Design and Implementation of Location-based Learning Games: Four Case Studies with "QuesTInSitu: The Game"

Javier Melero, Davinia Hernández-Leo

Abstract— Over the past few years the use of educational games for learning purposes has reported many educational benefits in terms of students' motivation and engagement towards learning. One of the challenges in the research field of Game-Based Learning (GBL) is to create or adapt educational games to teachers' requirements depending on their particular situations. An approach to face this problem is to provide teachers with strategies that allow them to design meaningful games for their learning scenarios. To address this issue, a metaphor has been proposed for supporting teachers in the design of the so-called location-based learning games. In this study, we describe four real learning contexts, including 16 secondary education teachers use the proposed metaphor to design their own location-based games. Besides, in order to gain meaningful insights about the impact of the designed games in students' satisfaction, we deployed the teachers' designs in "QuesTInSitu: The Game". A total of 253 students from the 4 secondary schools played the designed games. The main findings derived from the evaluation with teachers and students provide meaningful insights about main considerations when designing and deploying location-based learning games for outdoors and indoors.

Index Terms—Learning Technologies, Educational games, Mobile and personal devices

1 Introduction

EDUCATIONAL games have become a popular approach to engage and motivate learners in many topics. However, one concern in the research domain of Game-based Learning (GBL) is that teachers do not broadly adopt educational games in formal learning setting. The main reasons behind the low adoption include that 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 [1], [2], [3], [4]. Diverse research efforts focus on providing easy-to-use game editors. Unfortunately, these tools can be too complex for some instructors, hard to adapt to individual courses, and require too many resources and too much time for development [1], [2], [3].

In this paper we narrow our research down location-based learning games. Over the past few years the use mobile technologies for learning has attracted the interest of practitioners in all phases of education to facilitate informal learning in formal contexts [5]. Within the research field of GBL, mobile computing offers the possibility of creating the so-called location-based games [6], [7]. Location-based games are those approaches based on pervasive mobile learning that support contextualized learning in non-formal learning situations [8]. Location-based games have been proved beneficial in terms of: enriching learning experiences by extending the learning beyond traditional classrooms [9], [10] and interacting with physical items by adding virtual layers of information; creating fruitful learning experiences that involve exploration and cooperation [11]; allowing the access to contextualized information, communication, analysis and interrelation of real place [12], [13]; being entertaining, stimulating [6], [14], and effective in terms of increasing the motivation to learn and to acquire a deeper understanding of the exhibits [15].

There are several well-known research works on using location-based games for different learning purposes. In *Environmental Detectives* [16], students work in small teams playing the role 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* [17] 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* [18] 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 *Savannah* [19], children interact outdoors, through PDAs with GPS, with a virtual Savannah and explore the opportunities and risks to being lions. *Alien Contact!* [20] 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

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determine why the aliens have landed. The mobile city game called *Frequency 1550* [21] helps students playfully acquire historical knowledge of medieval Amsterdam.

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 used 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). However, none of these research works report on supporting teachers in the design process of location-based games, and how design decisions can have an impact on learners' satisfaction.

In order to facilitate teachers the design of location-based games, adapted to their particular educational situation, in this paper we propose the use of a metaphor based on puzzle board elements (see Fig. 1). Metaphors have been widely used in Human-Computer Interaction to facilitate reasoning about designing in unfamiliar contexts [22], [23], [24]. In the context of this work, one can assume that traditional board and puzzles are well-known concepts by teachers, while location-based games might not be familiar to them. We consider the adoption of puzzle board elements as a metaphor since board games have been studied as suitable approaches for structuring the design of location-based games [25], [26].

The originality of this work relies on the consideration that location-based games can be structured as board games, as well as on putting it into practice in real learning situations. Our main purposes are twofold. First, we aim to provide teachers with a puzzle board metaphor as an approach to allow them the design of location-based games. And second, we aim to evaluate the impact of the implemented game designs in learners' satisfaction. Thus, this paper focuses on the evaluation of not only teachers' designs but also on the implementations with their students.

Different experiments in real learning situations have been carried out in order to evaluate the proposed metaphor. Concretely, an evaluation has been carried out to evaluate the design process in which 16 secondary education teachers from 4 high schools have been involved in the design of their own location-based games. We also report the main results obtained from the students' opinions when performing the designed location-based games implemented in "QuesTInSitu: The Game", a mobile application compliant with the metaphor. Thus, in this research work, we describe the main considerations in designing and implementing location-based learning games. The main conclusions will contribute to the research domain with insights pointing out strengths and limitations of using this approach when designing and implementing location-based games.

In order to tackle the different research issues that have been previously described, the remainder of this paper is structured as follows. In Section 2, the proposed metaphor for designing location-based games is introduced. Then, the methodology followed to tackle the research issues of interest of this research work is described in Section 3. Section 4 describes the teachers' designs of the different location-based games. The main findings, obtained from the analysis of the teachers' designs and the process followed, are also described in this section. Next, a general overview of "QuesTInSitu: The Game" is presented in Section 5 in order to better understand how the different designs are implemented in a mobile application. Besides, this section also reports the results from an evaluation of the implemented location-based games with the secondary education students. Finally, Section 6 discusses the main conclusions of the paper.

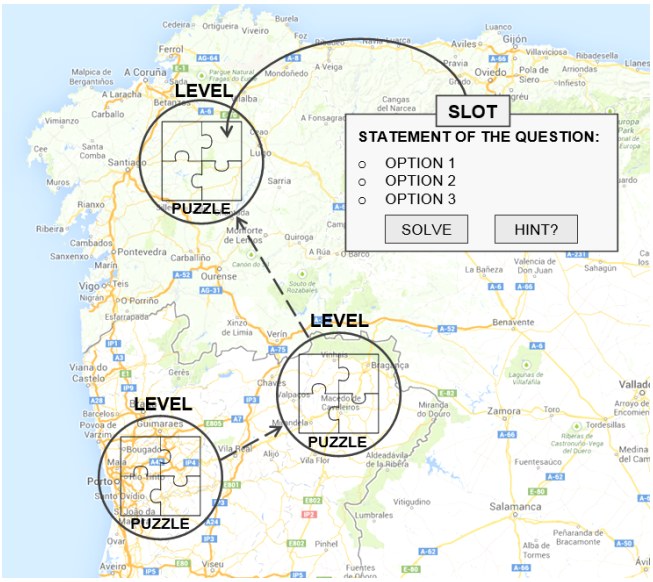

Fig. 1 Graphical representation of the puzzle board metaphor

2 A Puzzle Board Metaphor as as Strategy to Design Location-Based Games

According to [25], [26], the structural design of location-based learning games is often inspired by board games. For instance, in [27], [28] the authors propose an approach consisting in presenting quizzes in a map or board to teach specific topics. Board games permit the integration of not only quizzes but also puzzles or mini-games, adding extra value to educational scenarios [26]. Board games are also interesting because they can foster students' problem solving, analytical and memory skills [29], [30]. Besides, there are several reasons that make puzzle board games interesting approaches to involve teachers as designers: Puzzles usually have simple game rules; puzzles can be defined independently from content and therefore they can be applied in a wide range of subject matters; and their nature and duration is typically equivalent to other types of learning activities for the classroom or field trips [31], [32].

Melero & Hernández-Leo [33] propose a conceptual model and the information binding to computationally

represent different types of educational games, including location-based games, as puzzles. Main elements of the conceptual model include: a) a sequence of levels of the game; b) the activities, associated to each level, based on solving puzzles; c) the puzzles, formed by pieces and slots and the different relationships; d) scores associated to (right or wrong) relations between pieces and slots of puzzles, and e) feedback and hints to help learners while performing the different activities.

In order to metaphorically represent the location-based games as puzzle board games, in [34] we proposed the following mapping (see Fig. 1):

- "Board" is the physical place where the questions of a given level are associated.
- "Slots" are the different questions for a concrete puzzle.
- "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.
- "Puzzle" is formed by a board with a set of slots and associated puzzle pieces.
- "Level" contains only one puzzle. A designer can define different levels for each location-based game.
- "Scores" are defined to reflect the students' performance: a) correct answers add scores to the overall player's scoring, b) incorrect answers subtract scores to the overall player's scoring, and c) consulting hints subtract scores the overall player's scoring.
- "Bonus" is extra score 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 encourage students to correctly complete the different puzzles of the whole learning activity.
- "Feedbacks" are textual information associated to a specific range of scores in order to describe the students' activity performance.
- "Hints" can be provided to scaffold the learning process in order to avoid frustrations and advance forward the location-based learning game.

The underlying game mechanics consists in answering all the questions to correctly complete the puzzle board. Similarly to jigsaw puzzles, learners 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 mobile 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.). Indeed, we seek to engage students in reflecting on the correct solutions for each question proposed by the teacher.

With the aim of evaluating the proposed metaphor, in this study we apply the proposed strategy in different experiments with secondary education teachers of 4 high schools and their students. The evaluation with teachers aims to analyse the flexibility of the proposed metaphor and evaluate the understanding of its constituting elements, while the evaluation with students will give us insights of their satisfaction when using the implemented teachers' designs in a mobile application.

3 METHODOLOGY

A design-based research methodology has been followed since different participants are involved in both the design of location-based learning games and their enactment [35], [36], [37]. Overall, this 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 the proposed learning environment. Concretely, in this paper we adapt this methodology considering four different learning situations in which secondary education teachers of different schools were involved in the design of their own location-based learning games. These are: a) discovering the heritage of the city of l'Hospitalet ("l'Hospitalet Case"), b) discovering the art history of Vic ("Vic Case"), c) discovering the heritage of Sant Sadurni d'Anoia ("Sant Sadurni Case"), and d) learning about different contemporary pictures of the National Museum of Contemporary Art ("MNAC Case"). Besides, while different secondary education teachers became co-participants in the design of these location-based learning games (a-d), the enactment occurs in authentic learning contexts with their particular students.

Different data gathering have been used to evaluate the teachers' designs and students' satisfaction. More specifically, we used:

- A brief questionnaire for teachers[1] that contained Likert-scale questions (from strongly disagree to strongly disagree) to evaluate the difficulties understanding the elements of the metaphor.
- A questionnaire for students[2] that contained Likert-scale questions (from strongly disagree to strongly disagree) to evaluate the satisfaction. The questions were about specific elements (defined by teachers in the design process) of the location-based games. Besides, two open questions to indicate further positive or negative comments were included in the questionnaire.
- Log Files gathered from the system to analyse the students' interactions with the mobile application. These data are used to analyse whether the students access to all the features of the location-based games.
- Direct observations taken from the research team during the learning activities.

Thus, a mixed evaluation method [38] has been followed considering different data gathering techniques. Furthermore, we combine and triangulate [39] the collected data that provide insights into participants' opinions. In particular, in this paper we present a cross-case analysis study [40] comparing the results from the teachers' designs of l'Hospitalet Case [41] with Vic, Sant Sadurni, and MNAC Cases, and the implementation with students.

[1] Questionnaire available at www.javiermelero.es/quest_teachers.pdf
[2] Questionnaire available at www.javiermelero.es/quest_students.pdf

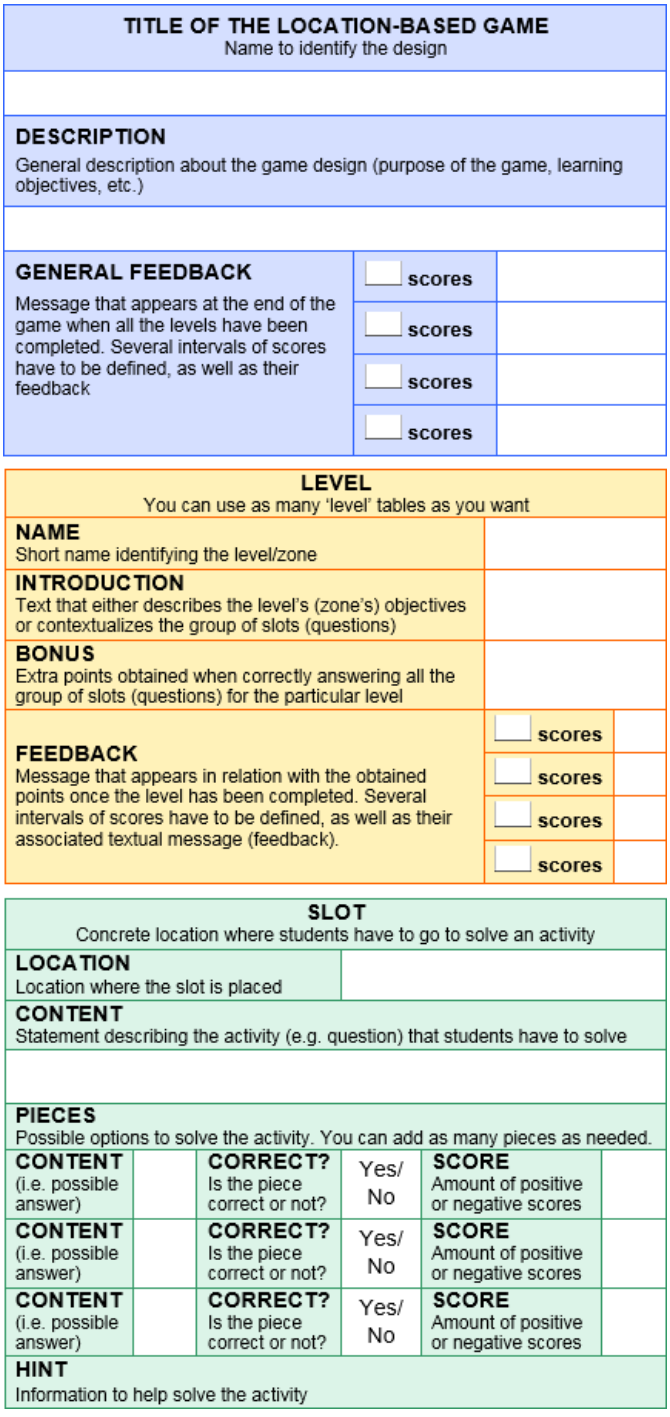

Fig. 2. Template containing the puzzle board metaphor elements

4 Design of Location-based Games

16 secondary education teachers from 4 different semi-public schools contacted us because they were interested in carrying out specific field trips using Smartphones. In "l'Hospitalet Case" 7 teachers from different disciplines designed an extracurricular activity with the purpose of discovering and learning about l'Hospitalet. Similarly, in "Sant Sadurni Case", also 7 teachers of different subjects designed an activity associated to a subject with the aim of enquiring about the heritage and the city of Sant Sadurni d'Anoia. In both cases, the designed questions include different topics such as maths, music, natural sciences, geography, and art history. In "Vic Case", 1 art teacher designed an activity associated to its specific subject to formatively assess their students in the art history of the Vic city. Finally, in MNAC Case, another art teacher designed an activity to practise the concepts associated to different pictures of a National Museum of Contemporary Art.

In all the 4 cases, the design process started with a session introducing the elements of the metaphor to the teachers. Afterwards, we provide the teachers with a set of paper-based templates containing the different elements of the puzzle board metaphor (see Fig. 2). Then, teachers dedicated between 2 and 3 weeks to design their own location-based games. That means: teachers visiting the different places, designing the questions associated to each place and filling the templates. We followed up the different teachers' design processes via email or scheduled meetings. Finally, once the design process was finished, we gathered the information provided by the paper-based templates, and we created the XMLs accordingly.

Furthermore, at the end of the design process the teachers filled a brief questionnaire (introduced in the Methodology section) evaluating the understanding of the different elements involved in metaphor. In particular, while all the teachers from l'Hospitalet, MNAC and Vic Cases answered the questionnaires; only 2 out of the 7 teachers from Sant Sadurni Case (i.e. the coordinators of the design activity) did it. Next subsection discusses the main considerations from both the resulted designs and the answers provided by the teachers in the questionnaire.

4.1 Results on Teachers' Designs and Discussion of Main Considerations

Teachers have been able to customize the different elements compiled in the metaphor according to their specific educational situations (Table 1 summarizes teachers' designs). From the designs we can observe that teachers were able to specify as many levels and questions as they wanted. Some teachers follow a scoring mechanism more familiar to traditional test (e.g., Vic Case), whilst others design a more game-based scoring mechanism (e.g., l'Hospitalet Case). Also, some of the teachers design hints similar to suggestions (e.g., l'Hospitalet and Vic Cases), while others offer additional information as clues to solve the different questions (e.g., MNAC and Sant Sadurni Cases). We also find differences in the writing: while the feedback of some designs is written in a formal way, other designs contain a more informal written feedback. Besides, concerning the flexibility of the proposed metaphor, only one teacher indicates in the questionnaire that a limitation is "*to define different routes per each group. I think it should be better that each group of students could define their own path*".

TABLE 1
SUMMARY OF THE TEACHERS' DESIGNS

	l'Hospitalet Case	Vic Case	Sant Sadurni Case	MNAC Case
Number Levels	10 levels	4 levels	8 levels	4 levels
Number Questions	58 questions	75 questions	64 questions	20 questions
Scores Correct Answers	+ 250 scores	+ 1 score	Number of questions per level / 1000 scores	+ 50 scores
Scores Incorrect Answers	- 100 scores	- 0.3 scores (first attempt), - 0.5 scores (second attempt), + 1 score (third attempt)	- 30 or - 60, depending on the number of questions per level	- 10 scores
Number Hints	52 hints	25 hints	64 hints	19 hints
Scores Hints	- 100 scores	- 0.2 scores	- 50 or - 100, depending on the number of questions per level	- 50 scores
Extra Bonus	Proportional to the number of questions per level	+ 1.5 scores when all the questions correctly answered at the first attempt; + 0.75 scores otherwise	+ 100 or + 150 scores, depending on the number of questions per level	+ 50 scores
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

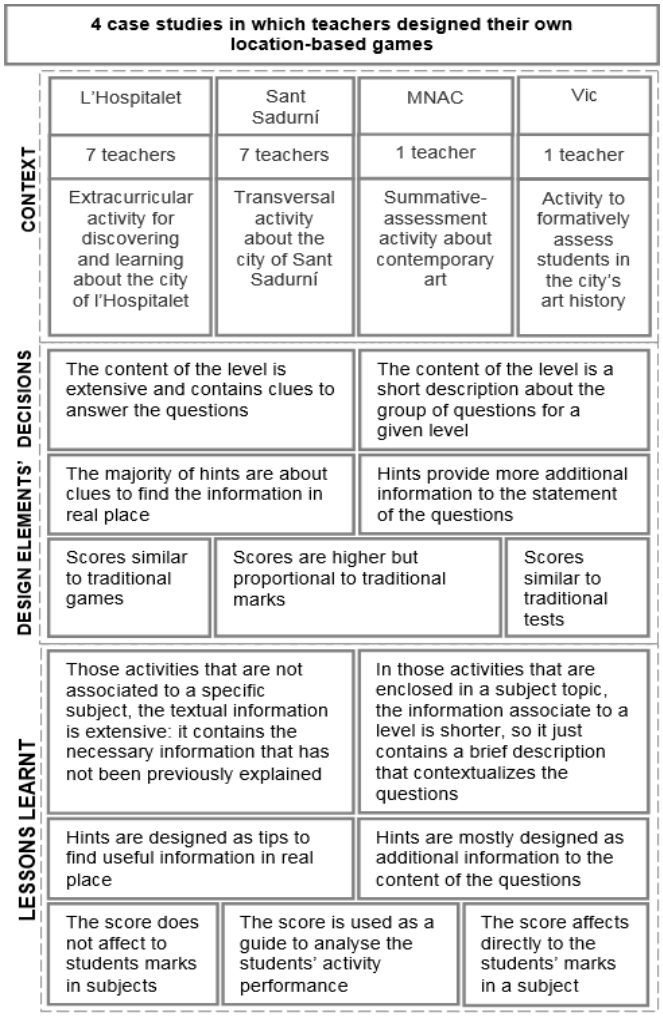

Fig. 3. Main considerations from teachers' designs

From the analysis of the resulted designs and questionnaires, we can highlight the following considerations (see Fig. 3). More teachers (6/11) quite or strongly agreed on understanding the meaning of the feedback when completing a level of the game, compared to those who did not (3/11). Similar results were obtained about the feedback when completing the whole game. While 5 out of the 11 teachers quite or strongly agreed that they understand this element, 2 teachers did not.

We identify two different strategies regarding the design of the textual information associated to a level of the game. First strategy concerns the educational contexts in which the location-based games are not associated to a concrete subject matter (i.e. l'Hospitalet and Sant Sadurni Cases). In these contexts, the textual information is detailed and extensive since no previous knowledge is explained to the students. A second strategy is applied in the location-based learning games designed as a part of a subject matter (i.e., Vic and MNAC Cases). In these contexts, the textual information tends to contain shorter explanations since knowledge has been previously explained in specific lessons.

Most of the teachers (9/11) quite or strongly agreed that they did not have problems understanding the meaning of the hints. Half of the teachers complained about having difficulties for creating hints to each single question. For instance, one comment was: "*Some questions are very focused and it is difficult to design hints that aren't too obvious*". In this line, teachers highlighted that not all the questions should have hints because it makes no sense and its design would imply a relatively high workload.

Furthermore, we detect two main differences in the way the hints are designed. In the location-based learning games designed as a part of a subject matter (i.e. Vic and MNAC Cases), the hints add information about knowledge

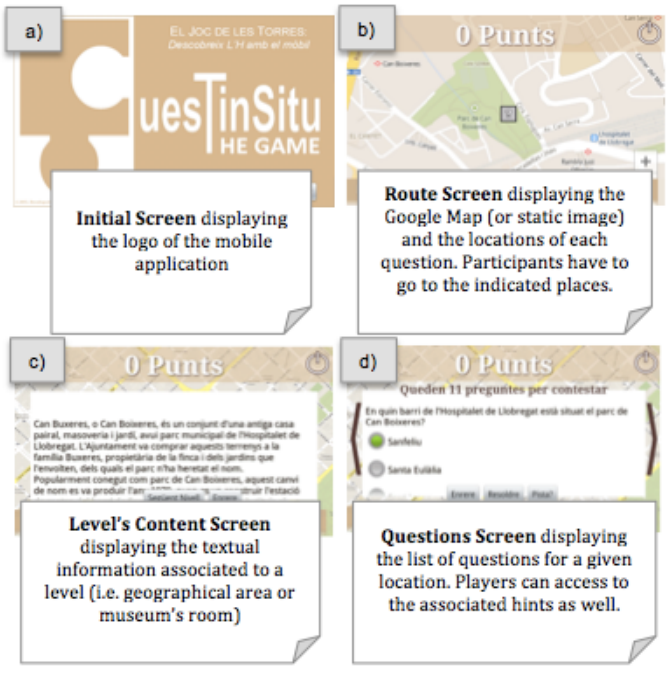

Fig. 4. Some screenshots of "QuesTInSitu: The Game" (for outdoors)

explained in the lessons previous to the location-based learning game. When the location-based game is part of an extracurricular or transversal activity of the educational centre (i.e. l'Hospitalet and Sant Sadurni Cases), hints are designed as tips about concrete physical places where students can find useful information to answer the questions.

Three different strategies are identified concerning the scoring mechanisms. For the extracurricular activity (i.e. l'Hospitalet Case), teachers try to follow an approach similar to "traditional" games, meaning that higher scores and bonus are obtained when correctly answering the questions. In those cases that the overall score of the location-based learning game has a direct impact in the students' marks (i.e. Vic Case), the teachers followed a strategy similar to traditional test-based scores. Finally, when the overall score obtained in the activity is a complementary mark to activities in specific subject matters (i.e. Sant Sadurni and MNAC Cases), the teachers designed scores higher than in traditional assessment activities but in a way that can be easily mapped to a mark.

The most problematic issue concerns the understanding of the 'level' element. 7 out of the 11 teachers strongly or quite agreed on having difficulties to understand the meaning of a level. One of the teachers indicated, "*The more problematic element is to differentiate between zone and level. We understand 'zone' while you say 'level'; for as level is something related to difficulty degree*". It is interesting to notice that the teachers with more problems were from l'Hospitalet Case (first case study, chronologycally). In this case, 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. In fact, teachers from Vic and Sant Sadurni Cases did not report specific problems. Thus, 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. We believe this is a result of having refined the definitions of the elements involved in the metaphor. In the particular case of the level element, 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 location-based learning games.

Therefore, from the teacher's opinions and the resulted designs, we can claim that the metaphor has been successfully applied to design location-based 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.

Next section presents "QuesTInSitu: The Game", a mobile application that is compliant with the conceptual model binding for puzzle board games design [33]. For each of the 4 teachers' designs of location-based learning games, we gathered the information provided by the paper-based templates and we created the XMLs used as inputs for "QuesTInSitu: The Game". Evaluations with students using this mobile application will provide useful information about how the design of the different elements of the games can have an impact on students' satisfaction.

5 Implementation and Evaluation of Location-based Games: "QuesTInSitu: The Game"

"QuesTInSitu: The Game", an extended version of the "QuesTInSitu" [42], [43], interprets the XMLs compliant with the puzzle board metaphor. "QuesTInSitu: The Game" is an Android mobile application that extends the former version by including game elements such as hints and bonus scores, and by allowing the implementation of not only outdoors settings (with Google Maps) but also indoors (with static images).

Different instances of "QuesTInSitu: The Game" were implemented for the 4 teachers' designs of location-based game. Overall, the workflow of the application (see Fig. 4) was the same in all the 4 cases. First, an initial screen displays the logo of the application (Fig. 4, a). The main screen shows a Google Maps (in l'Hospitalet, Vic and Sant Sadurni Cases) with the location of the different questions (Fig. 4, b). In MNAC Case, a static image of the museum's map was displayed contained the location of the questions. From the main screen, the students can also access to the textual information associated to a level of the game at anytime (Fig. 4, c). In the outdoor cases, once the students are close to a specific location, containing geolocated questions, a new screen appears showing the list of questions (Fig. 4, d). In MNAC Case, students have to manually click on each question to show them.

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 associate hint, if defined. The overall score is always shown in the screen and updated every time the player answers correct/incorrectly a question, access to the hints or obtains a bonus.

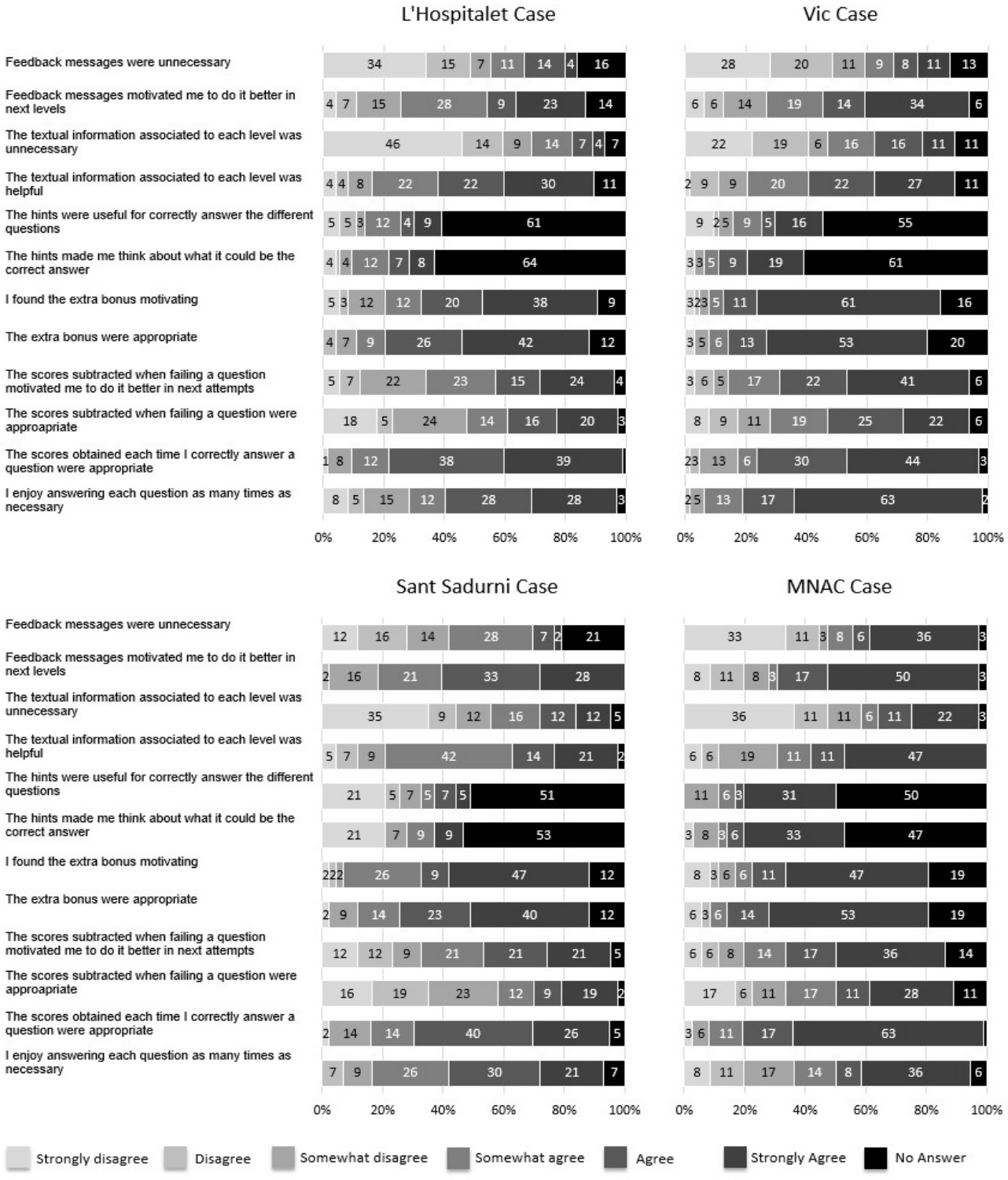

Fig. 5. Overview of the results from the students' opinions

An evaluation with secondary education students (girls and boys between 14 and 17 years old) has been carried out to analyse the students' satisfaction when performing the designed location-based games using "QuesTInSitu: The Game". Concretely, the evaluation was focused on the game dynamics and their different design elements (i.e. designed scores, bonus, hints, and feedbacks).

The number of students participating was: 74 students from l'Hospitalet Case (divided in groups between 2 and 5 students), 64 students from Vic Case (divided in groups between 4 and 5 students), 43 students from Sant Sadurni Case (divided in groups between 3 and 5 students), and 36 students from the MNAC Case (divided in groups between 3-4 students). Students formed the groups freely. The sole restriction was that one member of the group had to own an Android smartphone with, at least, version 2.3.3 (i.e. version used in "QuesTInSitu: The Game").

Furthermore, the teacher of MNAC case forced their

students to correctly solve all the questions of the game, and she defined a limited period of time (20 minutes) to solve the questions of each level (1 hour and a half, the whole learning activity). On the other hand, the teachers from l'Hospitalet, Vic, and Sant Sadurni Cases did not force their students to correctly solve all the questions of the game and they defined a general period of time to finish the overall game (around 2 hours the whole activity).

5.1 Results on Students' Opinions and Discussion of Main Considerations

Fig. 5 reports the main results on the students' opinions about the different designed elements: scoring mechanisms (positive and negative scores), bonus, hints, textual information associated to each level in the game, and feedbacks. ANOVA showed statistically significant differences (p-value < 0.05) between groups on some of the designed elements (see Table 2, highlighted in bold). From the obtained results, we also discuss the main considerations in regards to the students' satisfaction with the design elements (see Fig. 6).

More than a half of the students enjoyed answering as many times as needed the different questions until reaching a solution (56% of l'Hospitalet, 51% of Sant Sadurni and 80% of Vic strongly agreed or agreed on that). In fact, when looking at the log files, most of the groups from l'Hospitalet (10/14) and Vic (12/14) correctly solved all the questions and they avoided skipping levels. Slightly less positive ratings were obtained from the MNAC; 44% of these students agreed or strongly agreed that they enjoyed answering each question as many times as necessary. Some comments were "*I enjoy the intrigue to know the answer*", "*I like answering correctly the questions*", and "*I enjoy answering several times the questions until select the right answer*".

Students in general avoid using hints. Around two thirds of the students (i.e. 19/31 students from l'Hospitalet, 24/29 students from Vic, 17/21 students from Sant Sadurni, and 17/20 students from the MNAC) agreed or strongly agreed that they carefully consulted the hints because they subtracted scores. 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 scores. Some students indicated that they prefer: "*Asking people*", "*Asking the employees of the tourism office*", "*Using the phone's browser to find the answers*", "*Reading carefully the information provided in the level's description*", and "*Looking at the buildings and the surroundings*". Also, the observers noticed these different strategies to find the correct answers: "*The employee of the tourist office helps the students answering the questions*", "*The students ask the police*", "*a woman near the museum gives some clues to the students about the answers of the questions*".

When analysing the log files, we observed that only around a half of the groups from l'Hospitalet (7 out of the 14 groups) and Sant Sadurni (5/12) consulted hints. Regarding Vic, two thirds of the groups of students (9/14) accessed to the hints. 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. The accesses to the hints from Vic and Sant Sadurni were 2/25 and 4/64, respectively.

The students criticized more the hints designed as tips pointing to specific real places than those hints adding more information to the questions. Statistically significant differences were obtained when asking whether hints made students think about what could be the correct answer (p=0.00021, see Table 2). In this regard, better results were obtained from Vic (28%) and MNAC (39%) cases (hints providing additional information) compared with Sant Sadurni (18%) and l'Hospitalet (15%) cases (hints as clues pointing at physical places). Similarly, students from Vic (21%) and MNAC (34%) rated higher the usefulness of hints compared with the students from l'Hospitalet (13%) or Sant Sadurni (12%).

TABLE 2
RESULTS OF ANOVA ON THE DIFFERENT ELEMENTS

	p-values
Feedback messages were unnecessary	0.29742
Feedback messages motivated me to do it better in next levels	0.55064
The textual information associated to each level was unnecessary	**0.01397**
The textual information associated to each level was helpful	0.63720
The hints were useful for correctly answer the different questions	0.00564
The hints made me think about what it could be the correct answer	**0.00021**
I found the extra bonus motivating	**0.02719**
The extra bonus were appropriate	0.52879
The scores subtracted when failing a question motivated me to do it better in next attemps	**0.00385**
The scores subtracted when failing a question were appropriate	0.13888
The scores obtained each time I correctly answer a question were appropriate	0.90710

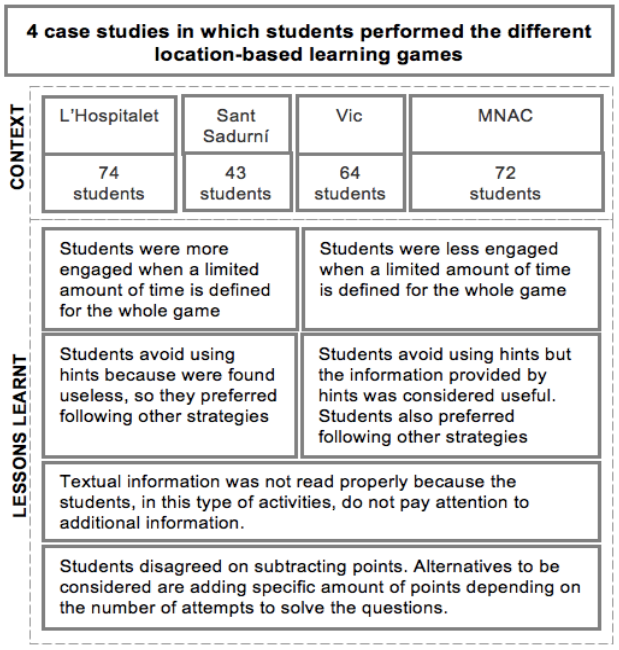

Fig. 6. Main considerations from the enactment with students

Most of the students agreed or strongly agreed that the added scores, when correctly answering the questions, were appropriate and motivating (77% of l'Hospitalet, 66% of Sant Sadurni and 74% of Vic, and 80% of MNAC). More than a half of students (68% of l'Hospitalet, 66% of Vic, 53% of Sant Sadurni, and 67% of MNAC) agreed or strongly agreed that the extra bonus obtained were appropriate. However, few students agreed or strongly agreed with the scores subtracted when failing the questions (36% of l'Hospitalet, 28% of Sant Sadurni and 57% of Vic, and 39% of MNAC). In this case, ANOVA reveals statistically significant differences (p=0.00385, see Table 2) between MNAC and Sant Sadurni (higher scores, but similar to traditional marks), Dolmen (scores similar to traditional games) and Vic (scores similar to traditional tests) when asking about subtracted points and motivation. Not surprisingly, negative feedback has not a positive effect in students' motivation. Other strategies can be 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.

Around half of the students from l'Hospitalet (52%), Vic (49%), and MNAC (58%) cases agreed or strongly 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 Sadurni (35%) agreed or strongly agreed on this assumption. Besides, statistically significant differences were obtained in regards to the necessity of textual information (p=0.01397, see Table 2). More students from MNAC and Vic cases (the designed textual information is extensive) compared with l'Hospitalet and Sant Sadurni cases (the designed textual information is shorter) agreed or strongly agreed that the textual information associated with each level was unnecessary. Finally, different ratings were obtained when asking the students about whether feedback messages are motivating (32% of l'Hospitalet, 48% of Vic, 61% of Sant Sadurni, and 67% of MNAC agreed on that) or unnecessary (18% of l'Hospitalet, 19% of Vic, 9% of Sant Sadurni, and 42% of MNAC agreed on that).

To summarize, there are several design elements that can influence students' satisfaction. 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. Providing teachers with techniques to inquire into their design decisions seems of relevant importance to create powerful location-based learning games.

6 Conclusions

In this paper we have used a puzzle board metaphor as an educational strategy to allow teachers the design of location-based games. The motivation behind this approach 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. The proposed metaphor considers elements of games (e.g., hints, feedback, bonus, etc.) and puzzles (meaning that the students have different attempts to solve the questions). We can conclude that the metaphor and associated templates have been considered suitable approaches to design location-based learning games. Teachers have been able to design their own location-based learning games according to their particular educational situations. Besides, some teachers' design decisions, such as textual information, hins, and subtracted score mechanisms, can have a significant impact in learners.

Considering the implementations of the designed location-based learning games using "QuesTInSitu: The Game", we can conclude that most of the students enjoyed the proposed approach. The different score mechanisms designed in all the experiments were positively rated by the students, having just some discrepancies when subtracting scores. Further research is needed to understand the negative feeling of the students in this respect. Potential venues for future exploration also include the adoption of more game-oriented score mechanisms.

Instead of consulting hints, students prefer to find by themselves the solutions using either the resources available in the real situ, asking people or searching the Internet, rather than losing scores. These findings suggest that it could be necessary to define another mechanism to promote the access to the hints. Also, scores subtracted when consulting hints are more accepted when hints are designed as clues containing information related to the questions rather than suggestions.

Finally, it is also important to consider that the context in which the students perform the activity can influence in their perception of the activity. While students performing the activity outside were free to follow their own path and behave in a more natural way, students performing the situated activity in the museum have to behave differently because they were controlled by the museum staff. Also, 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.

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References

[1] F. Frossard, "Fostering teachers' creativity through the creation of GBL scenarios," PhD dissertation, Universidad de Barcelona, Spain, 2013.

[2] R. Tornero, P. Moreno-Ger, and B. Fernández-Manjón, "e-Training DS: An Authoring Tool for Integrating Portable Computer Games in e-Learning," *In 9th International Conference on Advances in Web-Based Learning*, pp. 259–268, 2010.

[3] H.C. Yang, "A general framework for automatically creating games for learning," *In International Conference on Advanced Learning Technologies*, pp. 28–29, 2005.

[4] B. Williamson, "Computer games, schools, and young people," A report for educators on using games for learning, 2009. Retrieved from http://archive.futurelab.org.uk/resources/documents/project_reports/becta/Games_and_Learning_educators_report.pdf.

[5] N. Pachler, B. Bachmair, and J. Cook, *Mobile learning: structures, agency, practices (vol. 1)*. New York, Dordrecht, Heidelberg, London: Springer, 2010.

[6] S.M. Davis, "Research to industry. Four years of observations in classrooms using a network of handheld devices," *In Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education*, pp. 31–38, 2002.

[7] Y. Jeng, T. Wu, Y. Huang, Q. Tan, and S.J.H. Yang, "The add-on impact of mobile applications in learning strategies: A review study," *Educational Technology & Society*, vol. 13, no. 3, pp. 3–11, 2010.

[8] N. Avouris, and N. Yiannoutsou, "A review of mobile location-based games for learning across physical and virtual spaces," *Journal of Universal Computer Science*, vol. 18, no. 15, pp. 2120–2142, 2012.

[9] C.Y. Chang, and J.P. Sheu, "Design and implementation of Ad Hoc classroom and eSchoolbag systems for ubiquitous learning," In *IEEE international workshop on wireless and mobile technologies in education*, pp. 8–14, 2002.

[10] D. Kushner, "Location, location, location [location-based games]," *IEEE Spectrum*, vol. 43, no. 1, pp. 62-67, 2006.

[11] G. Hwang, C. Tsai, and S.J.H. Yang, "Criteria, strategies and research issues of context-aware ubiquitous learning," *Educational Technology & Society*, vol. 11, no. 2, pp. 81–91, 2008.

[12] J. Roschelle, "Unlocking the learning value of wireless mobile devices," *Journal Computer Assisted Learning*, vol. 19, no. 3, pp. 260–272, 2003.

[13] P.H. Wu, G.J. Hwang, and W.H. Chai, "An expert system-based context-aware ubiquitous learning approach for conducting science learning activities," *Educational Technology & Society*, vol. 16, no. 4, pp. 217-230, 2013.

[14] J.S. Cabrera, H.M. Frutos, A.G. Stoica, N. Avouris, Y. Dimitriadis, G. Fiotakis, and K.D. Liveri, "Mystery in the Museum: Collaborative learning activities using handheld devices," *In Proceedings of the 7th International Conference on Human Computer Interaction with Mobile Devices and Services*, pp. 315–318, 2005.

[15] K. Yatani, M. Onuma, M. Sugimoto, and F. Kusunoki, "Musex: A system for supporting children's collaborative learning in a museum with PDAs," *Systems and Computers in Japan*, vol. 35, no. 14, pp. 773–782, 2004.

[16] E. Klopfer, K. Squire, and H. Jenkins, "Environmental Detectives: PDAs as a window into a virtual simulated world," In *Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education*, pp. 95–98, 2002.

[17] K.D. Squire, and M. Jan, "Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers," *Journal of Science Education and Technology*, vol. 16, no. 1, pp. 5–29, 2007.

[18] K. Schrier, "Using augmented reality games to teach 21st century skills," In *Proceedings of the ACM SIGGRAPH*, pp. 1–8, 2006.

[19] K. Facer, R. Joiner, D. Stanton, J. Reid, R. Hull, and D. Kirk, "Savannah: mobile gaming and learning?," *Journal of Computer Assisted Learning*, vol. 20, no. 6, pp. 399–409, 2004.

[20] M. Dunleavy, C. Dede, and R. Mitchell, "Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning," *Journal of Science Education and Technology*, vol. 18, no. 1, pp. 7–22, 2009.

[21] J. Huizenga, W. Admiraal, S. Akkerman, and G. ten Dam, "Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game," *Journal of Computer Assisted Learning*, vol. 25, no. 4, pp. 332–334, 2009.

[22] A. Blackwell, "The reification of metaphor as a design tool," *Transactions on Computer-Human Interaction*, vol. 13, no. 4, pp. 490–530, 2006.

[23] G. Lakoff, "The contemporary theory of metaphor," In A. Ortony (Ed.), *Metaphor and thought*, New York: Cambridge University Press, 1993.

[24] D.C. Neale, and J.M. Carroll, J. M. "The role of metaphors in user interface design," In M. Helander, T. K. Landauer, & P. V. Prabhu (Eds.), *Handbook of human-computer interaction*, Amsterdam, Netherlands: Elsevier, 1997.

[25] D. Nicklas, C. Pfisterer, and B. Mitschang, "Towards location-based games," *In Proceedings of the International Conference on Applications and Development of Computer Games in the 21st Century*, pp. 61–67, 2001.

[26] C. Schlieder, P. Kiefer, and S. Matyas, "Geogames: Designing Location-based games from classic board games," *IEEE Intelligent Systems*, vol. 21, no. 5, pp. 40–46, 2006.

[27] B. Bontchev, N. Gabarev, and H. Pavlov, "A Mobile chess game," *In Proceedings of the 16th SAER Conference*, pp. 138–143, 2002.

[28] B. Bontchev, and D. Vassileva, "Modeling educational quizzes as board games," *In Proccedings of IADIS International Conference e-Society*, pp. 1–8, 2010.

[29] O.W.S Huang, H.N.H. Cheng, and T.W. Chan, "Number Jigsaw Puzzle: A mathematical puzzle game for facilitating players' problem solving strategies", *In Proceedings of the First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning*, pp. 130–134, 2007.

[30] G.J. Hwang, P.H. Wu, and C.C. Chen, "An online game approach for improving students' learning performance in web-based problem-solving activities," *Computers & Education*, vol. 59, no. 4, pp. 1246-1256, 2012.

[31] N. Falkner, R. Sooriamurthi, and Z. Michalewicz, "Puzzle-based learning for engineering and computer science," *Computer*, vol. 43, no. 4, pp. 20–28, 2010.

[32] Z. Michalewicz, and M. Michalewicz, *Puzzle-based Learning: An introduction to critical thinking, mathematics, and problem solving*, Melbourne, Australia, 2008.

[33] J. Melero, and D. Hernández-Leo, "A model for the design of puzzle-based games including virtual and physical objects," *Journal of Educational Technology & Society*, vol. 17, no. 3, pp. 192-207, 2014.

[34] J. Melero, D. Hernández-Leo, and J. Blat, "Teachers can be involved in the design of location-based learning games: The use of the puzzle board metaphor", In Proceedings of 6th International Conference on Computer Supported Education, pp. 179-186, 2014.

[35] T. Anderson, and J. Shattuck, "Design-Based Research: A Decade of Progress in Education Research," *Educational Researcher*, vol. 41, no. 1, pp. 16–25, 2012.

[36] S. McKenney, and T.C. Reeves, *Conducting Educational Design*

Research, Routledge, London, 2012.

[37] Y. Mor, and N. Winters, "Design approaches in technology-enhanced learning," *Interactive Learning Environments*, vol. 15, no. 1, pp. 61–75, 2007.

[38] P. Cairns, and A.L. Cox, *Research methods for human-computer interaction*, NY, USA, 2008.

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

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

[41] J. Melero, P. Santos, D. Hernández-Leo, and J. Blat, "Puzzle-based games as a metaphor for designing in situ learning activities," *In Proceedings of the 7th European Conference on Games Based Learning*, pp. 674–682, 2013.

[42] P. Santos, "Computing-Based Testing: Conceptual model, implementations and experiments extending IMS QTI", PhD dissertation, Universitat Pompeu Fabra, Barcelona, Spain, 2011. Retrieved from http://www.tdx.cat/handle/10803/69962

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

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