to the activities. This problem was not because of the understanding of the hints themselves, but because *the authoring tool did not provide any* *feedback indicating whether the hints were created correctly*. This was because the authoring tool only returned a feedback when a field was wrongly created or just when some mandatory information was missing.

- The second problem was about discerning between the different relationships that can be established in the design of a particular puzzle (i.e. “relation between pieces” and “relations between pieces and slots”).

- The third main problem that has been observed in the design process was concerned with differentiating attributes “tag”, “virtual” and “geo-located” in both pieces and slots. In this respect, the comments from the participants were: “*If you're not familiar with the vocabulary of the puzzle game design task, it is difficult to understand some of the options. For instance, I don’t understand the differences between tag and virtual*”, “*it would be useful to have a (?) item for each term. I didn’t understand the meaning of ‘Tag’ or ‘Virtual’*”.

In other words, teachers had some initial problems to understand the different types of computer-supported puzzle board games that can be created. This could indicate that different implementations of more specific authoring tools would facilitate the understanding of designing these types of games. A future research line is concerned about implementing specific authoring tools depending on the type of puzzle board game that the teacher aims to create. Also, creating more devoted authoring tools would simplify the game design task (e.g. the teacher won’t have to select among all possible options to create a game; the different options will be only focused on the specific type of puzzle board game). As a consequence, the design process would be less time demanding, more intuitive and easy to understand.

3.6.2 Implementation guidelines

The implementation guidelines introduced in this section should be understood as a possible approach suggested for the actual enactment of puzzle board games.

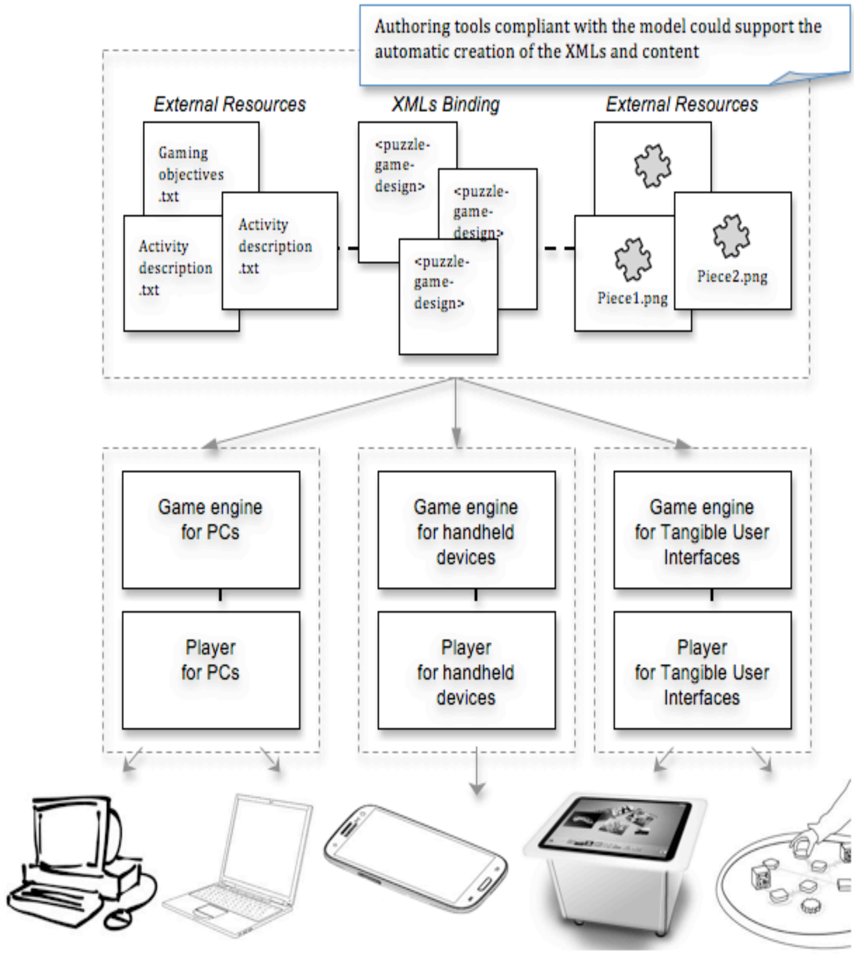

Figure 20. Schema of architectural components for enactment systems

It aims to help game developers with the system design process. Other approaches towards implementation are possible. However, our experience with the early prototype compliant with the model indicates that the recommended implementation architecture (Figure 20) satisfies a trade-off between ad-hoc game developments and generic players. Ad-hoc game developments would be only valid for a single concrete design, what would be against the goal of empowering teachers as designers of games meaningful to their particular situations. Generic players, on the other hand, would require being able of interpreting and playing any design, what would be in contraction of achieving games functional in multiple platforms considering the use of virtual and physical objects and spaces.

As explained, the information binding enables the specification of puzzle board games as a set of XML documents that structures and stores the elements of the overall design including the workflow of the game and the different puzzles associated to each activity. In other words, the information related to the activity flow, the activities that can be played by specific players' roles, and the elements of each puzzle including the properties for pieces (name, virtual vs. physical, position), slots (information, virtual vs. physical, location) and boards, would be stored in the binding. Authoring tools compliant with the model can deal with supporting the automatic creation of the XML documents and content.

Thus, the XML format allows storing the data independently from specific platforms. In this line, depending on the targeted platform, it would be needed, on the one hand, an engine able of interpreting (parsing and instantiating) these packages of information compliant with the puzzle board game model, and on the other hand, a player to execute the live interpretation of the game. Platform-specific engines (e.g., for handheld devices, tangible interfaces…) should read the information contained in the different XML documents and check the different constrains (e.g. to show the activities associated to a player role, to show the puzzle associated to a concrete activity, etc.). Therefore, platform-specific engines need to contain the business logic of the conceptual model for technology-supported puzzle games. The responsible of visualizing and dealing with the content provided by the engine is the platform-specific player. External interfacing can be included in the architecture by providing gateways to other systems (for instance, interoperability with IMS Learning Design compliant management systems will be possible through the inclusion of the games as part of the sequenced learning activities or via the scores of the games, as similarly achieved with IMS Question & Test Interoperability software (Santos, Llobet, Hernández-Leo, & Blat, 2009)).

Furthermore, in line with the proposed implementation guidelines, we could consider the related work of communicating <e-Adventure> with IMS LD (Burgos et al., 2008). Thus, we could also add, depending on the implementation technology, different game-based adaptive services to the corresponding LD engine. Figure 21 shows a proposal of the resulting high-level architecture. As in (Burgos et al., 2008), this layer facilitates the communication between the IMS-LD engine and the services required to support the different game-based learning activities.

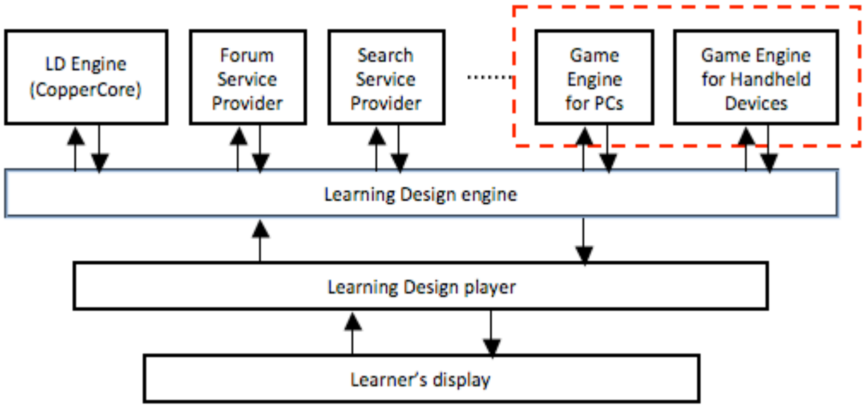

Figure 21. General architecture of communication between the learning flows and educational game services

3.7 Discussion and conclusions

This chapter has been focused on the first contribution of this Doctoral dissertation consisting in a model (conceptual model and XML information binding) that enables expressing diverse types of puzzle board games including virtual and physical objects. The simplicity and generality of puzzle board games make reasonable for teachers to act as their designers. As shown in the chapter, the games that can be computationally represented with the model share the basic rules of games (e.g., scoring and hint mechanisms) and puzzles (e.g., interrelating pieces, considering slots) but allow different types and nature of content (e.g., contextualized in locations, tangible, completely virtual). In this line, the framework proposed by (de Freitas & Oliver, 2006), has been useful to define the general elements needed to conceptualize puzzle games independent from context and interactions, while considering the player's role and activity flow. Besides, focusing on activity flow design, both Game Achievement Model (Amory & Seagram, 2003) and IMS Learning Design (Koper & Olivier, 2004) have been worthy examples to structure and interrelated the different elements of our proposed model. Besides, the implementation guidelines proposed in the chapter shows the feasibility of implementing puzzle-based game boards compliant with the proposed model.

To evaluate to what extent teachers are able to use and understand the different elements of the conceptual model, we carried out an exploratory user study with teachers from secondary and higher education. In particular, two different scenarios were proposed as game design tasks. The overall percentage of conformity for the first scenario (when compared to a prototype solution) was of 76%, whilst in the second scenario was of 85%. The degree of achieved conformity is valued as satisfactory, given that it was the first time the teachers were using the model (still low familiarity) and considering the limitations associated to the experimental design (snippets vs. proper authoring tool). The aspects of the model that hindered a complete conformity were related to difficulties in understanding the differences between activities' flows and single activities, and the virtual and tag attributes for pieces and slots. We will consider these details to refine how the model will be implemented in an authoring tool. Also, this bring us the need of simplifying the representation of the conceptual model to facilitate the teachers the comprehension and understanding of the different elements involved in the conceptual model to design their own games.

CHAPTER 4
DESIGN OF LOCATION-BASED LEARNING GAMES

This chapter addresses the objective of proposing techniques to support teachers in the design of their own location-based learning games for indoors and outdoors. Building on the model presented in the previous chapter, we propose a puzzle board metaphor and associated templates as design techniques for defining location-based learning games. Four real learning contexts are described and evaluated, in which sixteen secondary education teachers were involved in a game design task using the metaphor to define their own location-based learning games. A second iteration of the proposed approach is used by 20 primary and secondary education teachers participating in a workshop on the design of location-based learning games using the puzzle board metaphor. The main contributions of this chapter have been published in (Melero et al., 2013), accepted for publication in (Melero, Hernández-Leo, et al., accepted-a, accepted-b) or are currently under review in (Melero, Hernández-Leo, et al., submitted).

4.1 Introduction

This chapter focuses on the partial objective related to proposing techniques to facilitate teachers the design of their own location-based learning games for indoors and outdoors. In this line, as explained in Chapter 2, one of the findings from an exploratory user study with teachers was to simplify the elements involved in the proposed puzzle board game conceptual model. To this end, we consider the use of metaphors to simplify and represent the abstraction of the conceptual model, as well as to communicate the main concepts, criteria and vocabulary to facilitate teachers the design of location-based games. In fact, metaphors have been widely used in the Human-Computer Interaction field as well-known concepts that facilitate reasoning about design in unfamiliar contexts (Lakoff, 1993; Neale & Carroll, 1997). Besides, Blackwell (2006) collects straightforward advices in relation to metaphors. These advices include: “Metaphors are the tools we use to link highly technical, complex software with the user’s everyday world”

(Weinschenk, Jamar, & Yeo, 1997), "Select a metaphor or analogy for the defined objects... real-world metaphors are most often the best choice" (Galitz, 1997), "Real world metaphors allow users to transfer knowledge about how things should look and work" (Mandel, 1997), and "Metaphors make it easy to learn about unfamiliar objects" (Hill, 1995).

We claim that the use of a metaphor that simplifies the conceptual model for puzzle board games design is a good technique to facilitate the design of location-based learning games. In other words, we claim that the puzzle board metaphor is a flexible approach that can be used by the teachers as a design technique to define location-based games for educational purposes (independent of the subject matter). The reason of adopting puzzle board elements as a metaphor is because some authors have already worked on board games as relevant approaches for being considered location-based games since they can be mapped to real physical places (Nicklas et al., 2001; Schlieder et al., 2006). Particularly, the originality of this work relies on adopting the considerations stated by these authors and putting them into practice in real learning situations. The main conclusions obtained from different evaluations will contribute to the research domain with insights pointing strengths and limitations of using this approach when designing location-based learning games.

Therefore, this chapter focuses on the second contribution of this dissertation. This means, a metaphor that considers puzzle board games to allow teachers the design of their own location-based learning games for indoors and outdoors (see Figure 22). In particular, according to the research methodology, we report the work done in stages 5.1 (particularly, the proposal of a puzzle board metaphor), 6.1 (i.e. Review of the metaphor), and 6.2. (i.e. Evaluation of the metaphor in a workshop session).

The remainder of this chapter is structured as follows. First, we introduce the proposed metaphor based on puzzle board games. In section 4.3, we describe four real learning contexts in which secondary education teachers have been involved in the use of the puzzle board metaphor to design their own location-based learning games. The main findings obtained from an evaluation with these teachers are also reported in this section. Then, section 4.4 describes a second iteration of the use of the metaphor. Considering the lessons learnt from the previous learning experiences, we carry out a workshop with 20 secondary and primary education teachers. The results obtained from the workshop lead to the discussion and conclusions of this chapter.

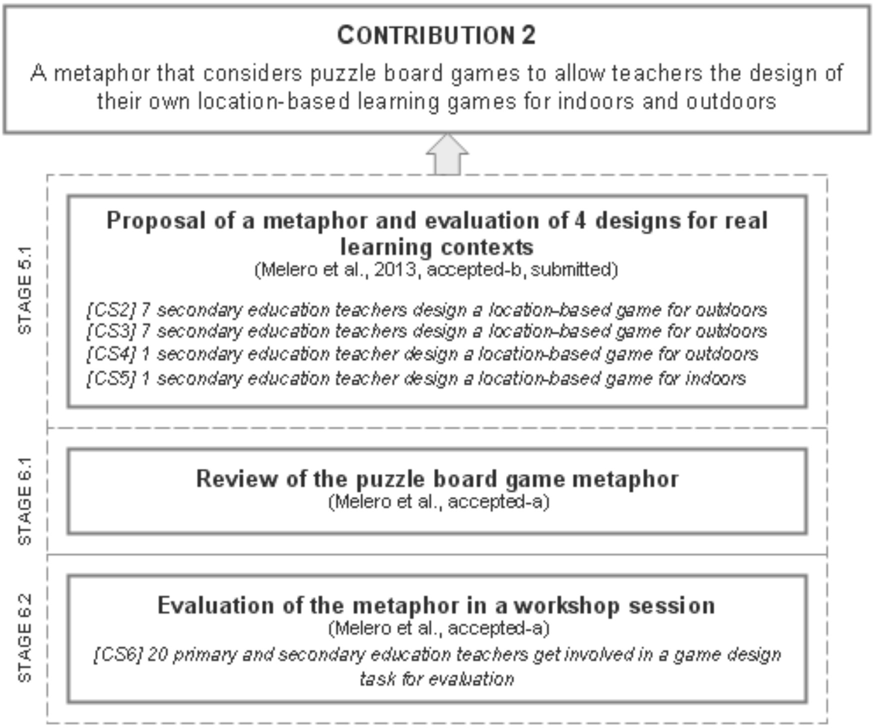

Figure 22. Overview of the tasks performed in relation to the second contribution

4.2 A metaphor based on puzzle board games

The conceptual model and the associated binding, described in Chapter 2, allow the design and implementation of computer-supported puzzle board games. In order to adopt this model for designing and implementing location-based games, we follow the approach of (Bontchev et al., 2002; Bontchev & Vassileva, 2010) consisting in presenting quizzes in map (or board approach) where knowledge from course material is taught in a safe navigation. Then, the puzzle board game will be completed when correctly answering all the questions of the associated quizzes. Besides, the aim of applying this strategy is to engage students in reflecting on the correct solutions for each question proposed by the teacher.

Similarly to jigsaw puzzles, players could try to solve the different questions as many times as needed until reaching a correct solution. We escape from just having one attempt to solve the questions and providing immediate feedback when solutions are incorrect. Instead, students have more chances to solve the questions until finding the right solution. In this way, students have the possibility of finding the correct solutions either by reflecting on their wrong past choices or taking benefit of the resources provided not only by the gamified application itself but also by the information that can be found in the real situ (e.g. information associated to each museum's pictures, museum's employees, etc.).

In order to metaphorically represent location-based game designs using the puzzle board games conceptual model, we identify the most representative elements and propose the following mapping (see Figure 23):

- The "board" is the physical place where the set of questions of a given level is associated.
- The "slots" are the different questions for a particular puzzle.
- The "puzzle pieces" are the different options associated to each question. Just one puzzle piece can fit in a concrete slot, meaning that there is only a correct option for each question.
- The "puzzle" is formed by a board with a set of slots and its associated puzzle pieces.
- The "level" has associated just one puzzle. A designer can define different levels for each location-based learning activity.
- The "points". Several scoring mechanisms are defined to reflect the students' performance: a) correct answers add points to the overall player's scoring, b) incorrect answers subtract points to the overall player's scoring, and c) consulting hints subtract points the overall player's scoring.
- The "bonus" is extra points added to the overall player's scoring once all the questions for a given level have been correctly answered. The extra bonus is a reward to engage and encourage students to correctly complete the different puzzles of the whole learning activity.
- The "feedback" is textual information associated to a specific range of points in order to describe to the students their performance.

- The “hints” can be provided to scaffold the learning process in order to avoid frustrations and advance forward the gamified location-based learning activity.

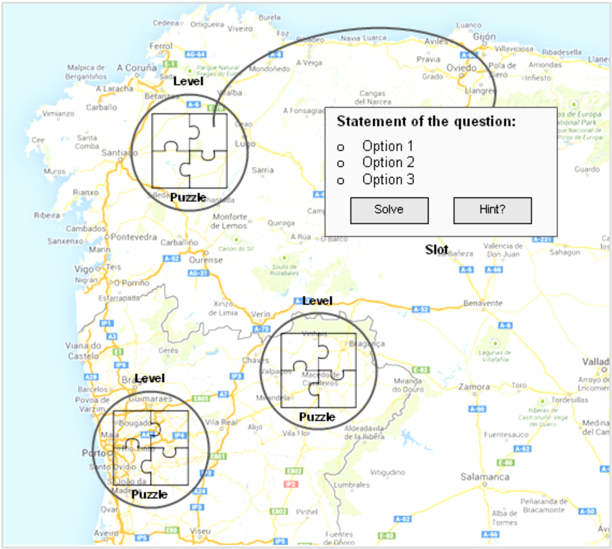

Figure 23. Graphical representation of the puzzle board metaphor

We carried out different case studies in real learning situations in order to evaluate the proposed metaphor compliant with the conceptual model for computationally representing puzzle board games designs described in (Melero, Hernández-Leo, et al., accepted-b).

4.3 First iteration: Teachers’ designs of 4 location-based learning games

16 Secondary education teachers from 4 different charter schools contact us because they were interested in carrying out specific field trips using Smartphones. Then we propose the puzzle board metaphor as a technique to involve the teachers in the design of their particular activities as location-based games. Table 7 summarizes the real learning contexts for each design: a) 7 teachers designed an extracurricular activity with the purpose of discovering and learning about l’Hospitalet (i.e. the city where the school is placed); b) 1 teacher designed an activity associated to its specific subject to formatively assess their students in the art history of the

Vic city; c) 7 teachers designed an activity associated also to a subject with the aim of enquiring about the heritage and the city of Sant Sadurní d'Anoia; and d) 1 teacher designed an activity to practise the concepts associated to different pictures of a National Museum of Contemporary Art (MNAC).

Table 7. General description of the different game design tasks

	l'Hospitalet Case	Vic Case	Sant Sadurní Case	MNAC Case
Teachers Involved	7 teachers	1 teacher	7 teachers	1 teacher
Purpose	Extracurricular activity in the school	Activity associated to a subject, as part of its formative assessment	Transversal activity, as a summative-assessment activity	Activity associated to a subject, as a summative-assessment activity
Context	Discovering and learning about the heritage of the city of l'Hospitalet (their own city)	Learning about the city of Vic and its art history (unfamiliar city for most of the students but studied as part of the curriculum)	Learning about the city of Sant Sadurní d'Anoia and its heritage	Learning about different contemporary pictures of the MNAC

In order to design the different location-based learning games, a set of paper-supported templates containing the different elements of the puzzle board metaphor were provided to the teachers (see Figure 24). Our claim is that the proposed metaphor is understandable and can be applied for designing different location-based learning games according to the teachers' needs. To this end, we asked the teachers to complete the templates with their game design. Several meetings where scheduled where the templates were explained, and the different aspects discussed.

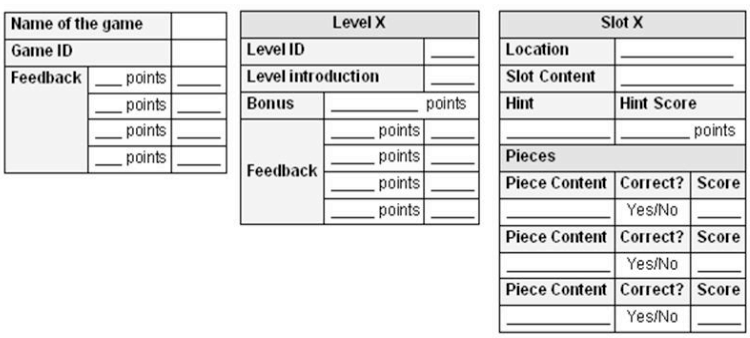

Figure 24. Sample of the templates according to the puzzle board metaphor

Teachers' resulting designs can be summarised as shown in Table 8.

Table 8. Summary of the teachers' designs

	l'Hospitalet Case	**Vic Case**	**Sant Sadurní Case**	**MNAC Case**
Number Levels	10 levels	4 levels	8 levels	4 levels
Number Questions	58 questions	75 questions	64 questions	20 questions
Points Correct Answers	250 points more	1 point more	Number of questions per level / 1000 points	50 points more
Points Incorrect Answers	100 points less	0.3 points less the first attempt, 0.5 point the second one, 1 point the third one	30 or 60, depending on the number of questions per level	10 points less
Number Hints	52 hints	25 hints	64 hints	19 hints
Points Hints	100 points less	0.2 points less	50 or 100, depending on the number of questions per level	50 points less
Extra Bonus	Proportional to the number of questions per level	1.5 points more when all the questions correctly answered at the first attempt, 0.75 points otherwise	100 or 150, depending on the number of questions per level	50 points more
Hints Content	Suggestions rather than clues (ask people, read the information that appears next to the statue, etc.)	Short text about the context related to the question	Suggestions rather than clues (ask people, read the information that appears next to the statue, etc.)	Short text about the context related to the question
Levels Information	General information about the zone and particular information about the questions	Short sentence of the geographical zone	Information related to the task that students have to perform in a specific location	Short sentence about the museum's room
Feedback Messages	Informal	Formal	Informal	Informal

From the designs we can observe that teachers were able to specify as many levels and questions as they wanted. Some teachers followed a scoring mechanism more familiar to traditional test (e.g., Vic), whilst others designed a more game-based scoring mechanism (e.g., l'Hospitalet). Also, depending on the teachers' decisions, some of them designed hints more similar to suggestions (e.g., l'Hospitalet), while other teachers offered additional information as a clue to solve the different questions (e.g., MNAC). Besides, differences in the language were found depending on the teachers' designs: while the feedback of some designs was written in a formal way, others were more informal. Considering the content of the templates filled by the different teachers, we created the computational representation compliant with the conceptual model binding for puzzle board games design (Melero & Hernández-Leo, in press). Therefore, each gamified location-based learning activity was implemented in a different instance of the "QuesTInSitu: The Game" application.

4.3.1 Evaluation of teachers' designs

The secondary education teachers designed their own location-based learning games by using the different paper-based templates. We follow up the different teachers' design processes via email or scheduled meetings. When the design process was finished, we implemented the resulted designs and enacted them with their own secondary education students (see Chapter 5). Once the enactment with students was carried out, the teachers filled a questionnaire evaluating the perceived usefulness of the proposed metaphor, the understanding of the different elements involved in the game design task, as well as the importance and possible issues from each of the puzzle and game elements. In particular, while all the teachers from l'Hospitalet, MNAC and Vic answered the questionnaires, only 2 out of the 7 teachers from Sant Sadurni (i.e. the coordinators of the design activity) did it.

Overall, the teachers perceived the use of the puzzle board metaphor as a flexible approach and a suitable design technique to define location-based learning games. The different opinions converge stating that the designed location-based learning games are "*stimulating; the metaphor moves away from the heavy* *exercises from class and situates the students in a funnier environment*" [T-Hospi-1], an approach with a lot of educational and learning benefits, such as "*researching, discovering the environment and the heritage, a good approach that fosters the collaboration*" [T-Hospi-5], "*promotes working in group, the interest, sharing and interacting with other people, decision making*" [T-Santsa-1], and approach that can be "*motivating and entertaining*" [T-MNAC-1]. Besides, the use of the metaphor did not limit the creation of the different location-based learning games [Hospi-1-2-4-5-6-7][T-Santsa-1-2][T-MNAC-1]. More concrete comments were: "*I don't think that the metaphor presents limitations*" [T-Hospi-1-2], "*not limitations but changing the way the activity has to be designed*" [T-Hospi-5-6]. However, one specific limitation was "*to define different routes per each group. I think it should be better that each group of students could define their own path*" [T-Vic-1].

Overall, the teachers easily understood most of the elements of the game design. Teachers did not have problems when designing the scoring, the bonus points, or the feedback mechanisms. However, the most problematic issue concerned the understanding of the level element. This issue appeared in l'Hospitalet case, in which a brief explanation of the element was provided. The rest of the case studies did not specify this concrete issue, since we indicated that the level element typically refers to specific physical zones or geographical areas. Specifically, the results supporting these assertions are the following ones. The teachers quite or totally agreed on: a) the bonus as a mechanism to motivate students (10/11), b) the scoring and feedback as mechanisms to inform the students about their actions (10/11), and c) the hints as a mechanism to help students reflect on their decisions (10/11). Similarly, the results from the questionnaires showed that 9 out of 11 of the teachers quite or totally agree that hints allow the students to progress through the game. Furthermore, concrete results regarding the understanding of the different elements of the metaphors were the following. Most of the teachers quite or totally agreed that they did not have problems understanding the meaning of the concepts the bonus (10/11) and the hints (9/11). Regarding the feedback when completing a level of the game, more teachers quite or totally agreed on understanding this element (6/11) compared to those who did not (3/11). Similar results were obtained regarding the feedback when completing the whole game. While 5 out of the 11 teachers quite or totally said to understand this element, 2 teachers did not. However most of the elements were understandable by the teachers, the most problematic ones seemed to be the levels followed by the slots. 7 out of the 11 teachers totally or quite agreed on having difficulties to understand the meaning of a level. Some comments were: "*It is difficult the design by levels*" [T-Hospi-3], and "*The more problematic element was to differentiate between zone and level. We understand zone while you said level; and we associate level to difficulty degree*" [T-Hospi-4]. Similarly, 6 out of the 11 teachers totally or quite agreed on having difficulties to understand the meaning of a slot. Overall, it seems that most difficulties regarding the understanding of the elements appeared at the beginning of the game design task but once explained, it become clear. Some comments support this assumption: "*At the beginning, I have some difficulties understanding the dynamic because I join to the work group later*" [T-Hospi-3], "*The difficulty was at the beginning when presenting the different elements*" [T-Hospi-5]. It is interesting to notice is that the teachers with more problems were from l'Hospitalet case (first case study), while the teachers from Vic and Sant Sadurní did not report specific problems. In this regard, one of the teachers pointed out that "*In general, I have no problems*" [T-Vic-1], and "*It was easy because we perfectly understand the dynamics of the game*" [T-Santsa-2]. We believe this is a result of having refined the definitions of the elements involved in the metaphor, including the case of the level element to which a supporting explanation was attached indicating that this element do not refer only to difficulty but it can be also a way to define different zones or places when designing gamified location-based learning activities.

Regarding the importance of the elements, the adapted scoring, followed by the bonus points and the feedback seem to be in the top positions. 10 out of the 11 teachers totally or quite agreed on considering the adapted scoring the most important element. Also, 8 out of the 11 teachers totally or quite agreed on considering the bonus as an important element to motivate the students during the game. Slightly positive ratings were also obtained in regards to the feedback (6/11 teachers totally or quite agreed on this). However, just 4 out of the 11 teachers quite or totally agreed on the importance of providing hints to each question. Some comments were about the complexity of creating hints associated to each question [O-Hospi-1-2][O-MNAC-1]: "*I found some difficulties when designing the hints; questions were focused and designing hints that aren't too obvious was difficult*" [T-MNAC-1]. However, half of the teachers thought that providing hints to each question was not very important or not important at all. In this line, some teachers highlighted that not all the questions had hints because it did not make sense and its design would imply a relatively high workload [O-Hospi-1-2].

4.3.2 Discussion

In the particular case of this four real learning context, the approach successfully enables the creation of location-based learning games depending on the teachers' needs. In fact, the proposed metaphor has been successfully applied as a design tool using paper-based templates to create four location-based learning games. Even though based on the same design model, the resulting games were different serving diverse purposes depending on the educational situation and teachers' creativity. They have different amounts of levels and questions, the feedback was designed in either informal or formal ways, different scoring mechanisms were formulated (i.e. one following a more traditional test-based approach and the others following a more game-based approach), and different strategies were followed to design the hints (suggestions vs. clues).

The proposed metaphor and the use of templates have been proved to be a flexible and feasible technique to design location-based learning games considering the teachers requirements. Besides, the teachers do not only perceive potential learning benefits from the use of the puzzle board metaphor but they also agree that the metaphor did not limit their designs. However, before using the metaphor, an explanation of the dynamics and their different elements is needed to appropriately use and understand how the location-based learning games should be designed. Because of the limited explanation in these cases, teachers had particular doubts regarding the mechanisms of the level element. This issue was tackled by indicating that the level element - when designing location-based learning activities - may refer typically to specific physical zones or geographical areas.

The teachers perceived as useful the proposed technique to design location-based learning games, highlighting its possibilities and potential educational benefits. The proposed puzzle board metaphor has been found stimulating and a good approach to motivate students. The teachers have perceived that puzzle board games elements can help students reflect on their mistakes. Besides, scoring and feedbacks were considered good strategies to engage students during the game. Besides, the teacher from the MNAC case really appreciated having the possibility of adaptive scoring depending on the students' choices. However, this teacher also pointed out that the design of points (when compared to the traditional calculation of marks in test) hinders a straightforward interpretation of what questions have been problematic. This concern suggests that further research lines should consider the provision of learning analytics offering teachers detailed information about the activity, such as how many times the students have failed each question.

Regarding the understanding of the elements considered in the game design task, results show that only the "level" element was the most troubled (using geographical-related vocabulary as examples improved understanding, i.e. "levels" represent "zones"). Teachers needed some time to internalize the different elements; some problems understanding how to apply some of the elements where detected at the beginning of the game design process. In this line, teachers understood easier the elements related to games (e.g.: hints or bonus) than those related to puzzles (e.g.: pieces, slots). Thus, it is crucial to be careful when presenting the puzzle board metaphor in order to foster the teachers' understanding. It is important a good initial explanation about the different elements and providing significant examples showing the applicability of them, as well as, supporting the teachers at the beginning of the design task.

From all the elements of the conceptual model, an especial attention deserves the use of hints. Nevertheless, the design of hints has been the most demanding element, since the purpose of the teachers was to not create obvious hints that can directly reveal the correct answer. Designing sound hints implies significant teachers' workload. In this sense, the teacher suggests to not associate hints to all the questions but only to those where this kind of help makes special sense. Besides, it will be important to analyse the impact that all these designed elements have on students. Students are the final users of the designed activities, and they will provide us with useful information about how they consider the inclusion of the free hints or bonus in gamified location-based learning activities.

Future research lines also include understanding the reasons about why the dynamics of answering the different questions does not make sense to some of the teachers, as well as a more clear definition of what elements will be important to consider for future experiments.

4.4 Second iteration: MWC workshop

The first iteration of design-based research methodology has shown the feasibility of applying the proposed approach when designing location-based learning games (Melero & Hernández-Leo, in press; Melero et al., 2013). Besides, previous results indicated that the teachers were able to design their own activities, but some issues were detected that required further improvements in the proposed metaphor and the way it is applied. These include: a detailed explanation of both the dynamics and the different elements of the puzzle board metaphor to appropriately design the location-based learning games; and a better definition about the "level" element.

A revision of the design task was carried out. Two considerations were made: 1) a need of devoting more time in the explanation and provision of more examples in relation to the puzzle board metaphor; and 2) a reformulation in the definition of the "level" element, indicating that it may typically refer to specific physical zones or geographical areas (not only difficulty). Thus, a second iteration was completed in a workshop session (see Figure 25) involving 20 teachers in a game design task.

The aim was to evaluate these changes with primary and secondary education teachers. Besides, the workshop session aimed at evaluating the metaphor as a suitable technique to design location-based learning games in different educational levels. The evaluation was focused on analysing the acceptance of the proposed puzzle board metaphor by the teachers, and the feasibility of using this approach to create location-based learning games with different educational purposes and education levels (not only secondary education).

Figure 25. Picture of the workshop session

The workshop session was divided as follows:

- Introduction (30 min). First, we introduced the context of the workshop focused on designing gamified m-learning activities. Then, we presented the puzzle board metaphor and a description of the different elements involved in the metaphor to design location-based learning games. Several examples of using the metaphor in real learning contexts (e.g. (Melero et al., 2013)) were also described in order to facilitate the teachers' comprehension of the proposed approach.
- 1st Questionnaire (15 min). The teachers were asked to fill a questionnaire concerning the different aspects presented before. In particular, we asked them to: a) give an opinion about the perceived benefits of using the puzzle board metaphor in m-learning activities; b) rate the importance of the elements involved in the metaphor, and the difficulties understanding these elements; and c) highlight the aspects that (positively or negatively) caught their attention.
- Game design task (60 min). The teachers were engaged in designing a gamified location-based m-learning activity meaningful to their particular teaching practices. In this sense, we encouraged teachers to think about an m-learning activity relevant to their teaching practices and provided the teachers with a set of templates (see Figure 26), conforming the proposed puzzle board metaphor. These templates aimed to facilitate the

design of the structure and content of their location-based learning game.

TITLE OF THE GAMIFIED ACTIVITY *Name to identify the gamified activity design*		
Description *General description about the game design (purpose of the game, learning objectives, etc.)*		
General Feedback *Message that appears at the end of the game when all the levels have been completed. Several intervals of points have to be defined, as well as their associated textual message (feedback).*	points	
	points	
	points	
	points	

LEVEL o ZONE *You can use as many 'level'/'zone' tables as you want*		
Level/Zone Name *Short name identifying the level/zone*		
Level/Zone Introduction *Text that either describes the level's (zone's) objectives or contextualizes the group of slots (questions)*		
Bonus *Extra points obtained when correctly answering all the group of slots (questions) for the particular level*		
Level Feedback *Message that appears in relation with the obtained points once the level has been completed. Several intervals of points have to be defined, as well as their associated textual message (feedback).*	points	
	points	
	points	
	points	

SLOT *A slot is an empty space in a concrete point of a map where students have to go to solve a learning activity* *You can use as many "slot" tables as you want*					
Localization *Location-based point where the slot is placed*					
Slot Content *Statement describing the learning activity (e.g. question) that the students have to solve*					
Puzzle pieces *Possible options to solve the learning activity. You can add as many puzzle pieces as you want.*					
Piece Content *Text identifying the piece (e.g. possible answer)*		**Correct?** *Indicates whether the piece is correct or not*	Yes/No	**Punctuation** *Amount of added (subtracted) points depending on whether the piece is correct (incorrect)*	
Piece Content *Text identifying the piece (e.g. possible answer)*		**Correct?** *Indicates whether the piece is correct or not*	Yes/No	**Punctuation** *Amount of added (subtracted) points depending on whether the piece is correct (incorrect)*	
Piece Content *Text identifying the piece (e.g. possible answer)*		**Correct?** *Indicates whether the piece is correct or not*	Yes/No	**Punctuation** *Amount of added (subtracted) points depending on whether the piece is correct (incorrect)*	
Hint *Information to help solve the learning activity*					
				Hint points *Amount of subtracted points when consulting the hint*	

Figure 26. Templates for designing location-based learning games

- 2nd Questionnaire (15 min). After finishing the game design task, each teacher filled out a second questionnaire about the use of the templates. Particularly, we asked them to: a) describe whether the use of the templates constrains the design of the m-learning activity or not; b) rate the difficulty of understanding the different elements of the templates; and c) specify the steps followed to design the m-learning activity.
- Test a demo game (45 min). The teachers, using their own smartphones, were able to test a mobile application demo of an implemented example of a location-based learning game following the puzzle board metaphor. This demo contained 2 levels, and 3 multiple-choice questions per level about different locations near the place where the workshop was carried out.
- Discussion group (45 min). Finally, a discussion group with the teachers was carried out to share the main impressions about the use of the puzzle board metaphor.

4.4.1 Evaluation of teachers' designs

A mixed method has been followed (Cairns & Cox, 2008) including several data sources have been used (see Table 9) to evaluate different aspects of the proposed metaphor and the teachers' game designs. The obtained qualitative and quantitative gathered data have been combined and triangulated (Guba, 1981). Quantitative data, obtained from the ratings given by the teachers in the questionnaires, provide insights into teachers' acceptance about the metaphor. This obtained information will be supported or rejected by the qualitative data (Guba, 1981).

Table 9. Data gathering techniques used in the workshop session

Data source	Type of data	Label
First Questionnaire	Quantitative ratings and qualitative opinions by the different participants	[1st-Quest-X] Where X is the number of the participant, from 1 to 20
Second Questionnaire	Quantitative ratings and qualitative opinions by the different participants	[2nd-Quest-Y] Where Y is the number of the participant, from 1 to 13
Game Designs	Paper-based templates that capture the game designs	[Design-Y] Where Y is the number assigned to a design, from 1 to 11
Observations	Record of direct observations taken during the discussion group	[Observation]

The teachers were provided with a set of templates intended to allow them to design a location-based learning game that could contain 2 levels and 6 questions. 7 teachers did not get involved in the game design tasks. Some of them have to leave the room because of personal matters, but others expected to use an authoring tool to perform the task. Some comments were: "*I think it would be more interesting to use the application*" [1st-Quest-15], "*Disappointed to not could use the authoring tool*" [1st-Quest-19].

11 location-based learning game designs resulted from this task. 9 participants individually designed their own activity, while 4 participants did it in pairs. 3 of these learning games were designed for primary education [Design-2-6-7], 6 for secondary education [Design-1-3-5-8-10-11], and 2 designs did not specify the educational level [Design-4-9]. Besides, the learning games were designed for different subject matters: natural science [Design-1-7], multidisciplinary activity (physical education, technology, etc.) [Design-2-3-4-9], arts [Design-5-11], literature [Design-6], technology [Design-8], and social science [Design-10]. In particular, the purpose of each design was:

- An activity about Olot's volcanos [Design-1],
- A walking tour in Barcelona to discover different monuments [Design-2],
- An activity for discovering the city of El Prat [Design-3],
- A gymkhana in Ripoll's river [Design-4],
- An activity in the school yard about several well-known design objects [Design-5],
- A learning route about the streets of Sabadell named with popular poets names [Design-6],
- A location-based activity in the Zoo of Barcelona about wild animals [Design-7],
- A learning activity about structures, types, and functionalities, history of different buildings and/or materials [Design-8],
- An activity about the recognition of certain landscape features near the high school [Design-9],
- A route for different economic institutions [Design-10],
- An activity about modernist buildings in Barcelona [Design-11].

Teachers followed different approaches to design the content of the different levels. In particular, the information of the levels was designed as a description of the geographical zone in which the questions are located [Design-1-2-7], as textual information about the content of the questions [Design-5-8], or as instructions about the dynamics of the game for the particular level [Design-4-9-11]. The rest of participants [Design-3-6-10] did not fill out the information associated to levels' content.

Paying attention to the designed hints, 9 out of the 11 gamified m-learning activities included hints as additional information about the statement of the questions [Design-1-3-4-5-6-7-8-9-11]. Only 1 participant used the hints' content to indicate possible ways to find useful information to answer the questions [Design-2].

About the design of scoring mechanisms two approaches were followed: one more oriented to traditional tests (e.g. 1 point correct answers, -0.3 points incorrect answers) [Design-3-11], and other more oriented to games (e.g. 100 or 50 points correct answers, 50 or 10 points incorrect answers) [Design-1-2-4-5-6-7-8-9-10]. Besides, different bonus strategies were followed in which participants indicated: the same amount of points as for correct answers [Design-3-4-5-7-11], higher amount of points than correct answers [Design-8-10], and lower amount of points than correct answers [Design-1-5-9]. Furthermore, considering the design of points when accessing the hints, several approaches were also followed. Some participants chose to subtract: the same points as with incorrect answers [Design-1-5], higher points than with incorrect answers [Design-3-7], and lower points than with incorrect answers [Design-2-4-8-9-10-11].

4.4.2 Evaluation of the design process

In general, the teachers had no problems understanding the different elements involved in the proposed puzzle board metaphor. Specifically, all the teachers quite or totally agreed that they did not have problems understanding the role of "slots", "bonus points", "hints", and feedback associated to the completeness of a level and the whole game. Also, 19 out of the 20 teachers quite or totally agreed that they understood the meaning of a "level" and a "puzzle piece". Some gathered comments were: "*The elements are very clear and understandable*" [1st-Quest-1]. One of the teachers said, "*I think it is difficult to implement this approach in Primary*

Education. I should have played the game before trying to do my own design, because I had difficulties understanding how to apply this approach in my teaching practices" [1st-Quest-14]. However, as one of the teachers indicated "*I think this approach could be perfectly implemented in primary education. Besides, it is a good approach to interpret maps and put in practice orientation skills*" [Observation].

Paying attention to the definitions of each element involved in the puzzle board metaphor the results were as follows. Two thirds of the teachers (14/20) quite or totally agreed on the definition of allowing students to solve each question as many times as needed until reaching the correct solution. After the game design task, some teachers pointed out that the number of trials to solve a question should have a maximum attempt limit, in order to be meaningful: "*I think the questions should not be answered indefinitely. Otherwise, the students could do trial and error*" [1st-Quest-3], "*I think that giving the possibility to answer the questions as many times as necessary could promote trial and error*" [1st-Quest-4], "*I would set up a maximum number of attempts*" [1st-Quest-13], "*if students have a limit amount of attempts to solve the questions, I think they would pay more attention*" [Observation]. However, each element involved in the puzzle board metaphor should not be seen as a standalone item as agreed in the discussion group: "*in order to make a right use of attempts when answering the different questions (to avoid trial and error), the scoring should be designed accordingly*" [Observation]. Besides, all the teachers totally agreed that the hints allow guiding the students to find the correct answers. However, two thirds of the teachers (15/ 20) indicated that hints should be designed in those cases that make them relevant. Otherwise, designing hints could become a tough task: "*we did not design hints to motivate more the exploration*" [Observation], "*I have problems to define hints that were not obvious*" [Observation]. 17 out of the 20 teachers quite or totally agreed that bonus points are a good mechanism to motivate students. Indeed, 14 out of the 20 teachers quite or totally agreed on the importance of rewarding students with an extra bonus when all questions for a given level have been correctly answered. Also, almost all the teachers (19/20) quite or totally agreed on the importance of providing feedback and adapted scores depending on the number of attempts when solving questions. Furthermore, 18 out of the 20 teachers quite or totally agreed that the points and feedbacks are good approaches to reflect the correct and incorrect students' actions. Some comments were: "*Feedback is indispensable when learning*" [1st-Quest-17]. However, despite of the perceived usefulness and importance of adapted scoring mechanisms and feedback, some difficulties aroused: "*I found difficult to design the intervals for the scoring mechanisms*" [2nd-Quest-13], "*I think higher points, similar to games (such as tetris), would engage more the students in the learning activity task*" [Observation], "*I had to be very careful with the different amount of points to design a meaningful activity*" [Observation], and "*I was not sure about the amount of points to define as bonus*" [Observation]. These results indicate that despite the elements involved in the metaphor are understandable, in some cases (e.g. designing scores), it is necessary to provide teachers with some kind of recommendations considering their particular requirements.

Once the teachers finished the game design task, they filled out a questionnaire intended to gather major impressions about the metaphor and use of the templates in the design task. Concerning the question "*Will you find useful the puzzle board metaphor to create your own m-learning activity?*", all the 13 teachers agreed that they would use the proposed approach to design their own gamified m-learning activities. Some comments were: "*This approach could be implemented in different subject topics of mine*" [2nd-Quest-9], and "*I would definitely use this approach to design punctual activities such as field trips*" [2nd-Quest-3]. Besides, the teachers highlighted several educational benefits such as puzzle board metaphor can be considered as a motivating approach [2nd-Quest-2-3-13] that encourages students to outperforming themselves [2nd-Quest-4], promotes learning in groups [2nd-Quest-5-7-8-12], and students become more actively engaged [2nd-Quest-5-10].

When asking the teachers about the use of paper-based templates, all the teachers considered the templates a useful approach to structure the design of their location-based games. Some comments were: "*the templates help to structure the information*" [2nd-Quest-7], "*[...] to structure the whole game*" [2nd-Quest-3], and "*I understood all the elements*" [2nd-Quest-11]. Also, most of the teachers quite or totally agreed on the user-friendliness of the templates for designing the levels (9/13), slots (9/13), puzzle pieces (10/13), scoring (10/13), hints (9/13), and feedbacks (9/13).

Finally, we asked the teachers to order a list of actions according to their process when designing the gamified learning activity: a) fill the information according to the both game's title and description; b) indicate the level's (zone's) name and description; c) define the level's scoring and feedback; d) specify the slot's description; e) define the hint associated to a slot; f) define the overall scoring and feedback of the game; g) define the bonus associated to a level; h) indicate the localization of the slots; i) define the points associated to the slot's answers; and j) define the points associated to the hints. In this line, all the participants started defining the game's name and its description, followed by the level's name and its description as well. But after this, participants followed different paths for designing their m-learning activities. For instance, some of them continued their design process by defining the slot's description [2nd-Quest-2-5-7-8-13] and others by indicating the localization of the slots [2nd-Quest-3-10-11-12].

4.5 Conclusions

Over the past years teachers have been facing the integration of technology in their teaching practices. Most of the time adopting new technological approaches in actual educational settings has been a hard challenge for teachers. In the context of m-learning, the use of handheld devices has been proved relevant not only because of the educational benefits that their use can potentially bring if their use is pedagogically sound, but also because of their ease-of-use and low-cost implementation. However, the adoption of this type of technological learning environments still presents some challenges when involving teachers in their design .

Some research efforts have been done towards supporting teachers in the creation of game-based learning environments. Nevertheless, most of these tools have reported problems, such as being hard to adapt to specific teaching practices, requiring too many resources and too much time for development. Then, it seems relevant to provide teachers with approaches that facilitate the design of meaningful gamified m-learning environments to their specific educational situations.

According to the second contribution of this thesis, this chapter has described two techniques based on a puzzle board metaphor and paper-based templates to facilitate teachers the design of their own location-based games. These techniques have been proposed as a way to facilitate teacher the comprehension of the game design task. In fact, both techniques have been proved to serve as feasible strategies to allow teachers the design of their own location-based games.

Particularly, in the frame of a design-based research methodology, the chapter presents two iterations in the formulation of the metaphor and the associated design process. In first iteration, the proposed metaphor has been proved to be a flexible and feasible technique to design location-based games considering the teachers' requirements. Besides, the teachers do not only perceive potential learning benefits from the use of the puzzle board metaphor but they also agree that the metaphor did not limit their designs. However, because of a limited explanation, teachers had doubts regarding the mechanisms of the level element. Then, this issue was tackled in the iterated approach by some changes performed in the definition of the "level" element and the dynamic of the game design task.

Before implementing an authoring tool compliant with the proposed metaphor, we believe that it is important to analyse the perceived usefulness and possible weaknesses. In this way, the puzzle board metaphor has been assured as suitable to design location-based games. Previous experiments, despite of some misunderstandings, have reported the feasibility of designing and enacting location-based learning games for secondary education. Teachers perceived the proposed approach relevant to their teaching practices. Besides, the enactment with secondary education students revealed that the proposed approach promoted students being more active when solving the designed questions. Specifically, students tried to avoid losing points by paying more attention to elements of the physical place, asking people and searching the Internet. Further research was needed to analyse a second iteration of the metaphor in different educational levels. This second iteration, presented in this chapter, has reported that elements involved in the puzzle board metaphor were properly understood. Different location-based game designs for primary and secondary education resulted from the task in which participants were involved. In fact, participants were able to design their own m-learning activities according to their specific requirements.

Furthermore, when designing location-based learning games it is important to notice that design elements may impact each other. In other words, different elements involved when designing this type of activities should not be treated in isolation. For instance, the design of the scoring mechanisms can influence on students' behaviours when deciding whether answering questions or accessing to the hints.

Paper-based templates have been proved to be a good technique to put into real practice the puzzle board metaphor. The templates have been useful to structure the content of the designed location-based games. Also, this paper-based approach gives insights towards the design and the development of an authoring tool compliant with the puzzle board metaphor. In this context, the authoring tool has to be flexible enough to allow teachers to follow different paths when designing their own location-based games. Besides, when teachers defined the scoring mechanisms, they can follow different strategies: adding/subtracting higher amount of points (e.g. 100 points correct answers, -50 points incorrect answers) versus following a more traditional assessment approach (e.g. 1 point correct answers, -0.3 points incorrect answers). In this sense, teachers were concerned about what strategy would be more suitable to their particular educational situation. Thus, it would be advisable to integrate some kind of guidance for teachers with suggestions related to scoring strategies that can be followed depending on their educational needs.

Finally, the resulted designs are to implemented and enacted in real learning situations to analyse their impact on students.

CHAPTER 5

IMPLEMENTATION OF LOCATION-BASED LEARNING GAMES

This chapter describes the implementation of four location-based learning games designed by secondary education teachers. “QuesTInSitu: The Game” is presented as the mobile application compliant with the conceptual model for puzzle board games designs that allows the implementation of location-based learning games. The enactments of the location-based game designs, as well as the findings from the different evaluations, are also reported in the chapter. The main contributions of this chapter have been conditionally accepted for publication in (Melero, Sun, et al., conditionally accepted), and submitted in (Melero, Hernández-Leo, et al., submitted).

5.1 Introduction

This chapter is focused on describing the implementation of the four location-based learning games designs that have been explained in section 4.3. We consider the information provided on the templates filled by the different teachers to develop a mobile application compliant with the conceptual model for designing computer-supported puzzle board games.

According to the research methodology followed, this chapter is focused on describing the results of the tasks performed in Stage 5.2 to achieve the contribution 3 (see Figure 27). The remainder of the chapter is structured as follows. First, we describe “QuesTInSitu: The Game”, the mobile application for location-based games that is compliant with the conceptual model for designing puzzle board games. Following section is focused on describing the evaluation results of the enactment of the four real learning contexts. On the one hand, this section focuses on qualitative opinions and ratings to report students’ engagement about the proposed approach. On the other hand, we particularly describe a case in with students’ activity performance has been evaluated in terms of a score obtained in a post-test. Finally, next section focuses on the importance of supporting teachers’ inquiry to detect the game design elements that requires further improvements.

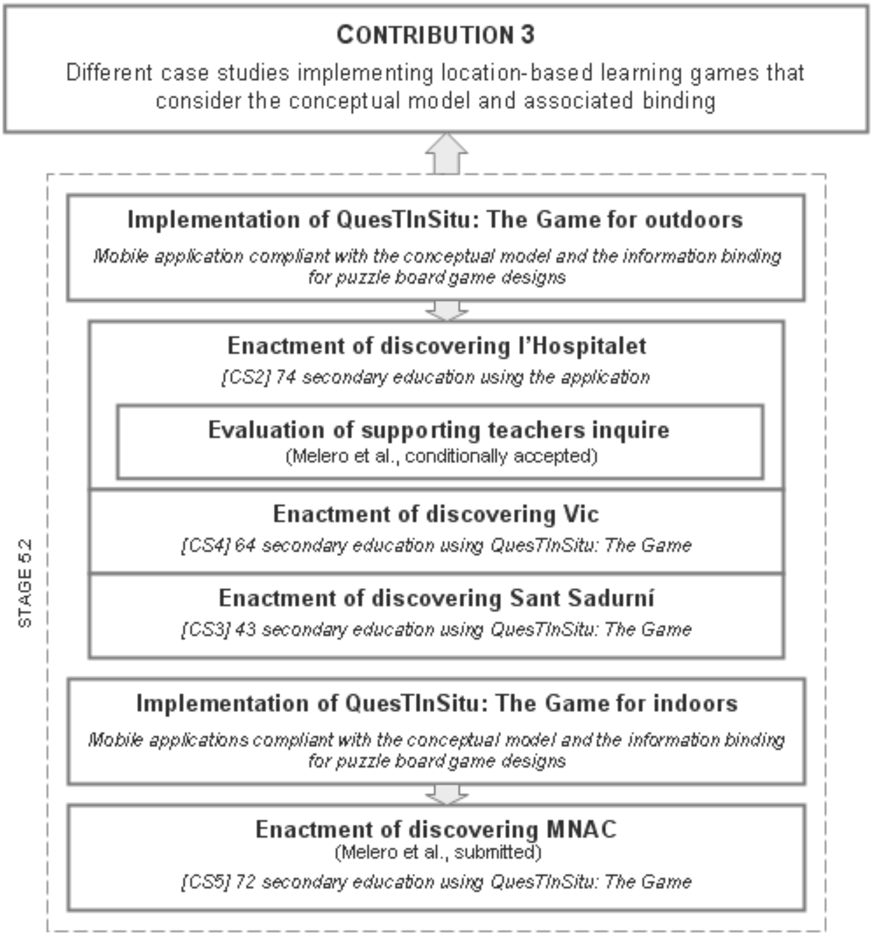

Figure 27. Overview of the tasks performed in relation to the third contribution

5.2 "QuesTInSitu: The Game": a mobile application for location-based learning games

"QuesTInSitu: The Game" is a mobile application compliant with the conceptual model for puzzle board game design, presented in Chapter 3 (Melero & Hernández-Leo, in press). The application, an enhanced version of the "QuesTInSitu" (Santos, Pérez-Sanagustín, Hernández-Leo, & Blat, 2011; Santos, 2011), interprets the teachers' designs compliant with the puzzle board metaphor.

In former version of "QuesTInSitu" (Santos et al., 2011; Santos, 2011), teachers designed routes of geolocated questions based on traditional tests. That means, student only have one attempt to solve each geolocated question, and direct feedback is provided after answering questions. Overall, “QuesTInSitu” aimed to implement augmented traditional tests associated to real physical places. Besides, considering the benefits of educational standards, this version of the application extended the IMS Question and Test Interoperability specification to create interoperable implementations consisting of routes of geolocated questions (Santos et al., 2009). Previous research experiments reported that students achieve and practice specific knowledge and skills regarding the topic selected by the teachers and it also promotes other transversal skills such as communication, teamwork or spatial orientation (Santos et al., 2011). However, further research work was identified in order to promote students reflection on wrong choices (Santos, 2011).

In this dissertation we proposed an approach based on games to engage students in learning and reflecting on their decisions. Students can solve each question as many times as necessary until reaching the correct solution, and game elements such as hints and bonus are included to enhance the learning experience. In this sense, we escape from giving immediate conclusive feedback when the solutions are incorrect. Instead we promote a more reflective methodology in which the answer is not provided to the students right away. The students have the possibility of finding the correct solutions either by reflecting on their wrong choices or taking benefit of the resources provided not only by the game design itself but also by the information that can be found interacting with the real environment (e.g. people, buildings, etc.). Indeed, we foster all the questions that are part of a puzzle can be answered correctly to have a global vision of the puzzle.

In order to develop “QuesTInSitu: The Game” we follow the implementation guidelines (presented in section 3.6) to develop the different versions of the mobile application (see Figure 28). In general, each location-based learning game is represented with a set of XML documents that are compliant with the conceptual model for puzzle board game designs. Then, a generic parser reads the different XML documents and instantiates the specific logic model of the game. Specific engines are created to adapt the different location-based games to specific educational context and settings. Besides, each engine uses the logic model instantiated by the parser and implements the different interactions and workflow for the specific game. Therefore, each platform-specific engine contains the business logic of the location-based learning games. Furthermore, each engine has associated a player, depending on the targeted device, to execute the live interpretation of the game.

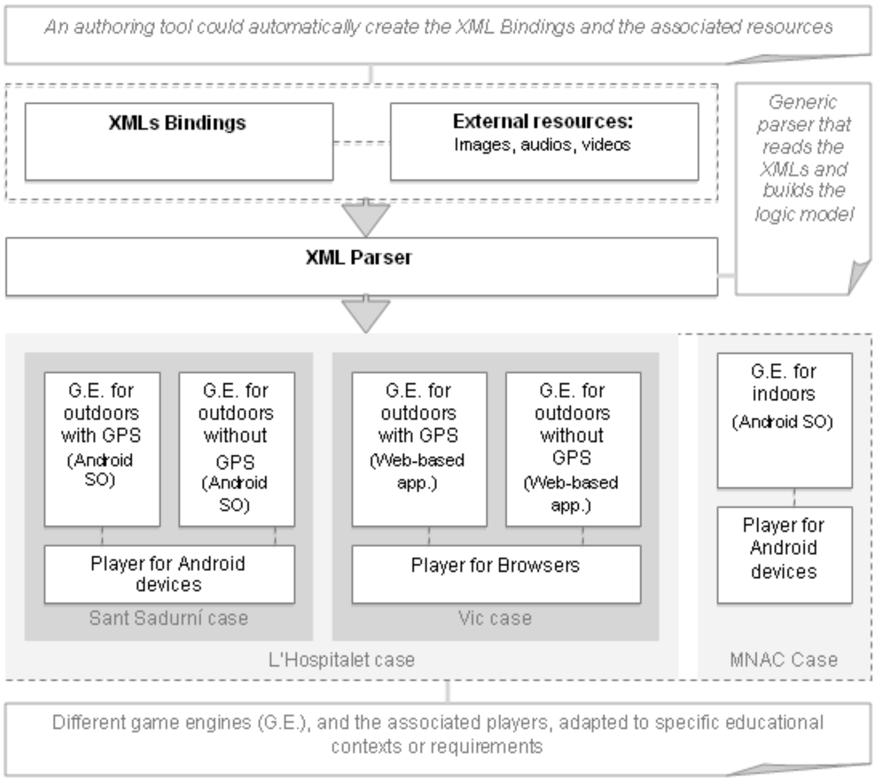

Figure 28. Development of location-based learning games following the implementation guidelines

This strategy allows us to easily create specific versions adapted to particular educational requirements. While section 5.2.1 describes the versions for outdoors settings (i.e. l'Hospitalet, Vic and Sant Sadurní cases), section 5.2.2 describes the implementation for the indoors setting (i.e. MNAC case).

5.2.1 "QuesTInSitu: The Game" for outdoors

Different instances of "QuesTInSitu: The Game" were generated for the case studies described in this work (available in the attached

CD-ROM). 3 out of the 4 real location-based learning game designs were designed for outdoors. In all these three location-based learning games, two versions of "QuesTInSitu: The Game" were implemented: one using GPS and automatic detection of the players' position; and other without using GPS, in case that there were connectivity problems. Overall, the workflow of the application was the same (see Figure 29).

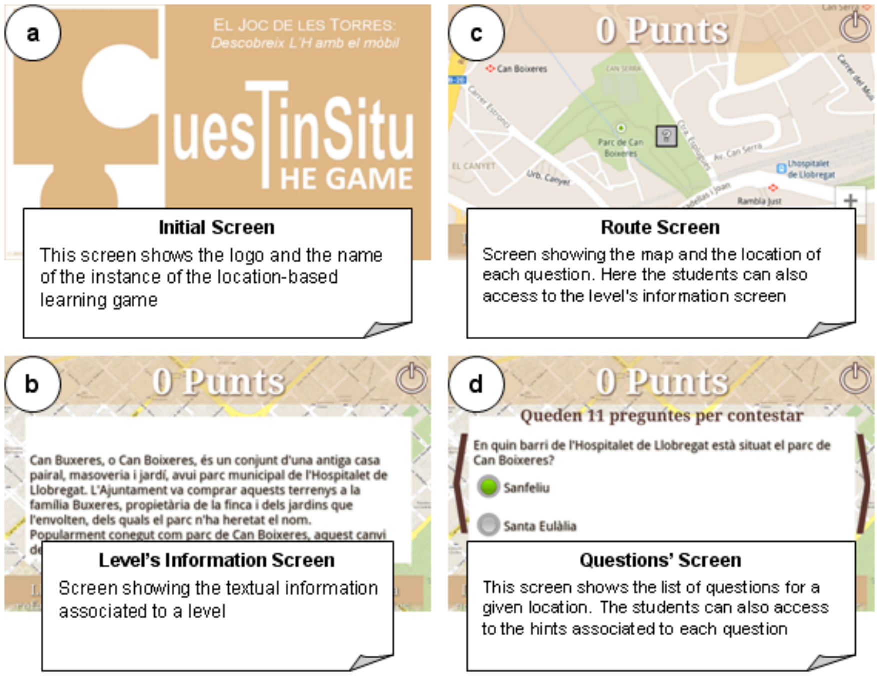

Figure 29. Some screenshots of the "QuesTInSitu: The Game" (Android version)

- An initial screen displaying the logo of the application (Figure 29, a).
- Once the students select the route they will play, a Google Maps showing the positions of the different questions appears. Also, an avatar indicating the player's position is displayed in the Smartphone's screen (Figure 29, c).
- The students can access to the textual information associated to a level of the game at anytime (Figure 29, b).
- Once the students are close to a specific point indicating the geolocated questions, a new screen showing the list of specific geolocated questions appears (Figure 29, d). When students were using the version without GPS, they had to manually click

on the question's item. Then, the students can answer the questions in the order they want, and as many times as needed. Also, for each question, the students can access to the specific hint. For each case, teachers designed specific scoring mechanisms to penalize wrong answers and accessing hints.

- The overall player's scoring is always shown in the screen and updated each time the player answers correct/incorrectly a question, access to the hints or obtains a bonus.

In this three cases, case each slot has associated, at least, one question that is located by latitude and longitude coordinates (see Figure 30). Pieces, on the other hand, correspond to the different options of the questions and are virtually represented and associated to each particular question using the tag "<rel-piece-slot>".


```xml
<piece id="canboix_piece1_question1">
    <name>Sanfeliu</name>
    <type>virtual</type>
</piece>
<piece id="canboix_piece2_question1">
    <name>Santa Eulàlia</name>
    <type>virtual</type>
</piece>
<piece id="canboix_piece3_question1">
    <name>Sant Josep</name>
    <type>virtual</type>
</piece>
<piece id="canboix_piece4_question1">
    <name>Pubilla Cases</name>
    <type>virtual</type>
</piece>
<slot id="canboix_slot_question1">
    <type>geolocated</type>
    <information>En quin barri de l'Hospitalet de Llobregat
            està situat el parc?</information>
    <latitude>41.364581</latitude>
    <longitude>2.097020</longitude>
    <hint-points>-100</hint-points>
    <file-slot-ref>images/slot.png</file-slot-ref>
</slot>
<rel-piece-slot id="canboix-rel-piece1-slot-question1">
    <piece-id-ref>canboix_piece1_question1</piece-id-ref>
    <slot-id-ref>canboix_slot_question1</slot-id-ref>
    <feedback>Correct!</feedback>
    <score>250</score>
</rel-piece-slot>
<rel-piece-slot id="canboix-rel-piece2-slot-question1">
    <piece-id-ref>canboix_piece2_question1</piece-id-ref>
    <slot-id-ref>canboix_slot_question1</slot-id-ref>
    <feedback>Incorrect!</feedback>
    <score>-100</score>
</rel-piece-slot>
```

Figure 30. Sample of an XML representation used in "QuesTInSitu: The Game" for outdoors

A first implementation of "QuesTInSitu: The Game" was developed for Web-based (HTML5) technology (see Figure 31). This version was used in two of the experiments of l'Hospitalet case and for Vic case. In both cases, the board of the game consisted in a GoogleMaps containing the concrete questions designed by the teachers. Besides, the concrete version for Vic integrated a Twitter plug-in to display messages from teachers and students.

Figure 31. Some screenshots of QuesTInSitu: The Game and pictures from l'Hospitalet and Vic cases (Web-based version)

Some (old) versions of Web browsers hindered the proper functioning of the complete functionality of the application. For example, students could not scroll down the list of questions or some features were not available (e.g. zooming in & out the

GoogleMap using the fingers) making difficult the interaction with the application. In order to prevent these issues, we also created a native application for Android of "QuesTInSitu: The Game". This version of the game was used in the third experiment of l'Hospitalet and in the Sant Sadurni case (see Figure 32).

Figure 32. Pictures of students from Sant Sadurní using of QuesTInSitu: The Game (Android version)

Besides, in the Sant Sadurní case, the mobile application included a feature that allowed students to read some QR codes containing information associated to the different levels of the game. This particular feature is useful for indoors settings where there is no possibility of accessing context-aware information by detecting geolocated positions.

5.2.2 "QuesTInSitu: The Game" for indoors

"QuesTInSitu: The Game" is also implemented for indoors, in the particular case of the MNAC. Since it is not possible to use GPS technology, positions of each slot (i.e. question) are virtually represented using static pictures. Overall, the workflow of the application for the MNAC case consists of (see Figure 33):

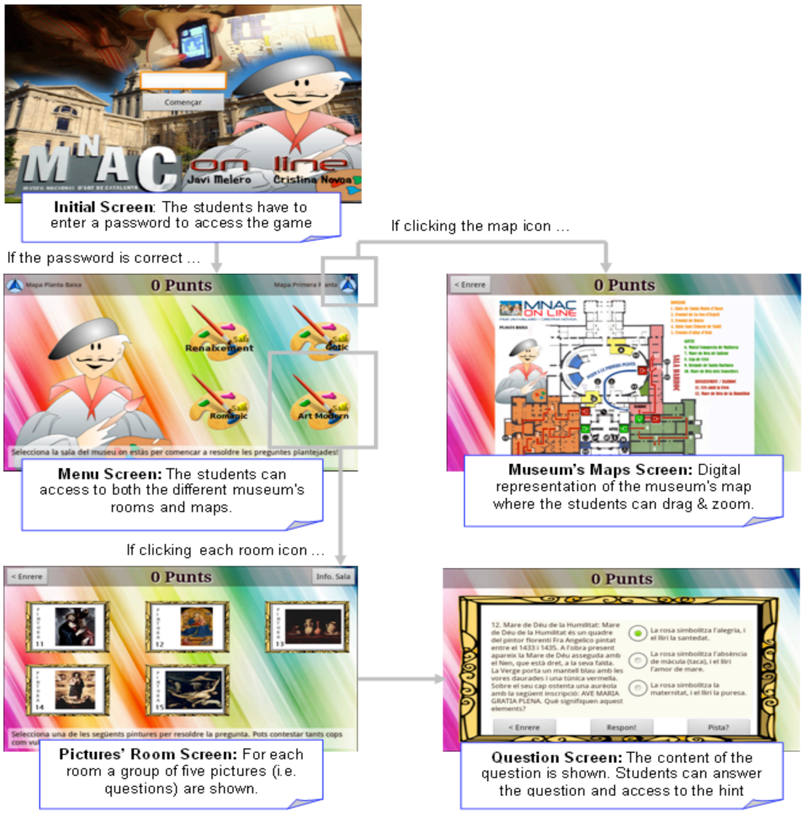

Figure 33. Some screenshots of the "QuesTInSitu: The Game" for the MNAC

- An initial screen where the students have to enter a password (provided by the teacher) in order to enter the game.
- Once the password has been correctly introduced, a menu screen appears. Here the students can access to the different museum's room and the museum's map that indicate the location of the different pictures of interest.
- When a student clicks on a museum's room, he/she access to a group of five pictures of interest. Also, in this screen, the students can access to the textual information associated to the room. This information can be useful to contextualize the group of questions, as well as a hint to solve the questions themselves.
- Each time a student clicks on a picture, he/she access to the screen containing the question's content. Here, the student can solve the question (as many times as necessary until reaching the correct solution). If the student has problems while solving the question, he/she can consult a hint. In order to minimize

situations in which students might answer questions without reflecting (because they will have more chances), wrong answers and use of hints are penalized. Particularly, the teacher defined 10 and 50 points to be subtracted from the overall score, respectively.

- While playing the game, the students can see at the top of the application their current scoring in order to get feedback about when their solutions are correct or not.

In the case of MNAC, each picture containing a question is virtually represented as a slot; the virtual pieces are represented as the possible options to answer the question associated to the slot (picture); and in order to indicate whether an option (i.e. piece) of a given question is correct or not, we use the "rel-piece-slot" element (see Figure 34).

Figure 34. Sample of the XML representation compliant with the model used in "QuesTInSitu: The Game" (MNAC version)

5.3 Evaluation of location-based learning games scenarios

We carried out different evaluations with the secondary education students to analyse their opinions when performing the designed location-based learning activity using “QuesTInSitu: The Game”. The number of students participating was: 74 students (l’Hospitalet case), 64 students (Vic case), 43 students (Sant Sadurní case), and 36 students (the MNAC case). In particular, we evaluated the students’ opinion on the game dynamics and their different elements (i.e. designed scoring, bonus, hints, and feedback).

5.3.1 Methodology

Different data gathering techniques have been used to evaluate students’ opinions (i.e. questionnaires, log files, observations). Table 10 lists the different data sources: a) Questionnaires to evaluate the students satisfaction when performing the learning activity through the use of “QuesTInSitu: The Game”, b) Log Files gathered from the system to analyse the students’ interactions with the mobile application, and c) observations from the research team during the learning activities during the different design tasks and enactments. Thus, a mixed evaluation method has been followed (Cairns & Cox, 2008) considering different data gathering techniques. Furthermore, we combine and triangulate (Guba, 1981) the collected qualitative data, which provide insights into participants’ opinions, with the quantitative data to support or reject the quantitative trends in the participants’ views.

Table 10. Data gathering techniques used in the enactment with students

Data source	Type of data	Label
Questionnaires Students	Quantitative ratings and qualitative opinions from the students after performing the gamified location-based learning activity	[S-Case-Y] Where ‘Case’ can be ‘Hospi’, ‘Vic’, ‘Santsa’ and ‘MNAC’ depending on the designed location-based learning activity. Where ‘Y’ is the identifier of the student
Log Files	Log Files gathered from the “QuesTInSitu: The Game”	[L-Case] Where ‘Case’ can be ‘Hospi’, ‘Vic’, ‘Santsa’ and ‘MNAC’ depending on the designed location-based learning activity

Observations	Observations gathered while the students were performing the location-based learning activity	[O-Case-Z] Where 'Case' can be 'Hospi', 'Vic', 'Santsa' and 'MNAC' depending on the designed location-based learning activity. Where 'Z' is the identifier of the observer

In particular, this section presents a cross-case analysis (Hernández-Leo, Jorrín-Abellán, Villasclaras, Asensio-Pérez, & Dimitriadis, 2010) of students' opinions. The aim of this evaluation is to identify issues in the design and enactment of the use of the puzzle board metaphor in different real learning situations, and provide the main highlights of using the proposed metaphor.

5.3.2 Results on students' engagement

Following results report the students' opinions about the game dynamics, the scoring mechanisms (positive and negative points), the hints, and the textual information associated to each level in the game.

Game dynamics

Overall, students enjoyed the game dynamics of answering as many times as needed the different questions until reaching a solution. Particularly, slightly higher ratings were obtained from the students performing the activity outdoors than those who visited the museum. Specifically, more than a half of the students from the case studies of l'Hospitalet (42/74), Sant Sadurní (22/43) and Vic (51/64) quite or totally agreed that they enjoyed answering each question as many times as necessary. Besides, most of the groups of students from l'Hospitalet (10/14) and Vic (12/14) correctly solved all the questions and avoided skipping levels [L-Hospi-Vic]. Some positive comments were "*I enjoy the intrigue to know the answer*" [S-Hospi-17], "*answering correctly the questions*" [S-Vic-37], "*having to correctly answer the different questions to obtain points and be the winner*" [S-Vic-1] and "*being able to see the right attempts and answering several times the questions*" [S-Vic-53]. Less positive ratings were obtained from the MNAC case; 16 out of 36 of the students quite or totally agreed that they enjoyed answering each question as many times as necessary (see Figure 35).

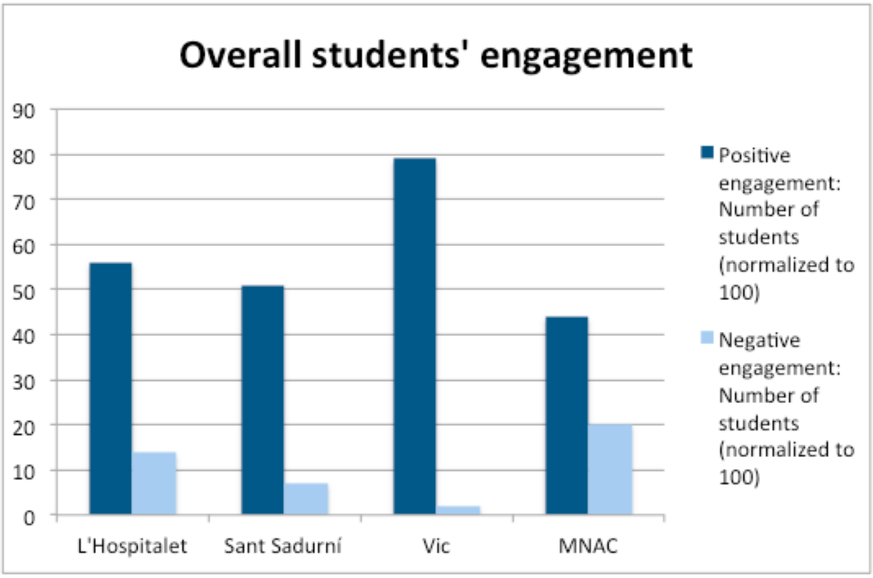

Figure 35. Overall engagement (i.e. students liked (or not) having the possibility of answering questions several times – neutral opinions are not considered)

Most of the students in all the case studies indicated that they reflected on the answers of the different questions. More than two thirds of the students in all case studies (i.e. 50/74 students from l'Hospitalet, 53/64 students from Vic, 36/43 students from Sant Sadurní, and 33/36 students from the MNAC) quite or totally agreed that they tried to think better the answers each time they failed a question. In fact, only few students (i.e. 6/74 students from l'Hospitalet, 5/64 students from Vic, and 4/43 students from Sant Sadurní, and 1/36 students from the MNAC) quite or totally agreed that they randomly answered the next attempt. Besides, around two thirds of the students in all the case studies (i.e. 48/74 students from l'Hospitalet, 49/64 students from Vic, 33/43 students from Sant Sadurní, and 25/36 students form the MNAC) quite or totally agreed that they read more carefully the statements in the questions.

Even though in general, students engage in game dynamics, better results were obtained from the students playing outdoors, especially from Vic case, than those who played in the museum. This leads us to further discuss whether differences in each context affect students' engagement with the dynamics of the game: being controlled by external people (i.e. museum's staff) or not, having limited amount of time to solve each level (i.e. MNAC case) or not, etc.

Students also described the aspects they enjoyed more. These were: "*discovering new things while using the mobile application*" [S-Hospi-13-22][S-Vic-7-14-24-25-31-34][S-Santsa-9-15-31], "*going outside to perform a learning activity*" [S-Vic-13-55][S-Santsa-5-8-26-39-40], "*learning to orientate myself*" [S-Hospi-8-44][S-Vic-4-33][S-Santa-11-31], "*the activity presented as a game of geolocated questions*" [S-Vic-8-11-47], and "*working in group*" [S-Hospi-1-2-23-31-73-74][S-Vic-12-15-26-42-58-59-61-62-64]. However, some negative comments were gathered in regards to the application not working properly because sometimes the map did not load or the application worked too slow [S-Hospi-32-44-49-51-54-56-67-71][S-Vic-3-13-18-19-20-36-62][S-Santsa-5-43][O-Hospi-1], the students seems to be impatient while waiting to load the application [O-Hospi-6], not having enough time to perform properly the tasks [S-Santa-12-24], the weather [S-Vic-4-15-16-23-24-25-26-47-49-57-60] and walking too much [S-Hospi-3-6-7-10-12-17-21-28-29-34-37-41-46-47-48-52-58-59-65-73][S-Vic-31-32-33-50-56-58-59][S-Santa-21-33-34-36-38-41].

Scoring mechanisms

In general, most of the students from all the case studies found appropriate and motivating the points added to their overall scoring each time they correctly answered the questions. Around two thirds of the students from all the case studies (i.e. 57/74 students from l'Hospitalet, 47/64 students from Vic, 28/43 students from Sant Sadurní, and 29/36 students from the MNAC) quite or totally agreed that they found the points obtained each time they correctly answered a question appropriate. In fact, only few students (i.e. 4/74 students from l'Hospitalet, 7/64 students from Vic, 7/43 students from Sant Sadurní, and 6/36 students from the MNAC) quite or totally disagreed with the amount of points obtained when correctly answering a question. Moreover, around two thirds of the students (i.e. 43/74 students from l'Hospitalet, 47/64 students from Vic, 31/43 students from Sant Sadurní, and 30/36 students from the MNAC) quite or totally agreed that the points obtained when correctly answering a question motivated them to find the correct solution at first attempt. In fact, some students pointed out as positive "*the motivation of obtaining points*" [S-Hospi-51-61].

When asking about the points subtracted when failing the questions, few students were satisfied. In this line, almost a half of the students from l'Hospitalet (27/74) and Vic (30/64) did not find appropriate the points subtracted when failing a question. Besides, less than a half of the students from Sant Sadurní (12/43) and the MNAC (14/36) quite or totally agreed on this assumption. Besides, different ratings were obtained when asking whether subtracting points motivated the students to do it better in the next attempts. Results showed that more than one third of the students from l'Hospitalet (29/74), almost two thirds of the students from Vic (40/64), and around a half of the students from Sant Sadurní (18/43) and the MNAC (19/36) quite or totally agreed on the points subtracting when failing a question. It is interesting to notice that the students from Vic case agreed more on the subtracted points compared to the others students (see Figure 36).

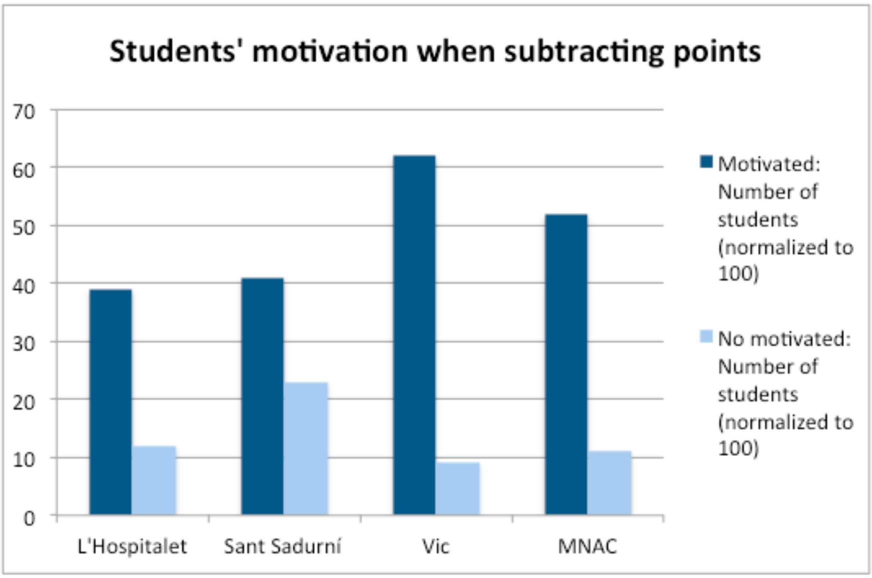

Figure 36. Students' motivation when subtracting points (i.e. students agreed (or not) that subtracting points motivated them to do it better in the next attempts – neutral opinions are not considered)

Around two thirds of the students (i.e. 50/74 students from l'Hospitalet, 42/64 students from Vic, 27/43 students from Sant Sadurní, and 24/36 students from the MNAC) quite or totally agreed that they found the extra bonus obtained, when all the questions of a level were right, appropriate. Also, around two thirds of the students (i.e. 43/74 students from l'Hospitalet, 46/64 students from Vic, 24/43 students from Sant Sadurní, and 21/36 students from the MNAC) quite or totally agreed that they found motivating the extra bonus achieved when correctly finishing a level. When asked for qualitative positive comments, some participants indicated, "*obtaining the bonus*" [S-Santsa-3].

While the design of positive points and extra bonus were broadly accepted by the students in the diverse cases, the design of the subtracted points provoke more discrepancies among cases. In this sense, further research is needed to understand why students from Vic accepted better the subtracted points than the others. One possible explanation is that the rules of the game were clearer and more meaningful to these students than to the others (e.g. the students were familiar with the scoring mechanisms - based on a traditional test-based approach; they were more concentrated on the rules because the outcome had a direct impact in their marks). In all the other case studies the students knew that they will lose points each time the answer of a question was wrong, but they did not exactly know the amount of points.

Hints

In all the case studies around two thirds of the students did not answer the questions related to the use of hints. In fact, only around a half of the groups from l'Hospitalet (7 out of the 14 groups) and Sant Sadurní (5/12) consulted hints [L-Hospi-Santsa]. Regarding Vic, two thirds of the groups of students (9/14) accessed to the hints [L-Vic]. Nevertheless, in all of the case studies, the groups did not access to more than an 8% of the hints: a maximum of 3 out of 52 of the hints were accessed from the groups of students from l'Hospitalet [L-Hospi]. The accesses to the hints from Vic and Sant Sadurní were 2/25 [L-Vic] and 4/64 [L-Santsa], respectively. In connection with this, around two thirds of the students (i.e. 19/31 students from l'Hospitalet, 24/29 students from Vic, 17/21 students from Sant Sadurní, and 17/20 students from the MNAC) quite or totally agreed that they carefully consulted the hints because they subtracted points. Also, some negative comments were "*subtracting points when accessing to the hints*" [S-Santsa-3][O-Hospi-2]. Besides, students from all the case studies followed different strategies to find the correct solutions that could influence students to not consult the hints [S-All]. Some comments were: "*Asking people*" [S-Hospi-9-59-60][S-Vic-5-6-7-8-23-26][S-Santa-9-36][O-Hospi-5], "*Asking the people and/or employees of the tourism office, and searching the*

Internet" [S-Hospi-13-16-18-35-46-47-48-70][S-Vic-18-19-20-22][S-Santsa-32][O-Hospi-2], "*Using the phone's browser to find the answers*" [S-Vic-42], "*Reading the question and agreeing in the answer*" [S-Vic-45-46-47-48-49], "*Reading carefully the information provided by the QR codes*" [S-Santsa-1-2-3-4-6-10-19-20-22-24-25-27-28-29-30-31-40], and "*Looking at the buildings and the surroundings*" [S-Hospi-3-23-24-25-26-57-58]. Also, the observers noticed these different strategies to solve the questions: "*The employee of the tourist office helps the students answering the questions*" [O-Vic-1-2], "*The students discuss the different questions a lot*" [O-Vic-1][O-Hospi-4], "*The students ask the police some questions*" [O-Hospi-1-6], "*a woman near the museum gives some clues to the students about the answers of the questions*" [O-Hospi-1].

From those students consulting hints, around two thirds of the students from Vic (18/29) and the MNAC (14/20), almost half of the students from l'Hospitalet (11/31), and less than one third of the students from Sant Sadurní (4/21) quite or totally agreed that the hints made them think about what could be the correct answer. In this line, two thirds of the students from the MNAC (12/20), and more than one third of the students from Vic (13/29) and l'Hospitalet (10/31) quite or totally agreed that the hints were useful to correctly answer the different questions. However, just 5 out of the 21 students from Sant Sadurní quite or totally agreed on this assumption (see Figure 37). Some comments were that, "*the hints were not useful*" [S-Santsa-8-40], "*the hints did not clarify the doubts*" [S-Santsa-37]. It is worth noticing that the rating from the Sant Sadurní and l'Hospitalet were lower than the students from Vic or the MNAC. In fact, some students from l'Hospitalet and Sant Sadurni when they consulted the hints said, "*Buff... what a hint!*" [O-Hospi-2][O-Santsa-1]. Furthermore, half of the students from Vic (14/29) and the MNAC (10/20) quite or totally agreed that the points subtracted when accessing to each hint were appropriate. However, fewer students from l'Hospitalet (5/31) and Sant Sadurní (4/21) agreed on this assumption (see Figure 37).

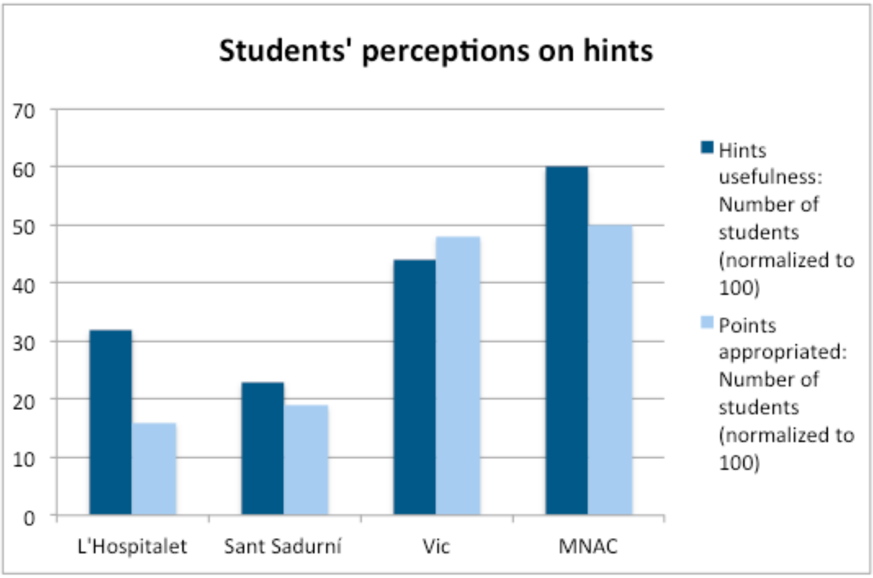

Figure 37. Students' perceptions on hints (i.e. students agreed on usefulness and subtracting points when accessing the hints – neutral opinions are not considered)

About the hints, similar results were obtained in the different case studies. Students did not found useful the use of hints, and they prefer to discover the correct answer by other means. Besides, results supported that perceived usefulness of the hints could directly depend on the designed hints. In this sense, while the hints designed from Sant Sadurní and l'Hospitalet were similar to suggestions (i.e. ask people, pay attention to the information, etc.), the designed hints from Vic or the MNAC contained small descriptions about the related questions.

Textual information

Around half of the students from l'Hospitalet (38/74), Vic (31/64), and the MNAC (21/36) quite or totally agreed that the textual information associated with each level was helpful to better understand the global context of the set of questions in each level. Fewer students from Sant Sadurní (15/43) quite or totally agreed on this assumption. In this line, only few students from l'Hospitalet (7/74) and around one third of the students from Vic (17/64), Sant Sadurní (10/43), and the MNAC (12/36) quite or totally agreed that the textual information associated with each level was unnecessary. Around one third of the students from l'Hospitalet (24/74), a half of the students from Vic (31/64) and Sant Sadurní (26/43), and two thirds of the students from the MNAC (24/36) quite or totally agreed that the messages appeared after they correctly answered all questions within a level motivated them to do it better in the following levels. Besides, less than one third of the students (i.e. 13/74 students from l'Hospitalet, 12/64 students from Vic, and 4/43 students from Sant Sadurní, and 15/36 students from the MNAC) quite or totally agreed that the messages when correctly answering all the questions within a level were unnecessary.

Students from Sant Sadurní case considered less useful the textual information than the rest of students. In this particular case, the textual information for each level was based on Web pages including extensive information about the set of questions to be solved. Then, the extension of the information in this type of games can influence on the students' perception.

5.3.3 Results on students' activity performance: The MNAC case

To offer some insights about students' activity performance, we have made a preliminary study within the MNAC case. To this end, 36 students used the proposed approach based on the puzzle board metaphor, while other 36 students used a plain test-based approach containing the same questions (one attempt per question, and no game elements included – i.e. hints, room's information, and extra bonus).

The study was organised as follows. Two weeks before the activity, the 72 students had a lecture where the teacher explained them concepts about contemporary art, related to the museum's visit. For each case, groups of four students were formed to use the respective mobile applications. After the activity, each student had to fill a questionnaire asking about several aspects of the game and a post-test including a selection of the questions experienced in the activity. In order to avoid cheating among them, the students answered both post-test and questionnaire in controlled groups of 20.

At the end of the museum's visit, students participating in the case study filled an opinion questionnaire. Two versions of the questionnaire were designed: one for those students that used the application following the puzzle-based approach, and other for the students using the traditional test-based approach. Both questionnaires were adapted to each case, and contained parallel questions in which students had to rate and comment concrete aspects of the activity experienced: (game) dynamics, scoring mechanisms, textual information, and feedback provided.

Despite the students enjoyed the dynamics of answering the questions as many times as necessary, less than one third of the students with the plain test-based approach (6/36) totally agreed that they would prefer to have several attempts to answer a question until identifying the correct solution. However, 23 out of these 36 students were discouraged when failing because they could not reach the correct answer. Some comments were: "*When failing a question, I would like to know the correct answer*" [Quest-NoPG-3]; "*When you fail a question, you cannot know the correct answer!*" [Quest-NoPG-4]. Similarly, more than a half of the students using the test-based approach (23/36) found appropriate the amount of points obtained when correctly answering a question. Also, more than a half of the students found appropriate (24/36) and motivating (21/36) the extra bonus obtained when all the questions of a room were correctly answered.

Furthermore, similar trends were obtained in both groups of students when asked whether they would remember the correct answer to each question of the application. 19 out of 36 students using the puzzle-based approach and 16 out of 36 students using the test-based approach totally or quite agree that they would remember the correct answers. Thus, the perception of students about remembering the correct answers was similar. Following, we focus on this assumption by analyzing a post-test filled by all the students once the activity finished. Besides filling the questionnaire, each student had to answer a post-test containing 8 questions that they already answered during the museum's visit. The results obtained from the post-test are shown in Table 11, indicating the number of students from both groups (i.e. puzzle-based version and test-based version) and the obtained mark.

Table 11. Marks obtained by the students in the MNAC case

Mark	# Students Puzzle Approach	# Students Test-based Approach
0	0	0
1	0	0
2	0	1
3	0	3
4	3	4
5	10	3
6	3	9
7	11	10
8	9	6

The difference between the marks of the two groups is not statistically significant but indicates a clear trend (see Figure 38) that is aligned with the perception of students about the reflection fostered by the puzzle-based approach.

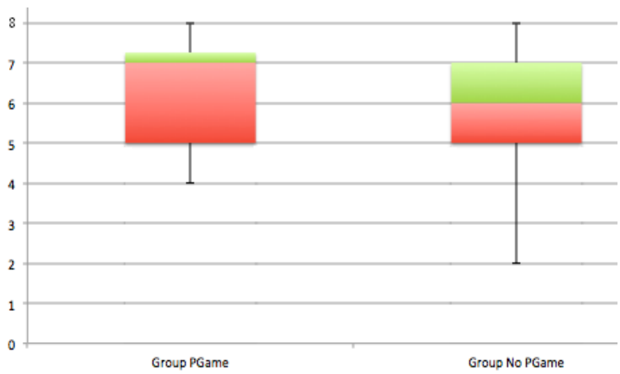

Figure 38. Marks obtained in each group

In fact, Figure 38 shows that in general students using the puzzle-based approach tend to obtain better outcomes in the post-test than the students using the test-based approach. The median of the students using the puzzle game approach was one point higher (i.e. 7) than the others (i.e. 6). Also, the range was more concentrated in one group than the other; being globally higher the range of scores of the students using the puzzle game approach. It is also interesting to observe that all the students using the game version passed the post-test (4 or more correct answers out of 8 questions), being all of them well engaged in the activity. In contrast, 4 students in the control group did not pass the post-test.

5.3.4 Discussion and conclusions

Regarding the students' opinions while using "QuesTInSitu: The Game", we can conclude that most of the students enjoyed the proposed approach. Students enjoyed the dynamics of the game and indicated that they reflected on the answers to the questions especially when they first try was wrong. However, from the obtained results it seems that it is important to offer students the possibility of moving to next levels without completing correctly all the questions. In the case of the MNAC, their main critical opinion suggests that they prefer no being forced to correctly answer all the questions for a given level (in this case, a museum's room) to advance forward the game. Like in jigsaw puzzle boards, one could leave it without finishing part of the slots – even though the full completion of the puzzle is what provides a comprehensive view of the contained knowledge.

The different scoring mechanisms designed in all the case studies were accepted by the students, having just some discrepancies when subtracting points in the cases of failing questions. In this line, the results suggest that further research is needed to understand the negative feeling of the students in this respect. Potential venues for future exploration include understanding the effect of the rules information presented to the students (details regarding the adaptive functioning of the points) or the adoption of more game-oriented scoring mechanisms.

Regarding the hints, surprisingly for the teachers, students did not consult them. Results show that students preferred to find by themselves the solutions using either the resources available in the real situ, asking people or searching the Internet, rather than losing points. These findings suggest that it could be necessary to define another mechanism to promote the access to the hints. Also, subtracting points when consulting hints is more accepted when hints are designed as clues containing information related to the questions rather than suggestions.

Results of an analysis comparing the data from students' post-tests show a trend indicating a better performance in students using the gamified approach than students using the plain test-based approach.

Finally, results show that decisions around game design elements can affect students' satisfaction and have an impact on learning. In this regard, students' opinions are interesting and should be considered in further iterations of the designs. In this sense, teachers could reflect on whether results obtained in the implementations were aligned with their expectations. Then, providing teachers with techniques to inquire into their design decisions seems of relevant importance to create powerful location-based learning games. Next section analyses the use of visualizations as a strategy to support teachers in reflecting on their designs.

5.4 Teachers' inquiry of location-based learning game enactment

Involving teachers in the design of m-learning experiences is important if they have to be aligned with the requirements of their particular educational situations (Melero et al., 2011a; Tornero et al., 2010; Yang, 2005). However, the potential of the educational improvement is not fully exploited if teachers and students neglect a careful reflection on the activity enactment. Equipping teachers with tools to inquire into the execution of their own designs is crucial to enable them the identification of design elements that need to be reinforced and revised in future editions of the activity (Kelly, 2003). Moreover, providing students with tools that facilitate their self-assessment can strengthen the learning and promote the development of meta-cognitive skills (Boud, 1995). Using learning analytics strategies, which capture, analyse and report data about students' activity performance (Siemens, 2010), seem to be the appropriate approach to base the features behind those tools. This section aims at contributing towards an improved understanding of what type of data and representations can effectively support inquiry and self-assessment in the specific domain of location-based m-learning, and to what extent the same data and representations can serve well both purposes.

In particular, the section proposes and studies a set of learning analytics visualizations as a twofold tool to support teachers' design inquiry and students' self-assessment. The study focuses on a design of a gamified location-based learning activity on a heritage of a city. The design was created by a secondary school teachers' team following a puzzle-based game model (Melero et al., 2013). Several reasons are behind the use of puzzles game boards as design elements to create this type of activities. On the one hand, board games offer an intuitive conceptualization to design location-based learning activities (Magerkurth et al., 2005; Nicklas et al., 2001; Schlieder et al., 2006). On the other hand, the use of game elements can immerse learners in meaningful and enjoyable learning, encouraging active learning (Ke, 2008), promoting the exploration of information, and activating prior learning to advance forward (Oblinger, 2004).

A total of 81 secondary school students, divided into 23 groups, performed the gamified m-learning activity using "QuesTInSitu: The Game", a mobile application implementing the teachers' design. During the activity, the application gathered information about students' interactions with the system and their locations. Several visualizations were designed considering the data extracted from the log files of the mobile application. Visualization techniques have been developed as a popular method to help people quickly grasp and effectively understand the required information. The goal of information visualization is to amplify human cognition, facilitating the identification of patterns, trends and anomalies in ways that would be much harder to accomplish from numerical datasets or textual descriptions (Card, MacKinlay, & Schneiderman, 1999). In this study, the applied visualizations were designed as a representation of learning analytics to report data about students' performance in the designed gamified learning activity. The visualizations were shown both to teachers and students to analyse their support for the two purposes of supporting inquiry (teachers) and self-assessment (students).

5.4.1 Visualizing the students' activity performance

Log files of "QuesTInSitu: The Game" gathered relevant data about the interactions from the 23 groups of students with the mobile application. The data include: both time used to answer questions and to reach the geographical zone of the questions, number of attempts to solve each questions, and points obtained per question. Considering this information, several learning analytics visualizations were designed as a twofold tool to allow (1) the teachers inquire into the enactment of their m-learning activity design, and (2) facilitate the students' self-assessment. In particular, the visualizations were divided into several sections:

- General information: This section presents the title of the game, the date when the activity was performed, the group name and the group members for the particular visualization, the total score obtained by the group, and a description of the game rules (see Figure 39).

Figure 39. Example of general information

- Time used: A clock metaphor has been used for showing the time dedicated of the students' group to performing the activity. One sector represents the time used to navigate from one geographical zone to another, while the other sector stands for the time used to solve the questions of a particular zone. Also, the zones are shown sequentially according to the route followed (see Figure 40).

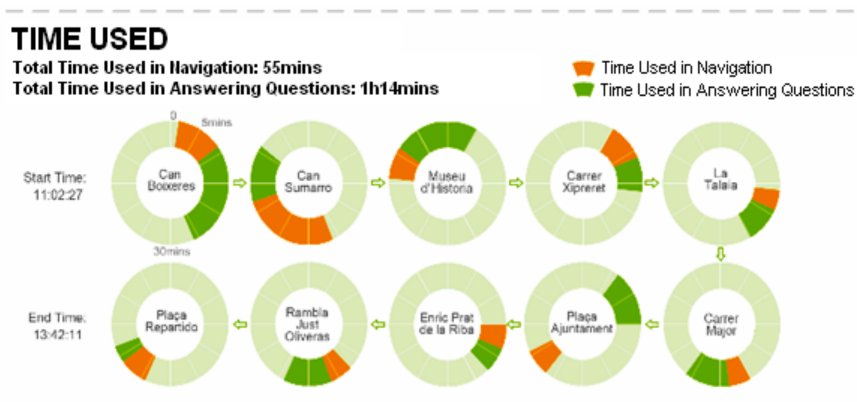

Figure 40. Example of time used visualization

- Track: A map visualization shows the route of the group (dotted line) and the state of every geographical zone (completed or uncompleted) (see Figure 41).

Figure 41. Example of track visualization

- Frequency: Since the students can answer as many times as necessary each question, this visualization depicts the amount of attempts that the students have accessed to each question until they submitted the correct answer. A reference line was set on the lowest frequency, meaning the students gave the correct answer in the first attempt. In addition, a point was set to represent the question that the students did not ever give a correct answer (see Figure 42).

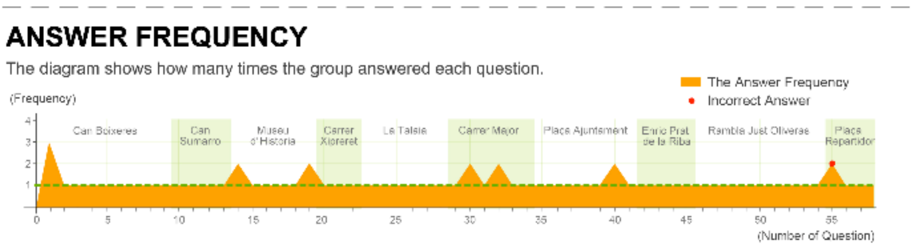

Figure 42. Example of answer frequency visualization

- Score: Considering the points and bonus designed by the teachers, this visualization shows the points obtained by the students for each question. The coloured area stands for the score the group got from each question and the dotted line shows the highest score that can be obtained for each question (see Figure 43).

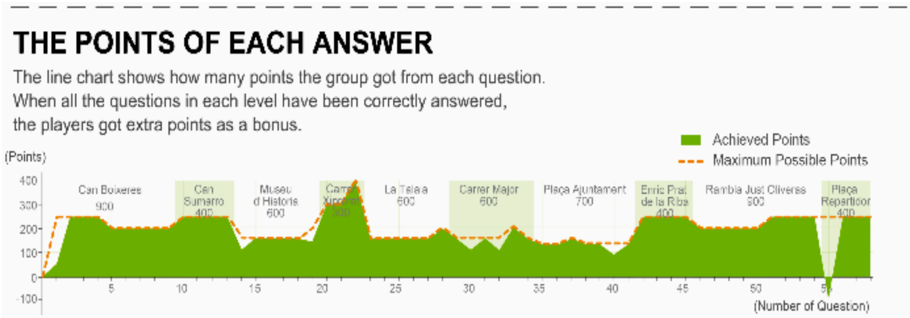

Figure 43. Example of score visualization

5.4.2 Evaluation

An evaluation including data collection from three teachers (out of the seven involved in the activity design) and the 81 secondary education students was carried out, including quantitative and qualitative data gathering techniques (see Table 12), in order analyse to what extent the proposed learning analytics visualizations are useful to support inquiry and self-assessment, respectively.

Table 12. Data gathering techniques used for evaluating the proposed visualizations

Data source	Gathered data	Focus method of analysis
Log files	Quantitative data capturing students' interactions with the "QuesTInSitu: The Game" using mobile phones	Statistical analysis to evaluate students' diagnose of their own activity performance Log files were used to validate students' answers from both pre- and post- questionnaires
Students' pre- and post-Questionnaires	Quantitative answers by students to multiple-choice questions about their perception of performance by game levels in terms of score and time, before and after looking at the visualizations	

Teachers' Questionnaire [qX], where X is the letter assigned to a teacher, from A to C.	Quantitative answers by teachers to Rank-in-Order questions regarding the relevance of different types of information that can be collected and visualized in m-learning activities	Qualitative analysis (driven by categories) to understand teachers' opinions on the design and usefulness of the visualizations as a teachers' inquiry tool
Observations [dY], where Y is the letter assigned to a teacher, from A to C	Record of direct observations taken during a discussion group with teachers. The discussion was organized around the topics of research (how teachers valued the characteristics of the visualizations, issues and ideas for improvement)	

Diagnosis from the teachers

Several weeks after the enactment, a discussion group was scheduled. Three out of the seven teachers involved in the design of the activity were available to participate in the discussion group. The session was recorded and we transcribed the participants' interventions [dA, dB, dC]. Besides, during the session, each teacher was provided with an example of the visualizations, and a document showing the results obtained from the students' opinions after performing the activity. Also, each teacher filled out a brief questionnaire [qA, qB, qC], consisting of Rank-in-Order questions, in which they had to indicate the most relevant information to be gathered in this type of m-learning activities. The data obtained from the teachers questionnaires and the discussion group were combined and analysed to gain insights into the most important data depicted in the learning analytics visualizations to support teachers' inquiry.

In general, the visualizations seem to contain a lot of information that cannot be analysed in a short time [dC]. However, the teachers highlighted the importance that visualizations provide objective information. During the discussion, the teachers indicated the main source to consider a redesign of the activity was based on the observations that one of the teachers took during the m-learning activity [dA, dB, dC]. These observations might be enough for a person who knows the route to reconsider aspects of the design. However, for a person who is not familiar with the route, the information provided by the visualizations would be essential for the redesign of the activity [dC].

Overall, the data from the visualizations have been considered a good approach to assess the redesign of the activity. One of the teachers pointed out that the visualizations can help to identify what elements, such as scoring mechanisms or routes' paths, should be modified and confirmed which elements should be kept as they were initially designed [dC]. Focusing on the different types of visualizations, the time used (Figure 40) was considered of great importance because the expected time used to perform the activity, when designing the activity, could differ from the reality [dA, dB, dC]. Besides, since each route follows different paths, the information about the time used could suggest the most efficient routes [dB]. It is interesting that two of the teachers, when answered the questionnaire, indicated the time used to answer questions as one of the less important elements to consider [qA, qC]. This result could be because this information is useful to design the activity's routes but not for evaluating the students' activity performance. In this sense, the teachers considered of great importance the frequency (Figure 42) and score (Figure 43) visualizations to evaluate the students' performance, in terms of what were the most difficult questions [dA, dB, dC]. Also, these two visualizations were considered essential to identify the level of difficulty of the questions [dC]. Nevertheless, the teachers considered the track visualization (Figure 41) the less useful to for the redesign of the activity.

One of the aspects mentioned during the discussion group was the importance of having aggregate data of all the groups of students [dB]. Specifically, the three teachers highlighted the need of having visualizations with aggregate data about the answers' frequency (Figure 42) and score (Figure 43) of all the groups of students. The main reason was that this information could be very relevant to have an impression about the questions that have been more difficult [dA, dB, dC]. However, having the aggregate data of the time used (Figure 40) were considered less important since each group follows different routes [dA, dB, dC].

Apart from the data shown in the visualizations, the teachers also highlighted the importance of considering the emotional side of the students: the degree of satisfaction, how the hints influenced the students' performance, what the students liked most and what they learned, [dA, dC], how the students used the information provided by the environment to answer the questions [qA, qB, qC], and whether all the members' of the group participated in solving the questions [qA, qB]. In this line, the information gathered from the questionnaires filled by the students after the activity was very interesting to the teachers because this allowed them to identify the complaints about having to walk too much or having to carry their backpacks [dA, dC]. Besides, the data obtained from the questionnaires were useful to confirm the teachers' feelings about the designed activity [dB]. For example, while performing the activity, some of the teachers observed that there were groups of students that did not consult the information associated to the different levels. Besides, one of the teachers pointed out that this tendency was reflected in the data obtained from the questionnaires [dB]. Then, this result might indicate that the information associated to the geographical zones was not probably the focus of the students. Therefore, this result made the teachers think that the information associated to a level should appear automatically before showing the questions to encourage the students to read it [dB].

Finally, the results of the questionnaires filled by the students were also useful to consider the redesign of some of the elements of the activity. In this line, some of the teachers checked that one of most controversial element was the subtraction of points; the teachers were surprised that students did not like explicitly loosing points when failing the questions [dB, dC]. In this sense, the teachers suggested that would be important to better explain the rules of the activity to the students [dB], or exactly understand the reasons behind this result in order to reconsider the design of the subtracted points [dC]. Teachers suggested that maybe the points should be consistent across all the levels of the game or maybe the students are used to play games in which points are not subtracted [dC]. Furthermore, the teachers highlighted the importance to know the preferences of the students while playing games to redesign the game [dC]. The teachers also mentioned that they have to encourage the students to do what the teachers expect; if subtracting points implies that students do not access to some of the functionalities, and then the point mechanisms should be rethought [dC]. In this line, the teachers discussed that despite of subtracting points prevents trial and error [dA], it is crucial to take into account the audience to whom the activity is intended with the aim that the students enjoy the activity and have fun [dC]. The teachers considered that a learning associated with a positive feeling leads the students to remember better what they have learned [dC]. In this sense, the teachers suggested that a possible solution would be to define specific amount of positive points, depending on the number of attempts when solving a question, instead of subtracting points [dC, dB]. In this line, the information gathered from the questionnaires was also considered valuable to teachers' inquiry. But, further research involves how this gathered data could be visualized.

Diagnosis from the students

This study also aimed at evaluating whether the learning analytics visualizations facilitates the students with a better diagnose of their own performance. To this end, the students answered a pre-questionnaire, without any kind of visualization, about their performance after finishing the gamified location-based learning activity. Then, 2/3 weeks after the activity, the students answered a post-questionnaire using the visualizations. Both pre- and post-questionnaires contained the same questions and were corrected using the data collected by the "QuesTInSitu: The Game" log files as the objective standard to measure the accuracy of the diagnosis. In particular, both questionnaires consisted of: a) 6 multiple-choice questions focused on the score and both time used to answer questions and to navigate (e.g. "In which level do you think you get the highest (lowest) score?", "In which level do you think you devoted more (less) time when answering questions?"); b) 2 questions were asked to assess the overall learning performance (e.g. "Indicate in which level you obtained the higher (lowest) score"). Since the score, time used or frequency of answers can be quite similar in different levels, the standard value (correct answer obtained from the log files) was equipped with 2 alternative correct answers, which are the approximate answers. When the student gave the approximate answer, he or she would obtain half score in this question.

After correcting all the pre- and post-questionnaires, we cleaned the dataset by deleting the data of the students that only completed one out of the two questionnaires. Therefore, pre- and post-questionnaire scores from 63 students were obtained (out of the 81 who completed the game). Then, a Kolmogorov-Smirnov test was ran and got the sample with normal distribution.

Since the aim of this evaluation was to compare the different diagnosis made by the same students, a dependent t-test was run to test the score differences between pre- and post-questionnaires. The result was, with the data of 63 students, the students made significant higher score in the post-questionnaire with visualizations (M=3.71 SD=1.59) than in the pre-questionnaire without visualizations (M=2.97 SD=1.31), p=.002 $p<0.05$ (Melero, Sun, et al., conditionally accepted).

Therefore, considering these results we can assert that the students using visualizations make a better diagnosis of their own performance.

5.4.3 Discussion and conclusions

The research presented in this section aims to gain insights when providing learning analytics visualizations as a tool for teachers' inquiry and students' self-assessment in location-based m-learning activities. As a whole, the section has presented a case of a gamified m-learning design consisting in geo-located questions. "QuesTInSitu: The Game" was used to enact the teachers' design, and several visualizations were provided to both teachers and students considering the data extracted from the log files of the mobile application.

From the teachers' perspective, the main conclusions show that the visualizations used are a good mechanism to represent and analyse objective data obtained from the enactment of their designed m-learning activity. However, the visualizations include too much information to be analysed on the fly during the activity or in short amount of time. In this line, it would be interesting to identify what visualizations are the most essential so they offer more dynamic teacher-led inquiring tools. The time used visualization has been considered of great importance to evaluate the overall design of the activity's routes, whilst the frequency and score visualizations are crucial to evaluate the students' performance and identify the most problematic questions. Besides, in this type of learning activities, the teachers highlight the usefulness of providing visualizations containing aggregate data from all the students' groups. Having aggregate data are considered useful to easily identify trends and the most problematic questions. Particularly, it would be great to have the aggregate data from the frequency and score visualizations. Besides, apart from having the objective data obtained from the learning analytics visualizations, teachers also highlight the importance of knowing the students' opinion in order to analyse whether they enjoy the activity, learn new concepts and have fun. These aspects are relevant to the teachers since they believe that those students who associate their learning with a positive feeling will remember better what they have actively learned. Thus, further research includes integrating students' opinions in the visualizations to help the teachers easily identify the main issues when enacting their design.

The use of the designed learning analytics visualizations has also led the secondary education teachers identify concrete design elements that should be revised. Specifically, the teachers noticed two main issues. On the one hand, the subtracting points should be redesigned, avoiding the use of negative points and using proportional positive points in relation to the attempts when solving each question. On the other hand, the teachers proposed to automatically show the information associated to each geographical point before answering the geo-located questions in order to encourage the students to read this information.

From the students' perspective, learning analytics visualizations have been provided as a tool to facilitate self-assessment. The use of visualizations by students aims to strengthen their learning and help their development of meta-cognitive skills. In this particular case, students using visualizations make a better diagnosis of their own performance in terms of identifying the most problematic questions and zones. Yet, further research is still needed in order to know which elements of the visualization are more useful to the students.

Therefore, next steps in research involve: a) integrating visualizations techniques of learning analytics in "QuesTInSitu: The Game"; b) gathering students' opinions that occurred during game play and associating them to specific game elements (e.g. hints, questions, level's content); c) providing to both students and teachers with overviews of visualizations that could be analysed in a short amount of time (e.g., real-time analytics to be considered on the fly during the activity); and d) providing meaningful visualization techniques for showing aggregate data on the performance of this type of location-based learning activities.

5.5 Summary

This chapter has presented the main results obtained in relation to the third contribution of this thesis. Specifically, we have presented and evaluated different case studies implementing the designs of location-based learning games reported in Chapter 4.

We have presented "QuesTInSitu: The Game", a mobile application compliant with the proposed conceptual model. More specifically, several instances of "QuesTInSitu: The Game" have been implemented according to the teachers' designs obtained from the different case studies. As a result, we have described both web-based (HTML5) and Android applications considering the implementation guidelines presented in Chapter 3. The latter was implemented to prevent some issues that were detected with the web-based application.

As a whole, after analysing the different case studies we realised that the context in which the students perform the activity can influence their perception of the activity. While students performing the activity outdoors were free to follow their own path and behave in a more natural way, students performing the location-based activity in the museum have to behave differently because they were controlled by the museum staff. Other conclusions that we reach after analysing the case studies is that the design decisions made on the constituting elements of the puzzle board metaphor could have an impact on students' engagement. Besides, the purpose (assessment vs. extracurricular activities) and duration (feeling of being exhausted, etc.) of the learning activity are also factors that may influence the performance and predisposition of the students towards the activity.

Furthermore, design decisions can have unexpected results in students during the enactment of the activity. For this reason, this chapter has analysed the effects of different visualizations, as a learning analytics technique, to show the information gathered from the students' interactions with the mobile application. Besides, we have discussed the relevance of providing teachers with appropriate visualizations to led them inquire into their own designs, and thus, reconsider improvements to revise the design of their location-based games.

CHAPTER 6
CONCLUSIONS AND FUTURE WORK

This thesis presents contributions in the field of Game-Based Learning (GBL). In particular, the thesis contributes to face challenges associated with the design and enactment of location-based learning games. This chapter presents a summary of the main contributions, including lessons learnt pointing out opportunities and challenges. To this end, the conclusions are organized into three sections: a) a model, for the computational representation of puzzle board games' designs, as an implementation technique of location-based learning games, b) design techniques based on puzzle board games to facilitate the involvement of teachers in the design of location-based learning games, and c) case studies at different scales applying the design and implementation techniques. Finally, the chapter list future research directions derived from this dissertation.

6.1. Conclusions and main contributions

Educational games provide educational benefits to students when they are correctly designed. However, supporting the active role of teachers in formulating game-based learning activities is highly important for its comprehensive integration in formal education. The main motivation behind this thesis has been the opportunities and challenges derived from the involvement of teachers in the design of their own games.

To understand better the current situation in Game-Based Learning, we have performed a literature review. The analysis of the literature has shown that the adoption of Game-Based Learning (GBL) environments in formal learning settings is still a challenge that includes several research problems. Our position is that games have to be aligned with the curriculum and adapted to teachers' requirements depending on their particular educational situations. In this context, current tools for facilitating the creation of educational games are still complex and costly in terms of time for most teachers. Thus, there are challenges and opportunities to face this problem in which technologies can contribute to support the design and implementation of educational games.

Particularly, we narrowed down our research focus to location-based learning games. Then, we identified the main design factors involved in the creation of good educational games. Besides, we also analysed the research literature for modelling computer-supported games that consider contextual information and physical space as part of their constituting game elements. In this context, we have identified that the structural design of location-based learning games is often inspired by board games, and has selected this strategy as the basis to address the problem of how teachers can design their own location-based games.

To support the involvement of teachers in their own location-based learning game designs, we redefined board games as puzzle boards and proposed different techniques to design and implement this type of games. The use of the Design-Based Research methodology has allowed us to collect (early) feedback from users in several iterations, leading to informed refinements of the proposed techniques. As a result, we have first contributed with a conceptual model as an implementation technique to computationally represent location-based learning games. Besides, in order to make the constituting elements of feasible customization by teachers, we have contributed with the proposal of a puzzle board metaphor and paper-based templates as design techniques to define location-based learning games. Finally, we have also contributed with a set of case studies at different scales to evaluate the different designs and implementations of location-based learning games. Next sections focus on each contribution.

6.1.1. Conclusions on the first contribution

This section discusses the main conclusions derived from the first contribution of this thesis: **A conceptual model and the associated binding for computationally representing puzzle board games' designs including virtual and physical objects**.

Our definition of puzzle board games highlights the possibility o using virtual and physical objects. We define puzzle board games as those games that consist of a set of pieces that have to be associated to concrete slots of a given board. Both pieces and slots can be represented as virtual or physical objects. Besides, applying puzzle board games also offer opportunities to foster students' reflection. In combination with adaptive scoring and formative feedback designs, students have the possibility of trying to find the correct solution as many times as needed. The final aim is that the full completion of the puzzle provides a comprehensive view of the contained knowledge.

Since there is the possibility of implementing different types of virtual and physical objects, the conceptual model has been defined in a way that only captures general data independent from specific technologies. Then, the internal representation of each object is left to concrete engines depending on the targeted platform.

Based on the proposed conceptual model, different prototype games have been developed compliant with the conceptual model. Purely-digital puzzle board games have been created for different subjects including, programming fundamentals, computer architecture or computing networks. Other approaches also compliant with the conceptual model have been created for tabletop interfaces. Finally, different location-based games have been developed and evaluated in real learning context. In all these cases, virtual and physical objects have been captured by the XML binding, and the specific platforms have implemented the concrete behaviour of each element. Particularly, the different location-based learning games followed the proposed implementation guidelines. Since the XML documents for each location-based game were compliant with the proposed model (had the same structure), the implemented XML parser was common for the different games. Then, variations of a generic implementation of the system have been developed according to teachers' designs: two of the games were designed for completely outdoors settings (based on the use of GPS technology and GoogleMaps) and one for indoors (using static images organized in levels/zones), a fourth game considered both types of settings (using QR-code technology).

This contribution is reflected in the following paper:

Melero, J., Hernández-Leo, D. & Blat, J. (in press). A Model for the Design of Puzzle-based Games including Virtual and Physical Objects. *Journal of Educational Technology & Society*.

Besides, the preliminary conceptual version and evaluations with several prototypes have been published in:

Melero, J., Hernández-Leo, D., & Blat, J. (2011b). Towards the Support of Scaffolding in Customizable Puzzle- based Learning Games. In *Proceedings of the 11th International Conference on Computational Science and its Applications* (pp. 254-257), Santander, Spain.

Melero, J., Hernández-Leo, D., & Blat, J. (2012). Considerations for the Design of Mini-games Integrating Hints for Puzzle Solving ICT-Related Concepts. In *Proceedings of the 12th IEEE International Conference on Advanced Learning Technologies* (pp. 138-140), Rome, Italy.

6.1.2. Conclusions on the second contribution

Considering the premise that the structural design of location-based learning games is often inspired by board games, we use the proposed conceptual model to contribute with **a metaphor that considers puzzle board games' elements to facilitate teachers the design of their own location-based learning games**.

Both the metaphor and a set of paper-based templates have been proposed as design techniques to involve teachers in the definition of their own location-based games. The motivation behind these two techniques is to provide teachers with a framework for the customization of their own location-based games adapted to their requirements depending on their particular educational situations.

Evaluations in real contexts and in a workshop have led to the conclusions that these two techniques can be successfully applied to design location-based learning games. Teachers have been able to customize the different elements compiled in the metaphor according to their specific educational situations. Besides, the evaluation of four designs in real learning context brings us with the following conclusions (see Figure 44):

- When paying attention to the textual information associated to a level, we identify two different design strategies. On the one hand, we differentiate the educational contexts in which the location-based games are not associated to a concrete subject matter (i.e. l'Hospitalet and Sant Sadurní case studies). In these cases, no previous knowledge is explained to the students. Then, all the necessary information to understand the context of each level in the game is included in the level's content. Thus, the level's content in this situation is detailed and extensive. On the other hand, the location-based learning games designed as a part of a subject matter (i.e., Vic and MNAC case studies) tend to contain shorter explanations as textual information for a given level. Knowledge, in those cases, has been previously explained in specific lessons, and as a consequence, the game just includes a brief description to contextualize the set of questions for a specific level.

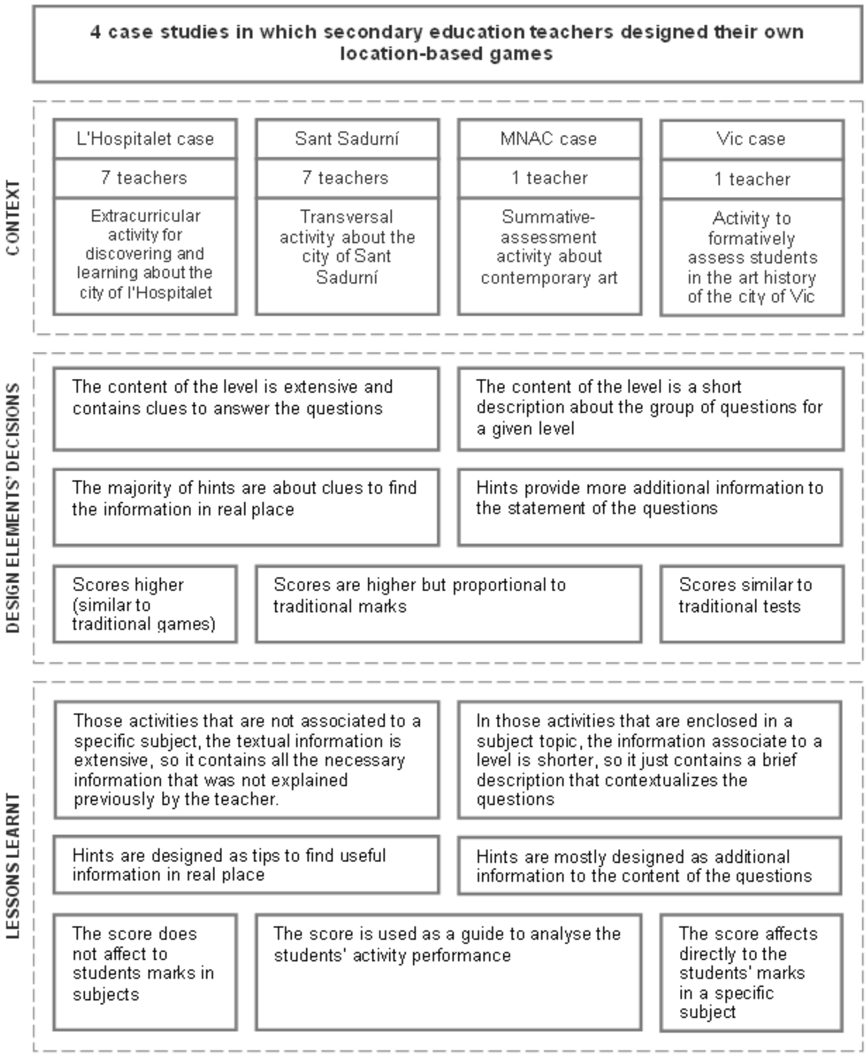

Figure 44. Lessons learnt associated to contribution 2

- Regarding the design of hints, we detect two main differences depending on the purpose of the activity. In the location-based learning games designed as a part of a subject matter (i.e. Vic and MNAC case studies), the hints consist of additional information to the statement of the questions, and concerning to concrete knowledge explained in the lessons previous to the m-learning activity. In those cases that the location-based game is part of an extracurricular or transversal activity of the educational centre (i.e. l'Hospitalet and Sant Sadurní case studies), hints are designed in a way that provides the students with some tips about concrete physical places where they can find useful information to answer the questions.

- Three different strategies are identified when teachers design the scoring mechanisms depending on the purpose of the activities. For the extracurricular activity (i.e. l'Hospitalet[1]), teachers try to follow an approach similar to "traditional" games in the sense that, higher scores and bonus are obtained when correctly answering the questions. In those cases that the result of performing the location-based learning game has a direct impact in the students' marks (i.e. Vic case), the approach followed consists in using a strategy similar to traditional test-based scores. Finally, when the overall scores obtained by students are planned as a complement to other activities in specific subject matters (i.e. Sant Sadurní and MNAC cases), the design strategy followed by teachers consists in designing scores higher than in traditional assessment activities but in a way that can be easily mapped to a mark.

[1] Impact in the media:

- La Vanguardia: http://www.lavanguardia.com/local/baix-llobregat/20130409/54372167234/nuevas-tecnologias-patrimonio-historia.html
- L'Hospitalet press: http://www.lhdigital.cat/web/digital-h/noticia/-/journal_content/56/11023/7302101;jsessionid=8023C4BC7EBC17940E07358350E9E4FD
- L'Hospitalet city council news: http://www.l-h.cat/detallNoticia.aspx?17xaxEDlMy9a8dqazCEJQ8JBVWGTvm6vCyER8uVvYjfgSysqazB
- TV news: http://lhdigital.cat/videos_2013/noticies/JocdelesTorres.mp4

Game's blog: http://eljocdelestorres.wordpress.com/

Therefore, the metaphor and paper-based templates can be considered as feasible techniques to support teachers in the design of their own location-based learning games for their particular educational situations.

Partial results of these contributions have been published and accepted in following peer-reviewed conference papers:

Melero, J., Hernández-Leo, D., & Blat, J. (accepted-a). Teachers can be involved in the design of gamified m-learning activities: the use of the puzzle metaphor, In *Proceedings of the 6th International Conference on Computer Supported Education*. Barcelona, Spain.

Melero, J., Hernández-Leo, D., & Blat, J. (accepted-b). Being able to accommodate activity's formal purposes as critical factor when designing for "location-based learning games" at scale, In *Ideas in Mobile Learning Symposium (BIIML)*. Bristol, UK.

Melero, J., Santos, P., Hernández-Leo, D., & Blat, J. (2013). Puzzle-based Games as a Metaphor for Designing In Situ Learning Activities. In *Proceedings of the 6th European Conference on Games Based Learning* (pp. 674-682), Porto, Portugal.

6.1.3. Conclusions on the third contribution

In order to evaluate the implementation of location-based learning games' designs, we carried out different experiments with secondary education students. In particular, the third contribution consists in **a set of case studies on the design and implementation of location-based learning games considering the conceptual model and the associated binding**.

The different case studies show the feasibility of using not only the puzzle board metaphor for designing location-based learning games but also the model for implementing this type of games. The case studies show that the resulting games reflect teachers' design decisions. Besides, they provide insights around several educational benefits observed during the activities. While playing the designed location-based games, students: a) are engaged in collaborating between each other to reach to the answers; b) put into practice social interaction skills to find the answers of the proposed questions, as well as exploration and orientation skills; c) are actively involved in finding the correct solutions (i.e. they follow different strategies such as asking people, other colleagues, searching the Internet or social networks); and d) reflect on their past choices.

Furthermore, the main conclusion derived from the evaluation of the different case studies with secondary education students is that not only design decisions made by teachers but also the contextual environment in which the activities are performed can influence students' engagement (see Figure 45). In particular, concrete conclusions about the lessons learnt from the different case studies are:

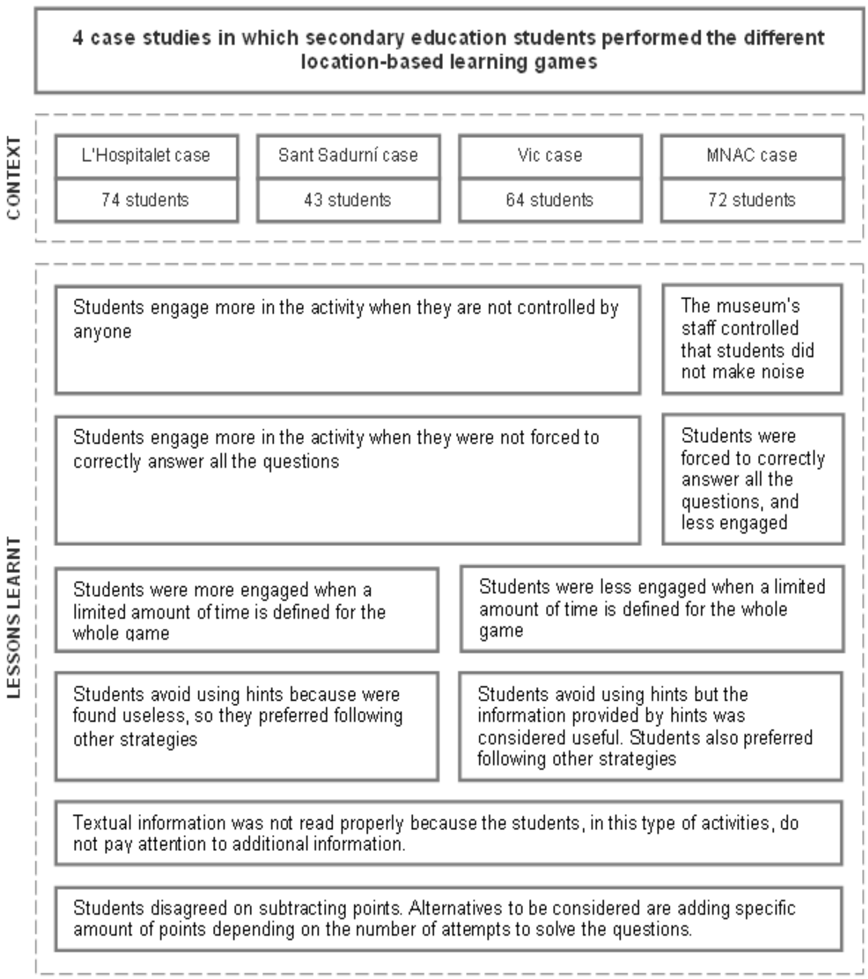

Figure 45. Lessons learnt associated to contribution 3

- Contextual environment can influence the overall students' engagement. When comparing the results of location-based learning games performed outdoors (i.e. l'Hospitalet, Vic and Sant Sadurní cases) and indoors (i.e. MNAC cases), we observed that students performing the activity in the museum are less engaged. While students playing outdoors are not controlled by anyone, students performing the activity in the museum have to control their behaviour and actions in order to avoid making too much noise, for example.
- In all of the activities, students avoid using hints. Hints have been designed in a way that some points are subtracted each time a student access them. It is interesting to notice that students prefer to become more active in finding the correct solution (i.e. asking people, searching the Internet, discussing among them) than having to lose points. Besides, when analysing the opinions around the designed hints, hints designed as tips pointing to specific real places (where useful information could be found) are those more criticized by students than those hints that complement the questions with additional information.
- The amount of time and having to correctly answer the questions are other factors to consider in the engagement achieved by the activity. The students with limited time to answer questions per level (specially, the students from the museum that also were forced to correctly answer all the questions) enjoy less the proposed approach. The students that do not have limit of time per level (i.e. l'Hospitalet and Vic cases) and are free to answer or not all the questions in a level enjoy more the activity. This indicates that depending on the setting of the activity, it is advisable not to force students to solve every question correctly and offer the flexibility to students to move to another level.
- In all the four cases, all the students have rarely accessed the textual information associated to each level. Instead, students directly accessed the different questions, and only few of them carefully read the information associated to the levels. These results indicate that students, in this type of educational games in physical locations, go straight to the focus of the activity and do not devote time to explore additional learning materials.
- Regarding the scoring mechanisms, students from all the four cases were disappointed with the subtraction points when

answering incorrectly and using hints. Not surprisingly, negative feedback has not a positive effect in students' motivation. Other strategies are suggested to overcome this issue. These strategies include considering only positive scores, but with different weights depending on the number of attempts used in each question and the resources used to solve the questions.

As wee can see, there are several elements that can influence students' engagement. Analysing the implementation of location-based games is critical for enabling the identification of learning design elements that should be revised and improved. It becomes crucial to support teachers' inquiry into their own designs, so they can evaluate and revise the designs for future activities. In this sense, learning analytics have been studied as a powerful strategy to capture, analyse and report data about the student's performance. In this line, we have analysed how learning analytics visualizations can lead teachers inquire into the students' outcomes when playing their designed location-based learning games. Conclusions derived from this contribution discuss how specific learning analytics visualizations are helpful tools to support teachers in the understanding of each student's activity performance and the importance of providing visualizations of aggregate data for providing teachers with the overall picture of the activity. Besides, in order to be meaningful for teachers, it is important that the visualizations are complemented with students' opinions.

Partial results of these contributions have been submitted for their consideration to be published as journal papers (currently under review):

Melero, J., Hernández-Leo, D., Sun, J., Santos, P., & Blat, J. (conditionally accepted). How was the activity? A visualization support for a case of situated m-learning design. *British Journal of Educational T*echnology.

Melero, J., Hernández-Leo, D., & Blat, J. (submitted). Puzzle-based game design elements in an in-situ indoor m-learning activity.

Overall, we can state that this dissertation has achieved its global objective which refers to **supporting the design and implementation of location-based learning games by considering computer-supported puzzle board games elements**

including virtual and physical objects. The proposed conceptual model and the associated information binding have allowed the implementation of different types of puzzle board games. In particular, we have successfully implemented not only purely-digital puzzle board games prototypes but also tangible games (using the ReacTIVision technology (Kaltenbrunner & Bencina, 2007)) compliant with the conceptual model. Besides, the conceptual model has allowed the computational representation of location-based learning games. In this context, the proposed metaphor and associated paper-based templates have been considered as suitable tools to design location-based learning games. Specifically, teachers have been able to design their own games, according to their particular requirements, inspired by the metaphor and using different paper-based templates. Furthermore, several technological implementations of location-based learning games have been successfully developed according to the proposed implementation guidelines. Accordingly, different instances of "QuesTInsitu: The Game" mobile application have been implemented according to the conceptual model. The development of the different versions of this application has considered diverse implementation techniques: a) static images to indicate location of questions for indoors, b) GoogleMaps to display the location of questions for outdoors, c) QR codes to access specific information for outdoors/indoors; and d) plug-ins of social tools (i.e. twitter) as a strategy to communicate teachers and students.

6.2. Future research directions

Apart from the aforementioned contributions and conclusions, this dissertation has also identified the following future research lines:

- Implementation of authoring tools devoted to different types of technologies. This PhD has contributed with a conceptual model that allows the modelling of computational representations of puzzle board games. These games are characterised for the possibility of integrating virtual and physical objects. Then, different opportunities for further research are based on supporting teachers in the creation of puzzle board games. As proposed in the implementation guidelines, authoring tools could be developed to create XML documents for platform-specific engines and players that depend on the adopted approach: a) completely digital puzzle board games, b) completely physical puzzle board games (e.g. using sensors, RFID technology, etc.); or c) puzzle board games integrating both virtual and physical objects. Besides, from the different evaluations, it seems relevant to consider the integration of recommendations in authoring tools to advise teachers about what strategy could be followed (e.g. designing scores, hint's content, etc.) depending on their purposes (e.g., formative assessment, introductory activity, etc.).

- Evaluating the effects of the different elements involved in the design of location-based learning games on students' performance. There are some challenges and opportunities to further research the impact of the elements in students. In particular, it could be interesting to further analyse the emotional effects that specific elements of the game (specifically positive and negative performance feedback) have on students (van Duijvenvoorde, Zanolie, Rombouts, Raijmakers, & Crone, 2008). In this thesis we identify that subtracting points affect negatively the students, and this suggests following other alternatives. Somehow similarly, students rarely use hints, and they prefer following other paths. Future research is needed to understand the reasons behind these aspects and refine the design elements.
- In this dissertation we have only partially evaluated the students' activity performance. We have seen that having the possibility of answering the questions several times (though obtaining less marks) promotes students' reflection. Teachers' and students' opinions support this hypothesis. Quantitative results also show a trend indicating that students using the game approach outperformed those students that did not use it. However, these results are no conclusive and further research is needed.
- We observe that in this type of learning activities, collaboration plays an important role. Several students share a device and they collaborate between them to propose a solution. However, the different collaborative dynamics that happen in the groups are not gathered by the system. How to collect these interactions and make them understandable for teachers are interesting aspects that deserve future research. Besides, since different types of collaborative and social tools can be integrated in

applications supporting location-based learning games, further research should analyse in which fruitful ways these tools should be integrated.

- In this dissertation we have evaluated different visualizations as techniques to lead the teachers inquire into their own designs. Learning analytics and visualizations are relevant to capture and make understandable to the teachers data related to how their students performed the activity. Researching the integration of meaningful visualizations in systems supporting location-based learning games could improve significantly the enactment of this type of games.
- During the enactment of the different implementations, unexpected contextual or technological problems can happen. Mobile devices and software implementations could derive to unexpected problems, as well as unexpected situations in the real places. In this sense, an interesting research line could be focused on proposing ways that allow changing the dynamics of the game on the fly. Not only providing teachers with mechanisms to change the dynamics of the game on the fly could be interesting to further research, but also analysing the impact that these changes could have on students.
- Finally, other future research line is associated to the extension of this type of games across different types of spaces, technologies and activities. As stated in the state-of-the-art, location-based learning games could fruitfully be combined with other activities to enrich the learning experience. Further research will deal with how to integrate and make interoperable location-based games with other learning activities. Initial efforts to explore the integration of location-based learning games with other tools and learning environments have been done in (Pérez-Sanagustín, Melero, Hernández-Leo, & Delgado Kloos, 2013). In this particular effort, we present an exploratory study in which first-year undergraduate students performed a tag-based learning activity. A location-based game was implemented to be used as a part of a set of learning activities. In particular, the location-based learning game was intended to familiarize students with the university services and encourage them to explore and learn about some university buildings and services of the campus. Other follow up activities required the students to perform some tasks with PCs accessing the

institutional learning management system. This scenario shows the importance of achieving the integration of location-based learning games in broader across-spaces/technologies scenarios enabling seamless learning experiences.

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APPENDICES

Appendices are available in a CD-ROM attached at the end of the dissertation:

A1. Digital puzzle board game prototype for learning Computer Architecture concepts

A2. Digital puzzle board game prototype for learning Programming Fundamentals concepts

A3. Digital puzzle board game prototype for learning Computing Networks concepts

A4. Tangible puzzle board game for learning Computer Architecture concepts

A5. Tangible puzzle board game for learning ICT-related concepts

A6. Complete collection of snippets composing the specification of the games described in the scenario 1

A7. Complete collection of snippets composing the specification of the games described in the scenario 2

A8. XMLs compliant with the conceptual model representing the teachers' designs for the different case studies

A8.1. XML documents for l'Hospitalet case

A8.2. XML documents for Vic case

A8.3. XML documents for Sant Sadurní case

A8.4. XML documents for MNAC case

A9. Source code of "QuesTInSitu: The Game" (Web-based application that uses GPS)

A10. Source code of “QuesTInSitu: The Game” (Web-based application that does not use GPS)

A11. Source code of “QuesTInSitu: The Game” (Android application that uses GPS)

A12. Source code of “QuesTInSitu: The Game” (Android application that does not use GPS)

A13. Source code of “QuesTInSitu: The Game” for the MNAC Case (gamified version)

A14. Source code of “QuesTInSitu: The Game” for the MNAC Case (not gamified version)

A15. “QuesTInSitu: The Game” for l’Hospitalet (version with GPS)

A16. “QuesTInSitu: The Game” for l’Hospitalet (version without GPS)

A17. “QuesTInSitu: The Game” for Sant Sadurní (version with GPS)

A18. “QuesTInSitu: The Game” for Sant Sadurní (version without GPS)

A19. “QuesTInSitu: The Game” for MNAC (gamified version)

A20. “QuesTInSitu: The Game” for MNAC (not gamified version)

A21. Raw data collected from different case studies (i.e. l’Hospitalet, Vic, Sant Sadurní and MNAC).