Designing pervasive games for learning

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Abstract. Pervasive games have been proposed as a suitable way to support learning, especially in places rich in information, as for example museums and cultural heritage sites. This paper reports on the work performed to identify guidelines that help designers in developing games able to provide an effective learning experience in such contexts. Such guidelines complement other proposals available in the literature. The presented contribution is a first step of a wider work aimed at deepening our understanding of pervasive educational games, with a special emphasis on games in the cultural heritage domain, in order to inform the designers of such challenging applications.

Keywords: Guidelines, educational pervasive games, design.

1 Introduction

A substantial amount of work has been carried out during the last years on designing applications that support people learning in sites of cultural heritage. Most applications exploit web technology to provide information about museums; historical sites, specific exhibitions, and also the so-called "intangible cultural heritage" (e.g. see [6]). The advent of mobile technology has pushed towards systems to be used by museum visitors. The first systems used portable devices without connections to each other and had no context-aware capabilities. By exploiting the latest technological developments, i.e. the miniaturization of computer devices, their increased processing power and their networking capabilities, latest generation systems for supporting museum visits go beyond electronic guides and become visitors' multimedia companions, which not only provide useful information, but also aim at improving the overall visitors' experience [3, 27].

A new kind of activity is represented by *pervasive games*: they expand the notion of game in space and time by exploiting mobile devices like smartphones and PDAs with positioning capabilities (e.g., GPS) and other locative media. Alternative terms used for pervasive games are location-based games, augmented-reality games. These games may be played outdoors or indoors and can be compelling for young players as

well as for adults [23]. Four main characteristics contribute to the pervasive games' appeal and to the players' emotional involvement: [14]: 1) physical experience; 2) mental challenge; 3) social experience; 4) immersion. Specifically, the physical experience pertains to what it is felt when interacting with real and tangible objects together with virtual elements. Moreover, players enjoy additional mental stimuli by having to solve riddles or to perform tasks. Pervasive games require people to meet, socialize and combine their efforts in order to be more effective while playing, thus providing a wider social experience. Finally, the feeling of immersion in the game setting is the main entertainment factor. From the point of view of mobile learning, which focuses on the enriched interaction with context [25], these four characteristics seem to make pervasive games suitable vehicles of learning activities. Thus, a pervasive game designed to support learning would involve: a) structuring the mental challenge around the physical experience with the tangible and virtual objects in question (e.g. museum exhibits); b) integrating in this interaction the social experience through collaboration or competition with others physically or virtually present; and c) using immersion in the game as a means of engagement and motivation for learning.

Pervasive games have been recently proposed to support visits not only to museums, but also to archaeological sites and historical cities [7, 15, 26]. They often have educational goals, aiming to combine learning with fun. It has been shown that these games are able to stimulate students and engage them in their learning activities by requiring different skills to be deployed simultaneously [7, 15, 26].

The increasing importance of pervasive games in the cultural heritage domain calls for increased support for their designers. This paper contributes to this goal by presenting a set of guidelines that will help designers of pervasive games, with a special attention to games to be played at cultural sites.

Next section provides the motivation for design guidelines for educational pervasive games by referring to related work. Next, section 3 describes the methodology adopted for identifying the guidelines, and reports the final set of guidelines, grouped in five dimensions. The paper ends with some final remarks on the use and future development of the presented framework.

2 Related work

Literature reports several sets of heuristics that have been identified for designing/evaluating games. These heuristics are often quite disparate, even though, in some cases, they address common issues [17]. Initially, researchers concentrated on heuristics for educational games; then, heuristics for video games were proposed; since 2008, educational games are again becoming an important research issue and new heuristics are being postulated.

One of the first researchers proposing heuristics for games was Malone in the 80s; he identified three basic principles: *challenge*, *fantasy* and *curiosity* [21]. Malone also highlighted the importance to evaluate the game content. Later, Lepper and Malone investigated the most important factors for engaging educational games: *challenge*;

balance between easy and difficult tasks in order to stimulate learners; *fun* activities that help learners address and revise their misconceptions [20]. More recently, Garris et al. [11] examined the literature on educational games and classified the factors that are important to their learning effectiveness. The framework they defined revealed that the motivation "to play and play again" is a key feature of the best educational games and that *feedback* is very useful in learning. On the other hand, Federoof compiled the first playability heuristics, that are very similar to the heuristics defined by Malone; he determined *gameplay* as the most important part of game design, with storytelling, graphics, and sound as auxiliary factors [10].

Looking at heuristics for designing and/or evaluating video games, Desurvire and her colleagues proposed a set of playability heuristics, called Heuristics for Evaluting Playability (HEP), specifically identified to evaluate video, computer and board games [8]. Such heuristics are useful for addressing problems and challenges related to game play, which is an important component of educational games.

In 2007, Korhonen and Koivisto proposed heuristics for mobile multiplayer games [16]. Their approach in identifying these heuristics is similar to ours, since it is based on the evaluation of three different multiplayer mobile games and on the review of existing literature. Seven heuristic were identified that highlighted the importance of *communication*, *collaboration* among players, the *minimization of deviant behaviour*, the *amount of multi-players* involved in the game, the *visibility* of other players, the *social interactions* in groups and communities, and, finally, the importance of a good *network connection* which is a relevant part in any online mobile game.

Wetzel et al. defined a set of guidelines for designing augmented reality games [29]. They analyzed three different games with the goal to identify what is needed to create good mobile location-sensitive games and what causes them to fail. The twelve guidelines focus on the inclusion of 3D features in such games and very marginally consider more general game design aspects.

Pinelle et al. published game usability heuristics based on usability inspections of 108 different video games [24]. They developed ten usability heuristics and many of them are very similar to the Nielsen's heuristics, e.g. *consistency* and *standards*, *visibility* of system status and *help* and *documentation*. Other heuristics are new but they are specific for video games used for entertainment; as the authors are not interested in educational aspects of games.

In our work, we are very much interested in studies that propose heuristics for designing or evaluating educational games. For example, Barnes et al., on the basis of the results of two exploratory studies performed on their prototypes of Game2Learn, a game that teaches introductory computer concepts, provided some important features to be considered to develop effective educational games [4]. The results of their studies highlighted the importance of providing appropriate feedback, that is particularly important in the case of educational games, and of motivating students to stay engaged enough to learn. They also declared that in-game rewards and punishments are vital to the motivation and potential learning of the students. As it will be outlined in the following sections, in our work we come to similar conclusions.

Bellotti et al. in the 2008 proposed a set of heuristics for educational games that exploit virtual reality [5]. Based on the results of informal tests on prototypes of a game that supports players in discovering/investigating historical/artistic details related to a virtually reconstructed area with which they interact, the authors provided some guidelines. However their results may be extended to any type of educational game, i.e. not specifically virtual reality based games. Indeed, examples of such guidelines: games should not be too long and they should be focused on a specific educational purpose, they should allow players to quit games at any time, game scores should be consistent with their difficulty and educational value. In our study we have also included similar guidelines in the set we defined.

In this paper, we propose guidelines that address a more wide view of mobile educational games and complement existing guidelines, found in the literature.

3 Methodology

In order to define guidelines that can help the design of educational pervasive games, we followed a systematic approach, which is inspired by the "case study methodology", an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence [30]. Case studies are useful to understand some particular problems or situations in great-depth. The case study methodology enables researchers to gain multi-perspective view of a certain phenomenon or series of events and can provide a thorough picture, since many sources of evidence are used [13]. Result generalization is also possible when findings are replicated in multiple case studies.

The first phase of our research was an extensive review of the literature on the topics of interest, namely pervasive games for exploring cultural heritage sites (museums, archaeological parks, historical cities, etc.) and guidelines for game design and evaluation. Several discussions with colleagues and experts in designing pervasive learning games were carried out. Then, the work concentrated on the analysis of three case studies. As a result, a large set of issues relevant for such games were defined. From these issues, preliminary guidelines were proposed. In a successive phase, such guidelines were refined and reduced in number. They were validated by involving some experts, as described in more detail in the rest of this paper. The resulting 36 guidelines, classified along 5 dimensions, are described in Section 3.2. Finally, designers were asked to create their own games by exploiting the proposed guidelines in order to validate the communicability and effectiveness of the guidelines. In the following, the performed activities are reported in more detail.

3.1 Defining the guidelines

A team of three researchers, experienced in the design of educational pervasive games but with different backgrounds, was formed. They initially investigated three specific pervasive games for the cultural heritage domain by analysing published papers. Their initial goal was to identify as many issues as possible, related to the design of such

games. The researchers' knowledge of the design process allowed them to reflect on their own experience, recount important details, highlight different understandings of the design practice, participate in in-depth discussions, and elaborate on issues and concerns.

Each one of the three researchers was assigned the same set of six papers to analyse independently. The papers reported the design and the evaluation of three pervasive games: Explore! for visitors of an archaeological park [2, 7], MuseumScrabble for museum visitors [26, 28] and Frequency 1550 for visitors of a city centre [1, 15]. All three games have the goal of supporting informal learning and utilise a different range of multimedia features, technologies and interaction techniques, in three different settings. Each researcher identified and reported a long list of game issues and then worked independently to clarify them and to eliminate redundancies. A total of 317 issues were reported by the three researchers.

The researchers met to analyze the initial list of 317 items from which a final list was produced, containing 94 issues related to the design of pervasive educational games. The process included identifying similar issues, merging related or duplicate issues, thus refining the whole list. The overall goal was to identify close issues in the final list, which could be addressed by a same guideline. For instance, some of the 94 final issues were: "Competition as a means to increase motivation", "Competition by hampering the other teams", "Competition for limited resources", "Competition for limited resources to induce collaboration (negotiate roles, discuss strategy)", "Competition for other team's points," "Allow competition", "Force Competition". These seven issues are covered by guidelines 3.4 and 5.3 in Table 1.

It is useful to organise a set of guidelines along dimensions, in order to support designers in realising important aspects related to design quickly. The process of defining these dimensions included an individual study phase, where the three researchers organised all 94 issues in subsets addressing a certain dimension, and a consolidation phase where the final set of dimensions was defined by combining the results of the individual work. The resulting five dimensions are:

1. *Game General Design*, which refers to issues related to the overall game design process;
2. *Control/Flexibility*, which is a basic dimension of system usability, that with respect to the games considered in this paper, also refers to helping players to be aware of the effects of their choices on the game execution;
3. *Engagement*, which informs on how to provide an experience that captivates the players, by providing hints on how to structure the game, which tools to adopt, etc.;
4. *Educational Aspects*, which informs on interweaving of learning content into the game context, so that the game can have a valid learning influence on the players;
5. *Social Aspects*, which concerns the interaction among the players, role allocation etc. (the underlying assumption is that social activity, e.g. competition, can act as a motivational factor).

Each of the three researchers was provided with a table containing the 94 game issues, organised according to the five identified dimensions. They first worked individually and defined design guidelines that emerged from the issues. The guiding

principle for this activity was the need to identify "a set of guidelines that could guide designers who had the task to build a pervasive game, which aims at improving the learning experience of people while visiting cultural heritage sites".

Prior to the joint refinement process, each researcher compared the set of guidelines he identified with those of the other researchers. Finally, in a discussion and negotiation phase, they consolidated their guidelines in a single set. As a result, 40 guidelines organised in five dimensions were defined, presented next.

3.2 Validating the guidelines

The first version of dimensions and guidelines, organized in table similar to Table 1, was submitted to four external HCI researchers with experience in the design of educational pervasive games. The main goal was to check if the formulation of the guidelines could be misinterpreted. Based on this feedback, some guidelines were rephrased and the final list of 36 guidelines, reported in Table 1, was produced.

Table 1a. The final set of 36 design guidelines organized in 5 dimensions.

Dimensions		Guidelines
Game General Design	1.1	Exploit metaphors from real-life games, activities, stories
	1.2	Minimize the changes to the physical places (e.g. modifications to the physical structure, installation of special equipment like projectors, big displays, etc.)
	1.3	Create a multidisciplinary design team (including e.g. HCI, cultural heritage, educational experts)
	1.4	Perform formative evaluations and pilot studies to check if tasks' difficulty is appropriate for the intended players
	1.5	Consider the social conventions of the place (e.g. not laughing in a church)
	1.6	Consider to extend the game experience beyond the game session (e.g. participating in a web community)
	1.7	Consider to include activities/events that are not part of the game, but happen in the real world (e.g. the ceremony of change of the guard at noon)
	1.8	Consider to include a game master (e.g. tutor, supervisor, coordinator) and her role: e.g. enforcing the rules, narrating the story
Control / Flexibility	2.1	Let players become familiar with the equipment and the game rules/structure (e.g. by including an introductory phase)
	2.2	Facilitate game learnability (i.e. tasks, rules, constraints, etc. should be easy to understand and to learn)
	2.3	Player should be free to switch between different tasks
	2.4	Reflect on whether to allow players to correct their mistakes: it could be useful to force them to evaluate the consequences of their actions
	2.5	Provide help or hint mechanisms to assist players
	2.6	Consider to provide increasing difficulty levels (either automatic adaptation or human-generated adaptation)
	2.7	Prevent rule breaking by either discouraging it (e.g. with penalties) or by incorporating cheating into the game
	2.8	Make clear the game goal/s (e.g. earning points, completing tasks, being the winner)
	2.9	Make clear the game ending condition/s (e.g. maximum time, target score, end of resources, ...)
	2.10	Consider to provide alternative ways for performing a task or completing the game
	2.11	Make clear the goal of each task and its effects on the overall game
	2.12	Provide immediate feedback about task execution showing its impact on the overall game

Table 1b. The final set of 36 design guidelines organized in 5 dimensions.

Dimensions		Guidelines
Engagement	3.1	Consider to integrate a back-story that is at the basis of game tasks
	3.2	Consider to exploit role-playing (i.e. impersonating a character) to meaningfully link tasks to the back-story (if any)
	3.3	Provide contextual cues linked to specific places or events to convey additional information (e.g. sounds reproducing noises of daily activities in an ancient city)
	3.4	Consider to allow players to interfere to competitors, e.g. stealing/acquiring points
	3.5	Let players practice different skills by including in the game a variety of tasks, such as: perform a quest, identify/visit certain locations, shoot a picture from a specific angle, videotape a route, search for a certain object, perform a certain action/gesture, search/identify a physical mark, answer a question, collect and classifying material
	3.6	Minimize the interaction with the game tools. Players' attention should be focused on the game and the environment
	3.7	Tune the level of awareness of other players' activities (hide/provide/delay information, e.g. showing the score and the progress of the competitors)
	3.8	Consider to include rewards in order to improve players' motivation/satisfaction (e.g. providing multimedia information as a prize for a successful task); integrate rewards tightly with the game tasks and back-story; consider when to provide the rewards to the players (during/after the game)
Educational Aspects	4.1	Consider to include a pre-game activity to prepare players (e.g. some lessons in classroom explaining the historical context in which the game is set)
	4.2	Game should emphasize either vertical or horizontal exploration of a place/topic, i.e., deeply exploring a limited space (or few objects or a specific topic) *vs.* more superficially exploring a broad space (or many objects or several topics)
	4.3	Tasks should require players to link areas, locations, physical objects to concepts, topics, etc.
	4.4	Balance between competition and knowledge acquisition. Too much competition may have a negative impact on knowledge acquisition
	4.5	Include a debriefing phase after the game to allow players to reflect on the game experience. Design it as an individual/collaborative game/activity that supports players to clarify and consolidate the game experience
Social Aspects	5.1	Team players (if any) should be selected based on players' social relations (e.g. friends to maximize collaboration) or according to their skills. Involve in this process a person that knows them very well (e.g. a teacher)
	5.2	Assign responsibilities and tools (e.g. mobile devices, maps, etc.) among team members to induce collaboration. Consider to force, forbid or allow responsibilities exchange among team members
	5.3	Consider to permit, force or neglect the competition among players/teams

We have performed a further informal study by providing a group of HCI students, engaged in game design projects, with the guidelines, requesting them to design a new mobile game or to evaluate their game design work that they had in progress. They reported that, thanks to the guidelines support, they trusted to have addressed important game design issues. More importantly, some students said that the guidelines helped them to make decisions on key points on which they were in doubt about.

We are now planning a more systematic study in order to involve a wide number of designers in the validation of the proposed guidelines. To this aim a website is being created at the web site of the first author; it reports the motivation of the research, the adopted methodology, the guidelines and the dimensions identified. Registered people, navigating through the pages of the website, can read the comments of other

people and insert their own. Each guideline has an explanation and/or a concrete example. By only giving the possibility to provide comments could lead to shallow responses; thus, a set of simple questions is provided to induce people to reflect more deeply: Is this guideline important? Is the phrasing correct/clear/understandable? Is it in the right dimension? Is it wrong? Do you expect that thinking about this guideline will contribute positively to the game design?

Researchers to be involved in this larger validation will be selected in order to have people with practical or theoretical background in mobile design, user experience, games, pervasive games, educational games, serious games, etc. To obtain contact information for such researchers, we used search engines on the Internet and our own knowledge of pervasive games designers.

The next step of the validation study will consists in the analysis of the comments posted in the website. This will help us to collect new elements for further discussions. The analysis of the interactions with the website will also allow us to identify the more active researchers among those that posted comments; such researchers can be later interviewed.

The purpose of the interviews is to gain more insight into the comments that have been expressed. Each selected researcher will undergo a semi-structured interview through a recorded Skype call. In order to do not have an interviewer biased by his/her previous experience, we have chosen an HCI researcher expert in carrying out interviews, but not directly involved in this study.

4 Conclusion

Pervasive games have been recently proposed to support visits to cultural heritage sites, such as museums, archaeological parks, historical cities. These games often have educational goals, i.e. they aim at supporting young students learning about history while having fun. Studies show that these games are indeed able to motivate students and effectively engage them in their learning activities [7, 15, 26].

The guidelines proposed in this paper offer insights on the issues that are relevant when designing educational pervasive games; they were defined by following a systematic methodology. Some guidelines we found in literature are similar to those proposed by us. This fact further validates our study, as the literature has not influenced the process of identifying our guidelines, which were produced in a bottom up approach from identified issues in three typical pervasive games. Our effort has been to integrate and to organize them in a unique set to be more operational for designers of pervasive games.

Even if we are motivated by pervasive games in the cultural heritage domain, the identified guidelines are quite general and may be used for educational pervasive games independently of the specific place of the game and the field of learning.

Current work consists in further validating and refining the proposed guidelines through more systematic studies involving a wider number of designers.

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