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A Review of Mobile Location-based Games for Learning across Physical and Virtual Spaces

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Abstract: In this paper we review mobile location-based games for learning. These games are played in physical space, but at the same time, they are supported by actions and events in an interconnected virtual space. Learning in these games is related to issues like the narrative structure, space and game rules and content that define the virtual game space. First, we introduce the theoretical and empirical considerations of mobile location based games, and then we discuss an analytical framework of their main characteristics through typical examples. In particular, we focus on their narrative structure, the interaction modes that they afford, their use of physical space as prop for action, the way this is linked to virtual space and the possible learning impact the game activities have. Finally we conclude with an outline of future trends and possibilities that these kinds of playful activities can have on learning, especially outside school, like in environmental studies and visits in museums and other sites of cultural and historical value.

Keywords: mobile games, mobile learning, informal learning, location based games, game-based learning
Categories: H.3.1, H.3.2, H.3.3, H.3.7, H.5.1

1 Introduction

Recent years have witnessed an explosion in the number of creative new games that are facilitated by mobile devices in such a way that the game activity evolves according to players' location. A term proposed to describe such games is "*mobile location-based games*". Their proliferation is due to the widespread use of mobile devices, like smart phones, with advanced location sensing capabilities, for example GPS satellite positioning. These games can be compelling for young players as well as adults [Montola 09]. A typical example of such games is the group of games referred to as "urban games" or "street games". These are typically multi-player games played out on city streets and in built up urban environments. Some of these mobile games transcend place and time and can be played in many diverse places and extend to long periods of time (a term used in this case is *pervasive games*), while others are designed to be event based, i.e. to be played in specific places at specific times, like during visits in museums and other non-traditional game venues. While most of these games are originally designed for the amusement of the players, on

many occasions learning is an implicit outcome and often an explicit objective of the designers. Inherent in these games is the fact that some activity takes place in physical space, like moving to a specific location, inspecting artefacts, taking pictures and recording videos or sounds. At the same time, some other part of the action takes place in virtual space, such as a) players interacting with simulators producing events, b) avatars and other characters interacting with each other and with the players, c) players doing riddles and puzzles, d) players generating information in digital form associated with physical objects etc. As a result, strong interplay between *physical* and *virtual space* activity takes place in these games. At the same time, the game rules define a *game space*, which is supported by the two interconnected physical and virtual spaces, but mostly is created and supported in players' minds. This latter space is defined as game space, or narrative space if the narrative element is prevailing in the activity. As [De Souza 06] has observed, it is the use of mobile technologies that connects these spaces as interface for game play.

The nature of learning that takes place in these games needs to be investigated. This may be the result of interaction between players, investigation of objects of learning potential, active search for information, development of new skills and engagement in meaning making activities, etc. Often these games are based on a narrative, a valuable tool for construction of meaning, and organization of experience [Sims, 03]. The main characteristic of the narrative is the emplotment, which is a synthesis of the heterogeneous elements of a story [Ricoeur, 91]. Thus, narration is a means for combining different heterogeneous parts (actions, events, etc.) into a coherent whole and crafting the relationships between these different parts (ibid). If we take into account the view that the narrative composition process is not completed in the narration itself but in the reader, who constructs a new interpretation of the world based on the narrative, we can assume that participation in a narrative either as a "reader", an "actor" or a "composer" can become a rich learning activity in the sense that the narration constructed offers an explanation about the world. In the case of mobile games, the physical space often immerses the players in a situated context where details of history, culture, and the available physical affordances provide opportunities and constraints that influence the choice of actions and interactions [Davenport, 05], generating new kinds of players' experiences.

In the rest of the paper we present an overview of the field. First a survey of the most cited location-based games and their characteristics is presented, thus establishing an analytic framework. Then we identify the main categories and for each one of them we present in more detail some typical examples which we discuss, from the point of view of the analytical framework defined, focusing in particular in their learning impact and establish a classification scheme of this field.

2 Preliminary study

In this section we outline the findings of the first phase of the survey. Typical games were identified and their main characteristics discussed, through a literature review of the most citied publications of the field. Then in the next section, based on the findings, we proceed with a review of typical examples for each class of games identified. The first phase of the review was based on the observation that the appearance of mobile games of this character coincides with the introduction of

powerful mobile devices with location sensing capabilities, in early 2000's. So a plausible assumption was that by now the early examples of such games have gathered enough attention by the research community, in terms of citations of relevant publications. So the first step in our survey involved identifying these early examples, in order to create a first map of the field. So an introductory bibliographical survey was conducted. We used a popular publicly available index of scholarly literature, using as keywords "location based game" and "learning", so that the search is easily reproducible. The search, using *Google Scholar* on March 13th, 2012 returned 375 publications from which 187 received at least one citation. This is a full text index, so the publications found may have these keywords anywhere in their body, thus more thorough search in their content is needed. From this set we selected the most cited publications, using as threshold the papers that have received at least 10 citations. These were 63 papers, which we studied more thoroughly. From them 11 publications were classified as irrelevant, 26 did not make extensive reference to a specific game, while the rest (26 papers) concerned specific games.

The 15 games discussed are: *Savannah* [Benford, 04], [Benford, 05a], [Benford 05b], *FeedingYoshi* [Bell, 06], *Mobilegame* [Schwabe 05], [Göth, 04], *UncleRoy* [Benford, 06], *Camelot* [Verhaegh, 06], [Soute, 07], [Soute, 10], *CitiTag* [Vogiazou, 07], [Vogiazou, 05], *Relive the Revolution (RTR),* [Schrier 06], [Schrier 05], *CityExplorer* [Matyas 07], [Schlieder 06], *Hitchers* [Drozd 06], *Mogi* [Licoppe 08], [Licoppe 05], *Jindeo* [Licoppe 06], *Riot!* [Blythe 06], *Frequency1550* [Raessens 07], *MobileHunters* [Lonthoff 07] and *AlienRevolt* [De Souza 08]. These games are shown in Table 1, sorted in terms of the number of cumulative citations that the corresponding papers received.

The summary table includes information on the source of the publications, and the main characteristics of the game, i.e. the physical and virtual game space characteristics, typical duration, technology used, narrative, and main objective of the game. The publications were produced in the period 2004 to 2010, so the games are typical of the first generation of such applications. The technology used in the reported games were PDAs (8 games, 53%), mobile phones (6, 40%) and specially made devices (1, 7%), reflecting the fact that the games were developed at a time before the current avalanche of powerful smart phones. The objectives of these games were mostly ludic, 8 out of 15 games (53%) were created so that the players have fun. 5 games (33%) have a stated objective related to learning while 2 games (13%) were of mixed objectives.

In terms of play duration, 8 games (58%) last less than a day, with typical duration ranging from 30 min to a whole day. On the other hand there were some games that extend over many days, usually interleaved in the everyday activities of the players, while one game allowed for both possibilities. In terms of the physical space used during these games, 10 of them (67%) were designed to be played in specific places, while the rest expand in any place that players may be found. The notion of a *pervasive game* is related often to this kind of games. This is a more general term to location-based mobile game, as pervasive games extend spatially, temporally or socially the boundaries of typical games, can be interleaved with ordinary life, and can be played at anyplace, anytime, etc. ([Montola, 09], p.12). Examples of games that presented such characteristics are *Jindeo, CityGame, Mobilegame*.

	Publications		Characteristics of game						
no	***sources***	***Σcitations***	***Game***	***physical space***	***virtual space***	***technology used***	***typical duration***	***narrative***	***main objective***
1	Benford et al. 2004, 2005	285 (3)	*Savannah*	Specific place, outdoors and indoors	Savannah ecosystem	PDAs with GPS positioning	2-3 hours	yes	Pedagogical goal: to experience life in the ecosystem, including animals etc.
2	Bell et al. 2006	155 (1)	*FeedingYoshi*	Spatially continuous game	A world of creatures (yoshis) food and plantations	PDAs, wifi networks	many days	weak	Have fum,compete with others, game interweaved in everyday life,
3	Schwabe et al. 2005, Göth et al. 2004	154 (3)	*Mobilegame*	Specific plase: University Campus	Representation of campus places, people, events	PDAs, ekahau positioning engine	few hours	weak	Support orientation of new Univesrity students, team hunting
4	Benford et al. 2006	91(2)	*UncleRoy*	Specific place, outdoors and indoors, 1 km3 of city streets	A narrative, a mystery, players search for a mysterious character	PDAs, sms, telephones, other physical objects	about 10 days (6 to 8 hours of play per day)	yes	Have an engaging experience, combining game and dramatic oppotrunities
5	Verhaegh et al. 2010, Soute et al. 2007, Soute et al. 2010	67(3)	*Camelot*	Specific place, an outdoors playground containing "resources" to be collected and castle construction sites	no virtual space	phidget based devices as resources collectors, resources zones, castle consturction site	around 30 min.	weak	To encourage social interaction and physical activity of 7-10 years old children
6	Vogiazou et al. 2005, 2007	35(2)	*CitiTag*	Any place with the presence of other players	Players position and state (e.g. captured)	PDAs with GPS positioning	few minutes	weak	Inspired by the playground game tag: two teams playing against each other
7	Schrier 2005, 2006	33(2)	*Relive the Revolution (RTR)*	Specific place: Lexington, Massachusetts	Information and characters related to a specific historic event	PDAs with GPS positioning	few hours	weak	Participate, debate and collectively solve the problem: who fired the first shot of the battle
8	Schlieder et al. 2006, Matyas 2007	33(2)	*CityExplorer*	Spatially continuous game	Tiles to build the city of Carcassonne (inspired by board game)	symbian mobile phones and GPS positioning, sms communication	two modes: (a) 30 min or (b) a week	weak	Have fun, compete with others to collect points, collect geospatial data (e.g. places fo churches etc.)
9	Drozd et al. 2006	25(1)	*hitchers*	Spatially continuous game, Outdoors, city centre	Hitchers (digital hitch hikers), information about places	mobile phone and GSM cells ID positioning	many days	weak	Have fun, provide information on places (GSM cells).
10	Licoppe et al. 2005, 2008	22(2)	*Mogi*	Specific place in which game virtual objects exist	Virtual objects: chests, quests, avatars of other players	mobile phone and GSM cells ID or GPS positioning	many days	weak	Have fun: collect objects, socialize with other nearby players
11	Licoppe et al. 2006	21(1)	*Jindeo*	Spatially continuous game	Teams, defensive and offensive equipment	mobile phones with GPS	many days	weak	Have fun: engage in a massively multiplayer activity, play roles, socialize
12	Blythe et al. 2006	21(1)	*Riot!*	Specific place: a square in Bristol	sounds that refer to a historic event	PDAs with GPS positioning	few hours	yes	Re-live a historic event on site
13	Raessens et al. 2007	19(1)	*Frequency 1550*	Specific place: Historic centre of Amsterdam	Meadival Amsterdam	PDAs with GPS positioning	one day	yes	Pedagogical goal: to experience life in medieval city, class system, trades and
14	Lonthoff 2007	15(1)	*MobileHunters*	Spatially continuous game, Outdoors, city centre	A world of hunters and fugitives	symbian mobile phones and GSM Cells ID	30 min	weak	Have fun: chase and be chased
15	De Souza e Silva 2008	14(1)	*AlienRevolt*	Specific place: City of Rio de Janeiro	Fighters, armor, weapons	spartphones, sms communication	many days	weak	Have fun, shooting game, earn points, destroy opponents

Table 1: Most cited location based games and their main characteristics, (relevant publications are included in the reference list)

The virtual space of these games, usually accessed through the mobile device was related to the story and the evolution of the game, and it contained information, maps, virtual creatures, or representation of other players. It is characteristic that only in one case there was no representation of the game story, when the players used specific physical devices (arduino devices) in *Camelot*.

There is an underlying narrative in all games, however this is often very weak, made of simple patterns that repeat again and again and player roles, while in 4 (27%) there is a stronger narrative that the players have to follow. 3 out of these 4 games have a pedagogic nature (*Savannah, Frequency 1550* and *Riot!*). One of the key issues in location based games is the relationship between games and narratives (see [Juul, 05a], [Neitzel, 05] and [Jenkins, 04]). According to some researchers (e.g. [Juul, 05a])

most games have the activity embedded in a larger story, called *backstory*, which acts as a background to the activity, without necessarily having any great affect on player experience. On the other hand, some game designers observe that the interactivity of game playing is almost the opposite of narrative; since "narrative flows under the direction of the author, while interactivity depends on the player for motive power" [Adams, 99]. It has been observed that in some games, the narrative was of less importance, like in *action games* (see for example the attack and defensive action game *Jindeo*, and the shooting game *AlienRevolt!)*. The rules of these games are simple and patterns of behaviour repeat over and over again. These produce the evolution of the story, which may take many twists. On the other hand, some other kinds of mobile games, such as *role playing games* and *alternate reality games* are based on a strong backstory (as was the case of *UncleRoy*). These games, according to [Juul, 05b], are "progression games", which are played until they are completed, after which they are finished. In this paper, we study games examining their narrative structure, we observe that these kinds of games, as opposed to games with less emphasis on narrative (e.g. action games), have a stronger interplay between the physical and virtual space and thus are more central to the perspective taken here.

From the description of the games studied, one may draw a typical architecture of the game set up, depicted in figure 1. Specifically, figure 1 shows that the action takes place in the physical space, while a digital infrastructure exists to support the activity. This infrastructure consists of the following elements: (i) the game engine, which is the mechanism that observes the state of the game and application of the game rules, (ii) the virtual space, which contains facts and media related to the story and activity, and (iii) the user profile database, which maintains the players identities and status, while it may also store historical data that can be used for adapting game-play and for enriching current player experience. Players interact with objects and each other and the events are recorded in the game engine. It should also be stressed that in some cases the play activity was supported by a backend office with run time support (*e.g. UncleRoy, Frequency 1550, AlienRevolt)* while in other cases the mobile activity was related to activity of other players at the headquarters (*Frequency 1550*) or at the "Den" (*Savannah*).

In conclusion of this first phase of the survey, we observe that the games studied were either of ludic or pedagogic nature and shared some common characteristics. The learning that occurred in these games was rarely studied, with the exception of *Savannah*, *Relive the Revolution (RTR)* and *Frequncy 1550*. However learning does occur even in games played just for fun, while in other cases games were built with the objective to engage the players in social activity or in physical activity, which also have certain educational value.

In the next section we proceed with examining in more detail some specific cases of games. The survey, presented next, is split in three parts, following three separate strands of research and practice: (a) the *ludic*, (b) the *pedagogic* (c) the *hybrid*. The ludic tradition concerns games built mainly for pleasure. The pedagogic one includes educational games either played within or outside school with well defined learning objectives. The hybrid tradition concerns games with no explicit or mixed objective, in this case we find games in cultural heritage environments, for example museums, historical city centres etc., or fiction in the city, novels and other traditional forms of storytelling that are transformed into playful activities with use of mobile devices.

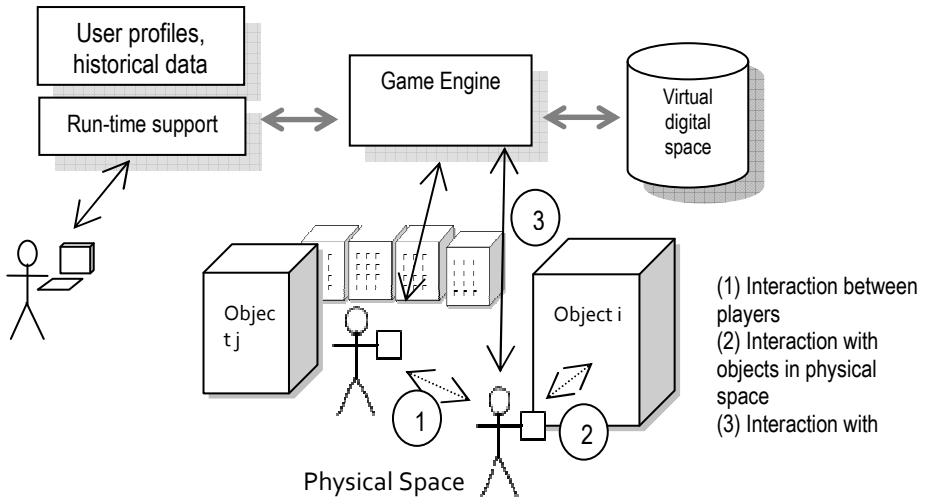

Figure 1: Setup for mobile location based games design and play

3 The Ludic tradition of location based games

The first group of games to be examined more thoroughly fall in the ludic strand which relates to games built for the enjoyment of the players. Despite the fact that learning is not a key objective in this case, often a compelling narrative is an important part of the game while learning takes place as a side effect. By far the most popular games fall in this group, as seen in the first phase of the survey. One may argue that there is not much point in studying the learning potential of mobile games of the ludic tradition because they are not designed to support learning. However, the lack of intended learning design does not necessarily mean that learning does not take place; it may just involve development of sensory-motoric skills, or social interaction and thus the question here is what this learning might involve. Successful games of the ludic tradition are highly engaging and motivating for the players. Engagement and motivation are prerequisites of the learning process and aims of the games of the pedagogic tradition (though not always successfully achieved in the games). Identifying how games of the ludic tradition support engagement and motivation offers useful insights for the design of educational games.

The source material of this class of games, extending the games studied in the first phase, included a review of publications: A thorough discussion of theoretical and practical issues related to pervasive games is provided by [Montola, 09]. 13 such games are presented in this publication, from which only one is not of purely ludic character (*Rexplorer*, ibid, pp. 215-218 and [Ballagas, 07]). Other surveys of games have been published by [Paelke, 07], who studied various patterns of interaction in the context of mobile location-based games and in particular the use of spatial representations in facilitating game development and play. [Magerkurth, 05] reviewed various kinds of pervasive games, among which was a group called “location-aware

pervasive games". Four games of this kind are discussed in the survey: the early game *Pirates!* and three more recent ones: *Treasure*, "*Can you see me now?*" and "*Uncle Roy*" already presented in section 2. [Rashid, 06] also conducted a survey of location based games, in particular those using mobile phone protocols for communication and location tracking. Despite the fact that the survey covers the field up to 2005, it is interesting as it reflects the concerns of those early days and provides some answers to them. In particular, the authors identify among other concerns their doubts whether mobile games can introduce a narrative and thus link to a virtual world. At the end of the survey, they mention that early attempts at mobile storytelling (e.g. the location-based adventure game *Journey* by mopius.com, based on a detective story) allow game players to engage in interactive stories, and this is considered a promising direction for the future of location-based mobile games. It should also be mentioned that in this early survey 16 games are reviewed: 14 of ludic character, one an educational activity for learning history (*Frequency 1550*), and one an experimental prototype of a story inspired by Finish Mythology (*Songs of North*). This last example contains some innovative characteristics, such as the use of sound as a locative medium, and it was argued that had educational value [Lankoski, 04]. Despite of its focus on pervasive games, most of the cases discussed in [Montola, 09] are typical examples of location-based mobile games, while on various occasions the games discussed have a strong narrative element.

In [Montola, 09], the following categories of games, are identified: The first one is **treasure hunts** in which players try to find objects either in a specific area or in an unlimited game space. These may or may not be related to a narrative and a virtual space. For instance, in *Insectopia* [Peitz, 07], the players collect virtual insects generated from Bluetooth IDs of other players' mobile phones in the vicinity or any other Bluetooth devices. Since these objects can be found at any place where other players may be found, there is no limitation on game space. Players can team up in order to become more effective in insect catching, thus gaining more points. Other similar games of this kind are *Mogi* [Licoppe, 08], [Joffe, 05], included in the games discussed in phase A of this survey, which was a predecessor of *Insectopia* that was located in Tokyo Japan and had as an objective collection of hidden items that where identified through their GPS coordinates. Both these games have no strong narrative and, although there is a sub-story in *Insectopia* about nourishing the insects in order not to let them die, the player does not participate in a full plot story in any way. This kind of game has little learning potential beyond development of orientation and exploration skills and to some limited degree development of social interaction skills. Very rarely, then, do location-based games have the form of simple treasure hunts. However, treasure hunting tasks can often be part of a more complex game situation that may involve a strong narrative, like in mixed reality games, adventure games, city games etc., or be part of educational games, as discussed in the following sections. It should be observed that even in this class of simple games, informal learning can take place through the interaction between players. In [Brown, 10], pp 10-12, there is a discussion on the use of *Geocaches* (a traditional form of treasure hunt, involving physical hiding places, in its modern form implemented through a combination of GPS enabled mobile devices and social networking technologies). It is reported that a single space, between the virtual spaces of the Internet and the physical spaces that surround the geocaches, contributes to the creation of persistent digital

narratives of locations that provide a temporal record of place made up of the accumulated experiences of community members. In this context, the analysis revealed that collaborative and cooperative informal learning took place among distributed networks of players (ibid, p.12).

Another kind of ludic location-based mobile game comes under the category of **action games**. An alternative name suggested for this group, characteristic of the typical activity involved, is *assassination games* [Montola, 09]. Players alternatively adopt the parts of the hunter or the prey, "killing" each other as part of the game. A typical example of this kind is *Killer- the game of assassination,* a multiplayer game that bears some similarities to massively multi-player online role- playing-games (MMORPG). In this game, geolocation data is combined with pictures of players and Bluetooth contact is used to confirm close conduct between players. The simple rules of such games allow many variations to emerge, with no real narrative as backstory. These are games in which action (shooting, fighting etc.) is a higher priority than plot, so the narrative, if it exists at all, is of secondary importance. The learning outcome of these games is more closely related to the strategic thinking and decision making that is often needed in order to gain advantage over opponents, while, in contrary to action video games, dexterity and eye-hand coordination is less important.

A third kind of ludic location-based mobile game is that of **role playing games**. These games are common in play of young children as they explore the different possibilities the world affords them, for instance when playing "doctor" or playing "house". The learning potential of role playing games has already been exploited in various subjects, like in economics, social sciences etc. Here technology facilitates and supports action.

There are several variations of this genre, one of which concerns the so-called *Alternate Reality Games (ARG),* which are role playing games that interleave reality with fiction. The narrative is a strong element in this case. These games are sometimes related to events or promotional campaigns and are played by many participants. Often role playing games are considered a version of action games or treasure hunt games with a strong narrative.

An example of such role playing game is "*I love bees"*, which has been created to promote the video game Halo 2, of Microsoft. ARGs are not strictly mobile location-based games, as mobile devices are just one of possible technologies used during the game. This is a group of games with a strong narrative in the background. For instance, in *"I love bees"*, the story begins with a military spaceship crashing on Earth in an unknown location, leaving the craft's controlling Artificial Intelligence (AI) damaged. This AI, in an effort to contact any other surviving allies, attempts to send signals that corrupt the content of a website. The players of the game are gradually involved in tasks to work together to solve problems, with little or no direction or guidance, demonstrating a vivid example of collective intelligence [McGonigal, 08]. For example, the game presented players with many pairs of global positioning system coordinates and time codes. Players eventually had to discover that the coordinates referred to pay phones and the times when the phones would ring for further instructions. So physical locations play an important role in this game and the narrative is a strong element that leads the action. Given these observations, it is expected that some learning potential exists in this case. There are, however, few reports of studies into the learning effectiveness of ARGs. [Dominik, 08] suggests

that, as ARGs have the advantage of blending reality with the imaginary world of a story, they permit extending reality and supporting construction of knowledge in a so-called "reality situated learning" setting. However, there is no extended empirical evidence on the effectiveness of such an approach. A study of the learning value of such a game is reported by [Gentes, 10]. In this study, the experience of designing an urban game with treasure hunt elements, called *"Team Exploration"* is discussed. This is a mobile role playing game that is played in a specific area of Paris. The area is partitioned in 20 rectangles. The competing teams are given pictures showing details of the city and have to decide which rectangle contains the detail shown in each image. Then, all members of the group should meet at a place that will only be disclosed once all the pictures have been identified correctly. In this game there is no strong narrative, however, as the authors argue, the city itself imposes a narrative, i.e. there are preconceived ideas about the function and social structure of different areas of Paris and this inevitably is mapped on to the game narrative, conditioning the spatial movement of players.

In conclusion, ludic tradition mobile games are to a large extent action oriented, involving either shooting, action or treasure hunt type of activities. These are weakly related to a narrative and a virtual world. However, the role-playing version of these games, includes a much stronger narrative and complex action, which permits merging real and imaginary elements. These games seem to have a higher learning potential, although this has yet to be confirmed through more extended empirical studies. On the other hand the social interaction that takes place and skills related to strategic decisions, observation, planning, physical activity are the main characteristics of this strand in terms of learning.

4 The pedagogic tradition of location based games

Another powerful, but less developed, tradition of location-based mobile games is the pedagogic tradition. This relates to mobile games that have been developed with the explicit objective of learning. In general, learning through mobile devices has been an active area of research and practice in recent years. In a literature review on mobile learning, [Naismith, 09], the characteristics of this approach are identified as the following: the contextual character of this kind of learning, the mobility that permits linking activities in the outside world with the classroom, the ability to extend the learning experience over time, and the contribution to informal learning. In the same review, the authors discuss current practice in terms of the theoretical traditions for learning: behaviourist, constructivist, situated and collaborative. The use of narratives with playful character in this survey is, however, quite limited. In particular, under the constructivist paradigm, it is argued that the most compelling examples of implementation of mobile technologies come from participatory simulators, in which the learners themselves act out key parts in an immersive recreation of a dynamic system [Naismith, 09]. **Participatory simulators** bear a strong resemblance to the role playing games discussed in the previous section. However, in this case the learning objective is explicit and the setup of the activity is often related to formal education. The learning value of such role playing activities is attributed to the fact that they help players understand complex, dynamic systems by immersing them into "life-sized," computer-supported simulations, creating powerful experiential paths to

scientific understanding. This is achieved through mobile devices that transform the students into "players" in a large-scale microworld. In this world, a scenario is built that is mediated by a set of underlying rules that enable inquiry and experimentation [Colella, 00].

An early example of this approach is discussed by [Colella, 98], who developed a mobile simulator of the spread of infectious viruses. The players interact with each other and observe the spreading of the virus through the display of the devices that they carry. These devices, which were a variation of 'Thinking Tag' technology developed at the Media Lab of MIT, USA, were very simple, small, name tag sized electronic devices that communicate with each-other via infra-red, and have limited display capabilities. The narrative, in this case, is quite simple (some players pretend that they are infected and some not) however the emergent story out of these interactions is powerful and can support the understanding of the dynamics of infectious diseases.

Another more recent example of a role playing mobile game is *Savannah* [Facer, 04], [Benford, 04, 05a, 05b] that was identified as the top cited game in phase A of this survey. In this case, school children play a simulation, through mobile devices. This helps them to take the role of lions in the African savannah. The players physically move around in virtual savannah areas and try to survive as a lion. In this way, they experience issues related to the balance of predators and prey and the impact of humans on the lions' living space. The overall structure of the *Savannah* game involves moving back and forth between active missions outdoors (using mobile technologies) and periods of reflection indoors (using a shared projected view), thus interleaving physical space activity supported by the mobile device and virtual space actions that invoke more reflective activity. The evaluation of this game has shown that, while there was a lot of social interaction among the players, the learning objectives were not fully achieved, e.g., for players to act as a pride of lions and experience this situation [Facer, 04]. The narrative in this case was much stronger than in the virus simulation game. The roles and interactions were more complex and the environment played a crucial role. However, it seems that there are still some doubts about how to achieve the learning goals. The game deliberately employed multiple learning paradigms and, consequently, multiple narratives since it necessitated moving between phases of active play and periods of reflection and planning. Thus, the players had to take different perspectives on their experience: an immersive perspective (inside the game), during which players were out on the field "being a lion", and an individual and reflective perspective (on the game from the outside), during which they acted more like a scientist observing lions' behaviour. It is evident that this approach is quite different to the ludic role-playing games discussed in the previous section, where the main concern is to intensify the immersive experience, and a single narrative is implemented.

Another example of a mobile game with similar characteristics for a more advanced age group is *Environmental Detectives* [Klopfer, 08b], also discussed in [Klopfer, 08a], (Chapter 7). This is a multi-player, mobile location based simulation game designed to support learning in advanced introductory (late high school and early college) environmental science, while *Outbreak* (ibid, Chapter 9), is a next generation game of the same project.

The narrative that drives action in *Environmental Detectives* is realistic and the students have to take multiple roles in it: Environmental Protection Agency workers, environmental agents at a hospital, workers for a manufacturing facility, environmental activists, etc. The mobile devices of different players contain different stories tailored to their role. *The narrative involves environmentalists who learn that a local watershed has become polluted with mercury after some students report unusual readings during a routine examination. Later, the authorities learn of increased levels of mercuric chloride in a near-by river. As fish begin washing ashore, the press implicates a textile facility near the river. Concerned parents start checking kids into a local hospital. Scientists hired by the corporations deal with angry emails and messages from concerned citizens. Through gathering field data, processing data, and interviewing virtual witnesses, players learn that spillage of mercuric chloride has occurred, an extremely harmful substance. As time passes, players need to contain the spread of this harmful chemical...* The students enjoyed participating in this game however some concerns have been expressed about its learning outcome. As [Ketelhut, 10] remarks, no solid validation of learning outcome has yet been reported beyond the subjective opinions of the students involved, who refer to the experience as 'compelling and interesting'. This raises the wider concern of how to evaluate the learning outcome of such an authentic experience as participating in a narrative driven complex role playing game activity.

Another kind of educational mobile game is related to learning foreign languages in authentic settings. A term used for these games is **situated language learning**. [Liu, 10] report on the development and evaluation of context-aware learning tactics using the *HELLO* platform, with the objective to enhance students' authentic learning experience in real situations. The students, in this case, played a mobile location based game in which they used a mobile device to practice listening and speaking during their free time, to perform a treasure hunt game (which used a context-aware learning strategy) outdoors during class time, and to collaboratively perform a story relay race in an actual context. The experimental results showed that the use of mobile games in learning English as a foreign language produced better learning outcomes than the non-gaming method, demonstrating the effectiveness of the approach used. The survey results indicated that the experimental group students gained better learning motivation for attention, relevance, confidence and satisfaction, further demonstrating the positive relationship between learning outcomes and motivation. The narrative in this case was a strong element as the activity involved realistic situations and so the students played roles and participated in authentic situations. In general, language learning, like history learning, lends itself favourably to a narrative learning approach, especially on that is well embedded in physical settings, where the mobile device supports as a prompt for the linguistic actions of the actors in the context of the given scenario, while it also provides them with aids like a dictionary etc.

Finally, another kind of location based game for learning consists of **educational action games.** These involve intense physical activity, like the action games of the previous section, but this time with clear learning objectives. A typical example is *MobileMaths* [Wijers, 10]. This game involves teams of players who compete on a playing field, with the goal to cover as much area as possible by constructing squares, rectangles or parallelograms using mobile phones with GPS receivers. This is done by

physically walking to and clicking on each vertex (point). The constructed shapes are virtual elements added to the real world. The players can see the shapes in the mobile screen. As the game proceeds, the free playing space gets smaller. It is possible to 'hinder' other teams and to de-construct their shapes. Points are gained relative to the area of the shapes. This game resembles action games of the ludic tradition, with very limited narrative which emerges from the simple acts of competing teams, as they try to occupy territory. The learning outcome of such approaches has, however, yet to be fully evaluated.

In conclusion, the mobile games of pedagogic character are mostly role playing games. These allow users to play realistic roles involving physical space in order to understand different perspectives in a complex scenario, or to perform linguistic acts in an authentic setting. In both these cases, the narrative is strong and the physical space supports the action, while the learning potential is related to the strong interconnection between the narrative supported by the virtual world and the physical action. The last case of action games is directed to children of younger ages. In these games, the narrative is limited and the learning potential needs to be further explored.

5 The Hybrid tradition of Location-Based Games

The third case to be discussed relates to location based mobile games designed for both entertainment and learning. These are usually built for a wider audience by institutions outside formal education establishments, related to cultural heritage, for example cultural and historical societies, museums, tourist boards, etc. [Tallon, 08]. While the ludic character is prominent, the nature of the institutions involved and the settings of the games mean that activities will often result in informal learning.

Examples of location-based games of this kind can be found in recent literature. [Raptis, 05] reviewed the use of location based mobile devices in museums, while in a subsequent survey of mobile learning applications in museums by [Tselios, 07] three distinct categories where identified in terms of learning theory approaches used: (a) *Museum mobile guides*, (b) *Museum mobile interactive guides* and (c) *Role-playing mobile activities*.

Museum mobile interactive games are mobile applications that, in addition to providing information about the exhibits, support more advanced interactivity with them, applying socio-cultural theories of learning, and providing visitors with tools to organize and control the supplied information. Examples of this kind are the *Sotto Voce System* [Grinter, 02], an electronic guide with audio content and the ability of synchronized sharing of this content between visitors. Another example is the set of applications developed for the *Exploratorium*, a Science Museum in San Francisco [Fleck, 02], where visitors are allowed to manipulate and experiment with the exhibits permitting deeper visitors' engagement.

The *DinoHunter* project includes several applications for the transmission of knowledge through game-based and mixed reality activities in the Senckenberg museum, Frankfurt, Germany. Three of these applications, *DinoExplorer*, *DinoPick* and *DinoQuiz*, involve mobile technologies [Feix, 04]. In particular, *DinoPick* allows users to choose one part of a dinosaur's body and receive further multimedia information about this part and *DinoQuiz* provides a set of questions for further exploration of the exhibits of the museum. In conclusion, the main objective of

mobile games of this genre is to deliver information in various forms and allow interaction between the exhibits and groups of visitors. While these activities make the visit to the site more interesting for visitors, the narratives are rather limited.

A second case are **Museum role playing games,** applications based on more elaborate scenarios, of a playful character, following constructivist approaches. These are of particular interest for our study, as they often have strong narrative elements and resemble role playing games with location sensitive characteristics, as discussed next through some typical examples.

One example is the *MUSEX* application [Yatani, 04], deployed in the National Museum of Emerging Science and Innovation in Japan. MUSEX is a typical drill and practice educational game in which children work in pairs to answer a number of questions. Players select an exhibit and are asked a number of related questions through their mobile device. Children may collaborate and monitor each other's progress through a shared screen. After the activity, they may review their path through the museum.

Mystery at the Museum is another mobile, game-based, educational activity created for the Boston Museum of Science. It engages visitors in exploring and thinking in depth about the exhibits, making connections between them and encouraging collaboration [Klopfer, 05]. Visitors are called to solve a crime mystery where a band of thieves has stolen one of the exhibits. The users try to locate the criminals using mobile technology. Various roles of a typical role playing game situation can be assigned to the players, e.g. a technologist, a biologist or a detective. The players can interview virtual characters, pick up and examine virtual objects using virtual equipment (e.g. a microscope), collect virtual samples via infra-red tags and exchange objects and interviews through walkie-talkies. A study confirmed deep engagement of the participants and extensive collaboration due to the roles set.

Explore! is a treasure hunt like game designed for the archaeological site of Egnazia, Italy [Costabile, 08]. This activity is designed for middle school students to take part in during a visit to the site, and is loosely based on a back-story. The main novelty of Explore! is that it exploits a learning technique called an *excursion-game*, the aim of which is to help students to acquire historical notions while engaged in playful activities and to make archaeological visits more exciting. The excursion-game is played by groups of 3-5 students and encourages independent enquiry and exploration of the site. It resembles a treasure-hunt game, combining the pleasure of "solving the case" with that of roaming freely around a place and discovering its hidden secrets. During the evaluation of Explore! it was discovered that the players managed to explore the site effectively and to identify meaningful places which were the target of the treasure hunt. Aspects of the activity they found particularly engaging included the use of multiple representations and media, such as sounds, reproductions of the site and maps, etc.

The games *Donation/Inheritance* and *MuseumScrabble* also share similar characteristics, as discussed in [Yiannoutsou, 09]. Built for a history museum in Zakynthos, Greece, "Donation/ Inheritance" [Tselios, 07] is a group mobile game which enables visitors to engage in collection and manipulation of information about the museum exhibits. It is based on a compelling narrative that is introduced to the children at the beginning of the game. According to this back-story of action, the players are asked to discover a specific exhibit in order to help an imaginary art

benefactor to donate an artefact to the Museum. Children scan the exhibits for hidden hints with their mobile devices. Through them, they seek the hidden exhibit. They are asked to trade hint phrases between them as an encouragement for collaboration. Collaboration is also encouraged through a set of restrictions that do not allow teams to collect all available hints. *MuseumScrabble* [Sintoris, 10] is an action game based on a pattern of linking common themes with exhibits. The basic components of the game are the clues, the triggers and the exhibits. Clues are pieces of textual information associated with a specific exhibit that contain triggers for linking to other exhibits. These links have varying strengths, and so the challenge for the players is to identify the stronger links, thereby collecting more points. Clues refer to those exhibits which are the focus of the visit (e.g. the works of an author or the paintings of the specific period). In order to link the exhibit to the trigger of the clue, the children have to search in the museum for the most relevant exhibit and point to it using their mobile device. The rationale behind the design of this game is to offer some basic information about a set of key exhibits and engage students in the use of this information as a point of reference for searching relevant exhibits. Through this pattern, a narrative of action emerges, in a similar fashion to other activity games. However, the action is interwoven effectively with cognitive activity relative to the learning objectives [Sintoris, 10].

Finally, we discuss *Frequency 1550* [Raessens 07], [Huizenga, 09], [Akkerman, 09], already presented in phase A of this survey. This is a highly acclaimed educational mobile game about medieval Amsterdam, designed to be played in the historic centre of the city. This game has a strong narrative element however the role of this narrative in learning has been debated (e.g. [Akkerman, 09]). The back-story of Frequency 1550 asks the students to move to medieval Amsterdam using their mobile devices. For one day, they roamed through the city in small groups, using GPS to help them identify their own positions as well as that of other players and objects. The players needed to demonstrate their knowledge of medieval Amsterdam by doing location-based media-assignments on the city's history. The location was a strong element of the action. Most assignments had to be performed in specific parts of the city, were related to specific buildings, points of interest etc., and were intended to trigger environmental awareness. In particular, the old city of Amsterdam was divided into six areas. In each of these areas, one of six different themes of medieval times was addressed; labour, trade, religion, rules and government, knowledge and defence. An interesting aspect of this game, then, was a mapping between themes and space. Each assignment was related to one of these themes and so was undertaken in the corresponding area of the city. In addition, part of each team, resided in a different space, the headquarters, where they were assigned a different role, that of receiving the information from the field and making further investigations to assist with specific tasks. Here, we observe a distinct role assignment related to physical and virtual space activity.

In terms of the interaction and technology used, the field teams used smartphones with multimedia capturing capabilities and GPS. Through them, the team members could capture snapshots of the urban setting and relate them to their tasks. The no-mobile members of the team at the headquarters interacted with desktop equipment that allowed them to search for further information in order to complete the task. Strong interactions took place between the team members, and in particular between

the city and the headquarter teams, since the former supplied the latter with information while navigation instructions flowed in the other direction. Lastly, at a final plenary meeting, all team members interacted and discussed the experience with other groups.

The findings of the empirical study identified a strong engagement dimension, typical of game activities. The designers of "Frequency 1550" have put emphasis on the use of narrative; there is a back-story that acts as a canvas for the action. In the discussion of a quasi-experimental empirical study that involved over 200 secondary education students who played the game [Huizenga, 09], it was observed that the story did not play the expected role in the activity. The pupils "were told to gather points as much as possible, with no reference to earning civil rights" and were not always informed about their identities as beggar and merchant. Therefore, a finding of the study was that the narrative did not draw the attention of participants, and so did not contribute to the learning outcome. This is also the conclusion of [Akkerman, 09] who focused on the role of narrative in this activity: it was observed that while the design of the activity involved tasks for receiving, constructing and participating in the story, the players, and in particular the city teams who enacted the story, were often distracted by all that was happening in real time in the street, so while trying to find their way through the city, searching for assignment locations and completing the assignments, students lost the sight of the overall structure of the game and its narrative.

In conclusion, cultural heritage sites (museums, historical cities etc.) provide interesting physical spaces for location-based games with strong learning potential, due to the nature of the objects in the physical space. These sites are rich in information (i.e. associated virtual information spaces) and thus also rich in opportunities for learning. The challenge in this case is to maintain the balance between the playful character of the activity and the strength of the learning outcome and, in order to achieve this, to identify the most effective mechanics of the games and find the most appropriate stories to engage the visitors and drive the action.

Another kind of hybrid location-based games is based on existing stories that are "played" through mobile devices in specific locations. These have been called **mobile fiction** or fiction in the city. The playful character and the situated nature of the reader experience make these activities similar to location-based mobile games, while some learning side effects are expected as they result in exploration of the setting. The design of activities of this kind is based on a story, usually in traditional form (e.g. a crime novel) that is adapted and integrated in a location that can be associated with it, usually the place in which action takes place. Interactivity is then built into the story. The users are asked to move to different locations in a city or a building in order to follow the story that is delivered through a mobile device and possibly interact with or play the part of story characters or take part in the action and use props, in the same way as in a theatrical performance. In this way, the participants are engaged in a combination of mental and physical activity, the former when they are asked to solve puzzles in order to advance the story and the latter when they are asked to walk between places in order to move on with the narrative. This, according to [Ruston, 06], supports the "diegetic immersion" of the participant. This is because user actions, like walking from place A to place B, are the same in the story (virtual) world and the physical world, so the problem of who is in control between the author of the story

and the participant is tackled since the players, through meaningful actions, contribute to the delivery of narrative material. The purpose of mobile fiction may be the enjoyment of immersing oneself in a story in location, or the pleasure of discovering a place through a story. Examples of this location-based mobile storytelling include: *Riot!* [Blythe, 06] that was included in the first phase of this survey, *Hopstory* [Nisi, 04], *"Who killed Hanne Holmgaard"* [Paay, 08], and *"Tracking Agama"* [Stein, 09]. In addition, some commercial products exist mostly in the form of alternative tourist city guides, as discussed next.

In [Kjeldskov, 07] different kinds of fictional mobile guides have been explored and discussed in terms of the way the parts of the story are related. The following cases were identified: (i) *Linear stories* are stories in which the parts are linked in a certain fixed order, so that the participants have to follow the exact steps in order to reach the end of the story, providing the author with high degree of control over the narrative. (ii) *Non-linear stories* consist of a number of parts that the participant may read or listen to in any order they like in order to create the whole story. These, from a user experience point of view, increase the level of interactivity in terms of composition and have a built-in quality for exploration, for finding the next piece, and for putting the pieces together (an example of this kind being Riot!). (iii) The third kind is a narrative that contains a *set of self-contained short stories* related to physical locations, where the next possible story depends on the current one. However, in this case, there is no overall storyline, but at each step there is a link from one story to the next by means of some similarity between them, the meaning lying in the transition. A typical example is Hopstory, with its linear plot, delivered from different character viewpoints, that provides a collection of scenes that can be collected in any order. (iv) A fourth case, *fragmented fiction*, includes narratives that are made up of many small fragments which can be put together in many different ways. However, in this case, it is particularly challenging to author meaningful stories, while most of the control is left to the users and the serendipity of events that take place around them. A variation of this case is narratives that are based on self-contained short stories related to physical locations but with no predetermined relation to each other. In this case, the model is simple, since when the participant enters a particular place, she is offered with a number of stories that fit the location. The author has full control over each short story, and the participant controls the overall picture, made up of the individual stories.

Some interesting examples of mobile fiction have started to emerge in recent years, applying some of the above approaches. The objective in this case is either to investigate new ways of experiencing fiction, or to use fiction as the background for engaging the reader in activities in order to explore sites of cultural interest. The latter objective has been pursued by alternative tourist guides that are based on fiction rather than the more traditional database-like approach that fragments narration of places of interest. [Whaiwhai, 11] is a publisher of a number of such guides for various Italian cities. A typical example of such a guide is that built for the city of Florence, called *Firenze 2054*. This is based on a story by Luciano Artusi, a local writer. The participant is provided with a map, a notebook and the guide. The guide is cut into three sections. A mobile phone is used for receiving clues for the puzzles to solve in conjunction with the instructions on the guide. The narrative starts *"...on October 27th, 1954 when twenty unidentified flying objects soar through the skies of*

Florence and hover above the city's famous monuments for a good fifteen minutes. The aliens are looking for something that fell to the Earth centuries ago". The narrative is segmented into forty-five stories about different places in Florence and evolves in a non-sequential fashion. In order to advance the story the reader has to visit physically the places of the city, and finding out where to go is not a trivial task. In addition, the clues on the spot to find are also not trivial. Mostly, the game provides the players with knowledge about the urban places it utilizes, relating to names, structures and conformations of the city. While there has not been any academic publications evaluating the user experience associated with the Whaiwhai guides, in [Whaiwhai, 11] many positive accounts of user experience are reported.

A more experimental example of this genre is presented by [Paay, 08]. In this, users experience the mystery story '*Who killed Hanne Holmgaard*' interactively, as they move through the city of Aalborg, Denmark. In this activity, the players become part of the narrative as they play one of the characters described in the story. Users are expected to follow and "discover" a pre-constructed storyline. In this case, the users do not establish the relationships between the different parts of the story but they use the offered information to discover them. The structure of the narrative, in this case, is linear and based on a temporal sequence, as the users can only go from location A to location B (and accordingly from episode or chapter 1 to chapter 2) in order to collect all the necessary clues and solve the case. In each location, however, the two players that form a team can act in parallel interrogating different suspects and then combining the evidence they collected. It seems then that, in the sequential structure of the narrative, there are key points where things can happen in parallel but the result of these parallel actions feeds back to the linear sequence of the storyline.

In this case, space is important for structuring the narrative and is the context where the enactment of the story takes place. Specifically, different episodes of the story were "attached" to the places of the city (e.g. the killing of Hanne took place in a park, interrogation of some of the suspects took place in a convent of the city as Hanne was a nun, etc). Users, in order to solve the case of the murder, had to visit each of the different places, where the story was taking place, in order to collect the necessary information. Even though the story evolves around space, the objectives of the users' actions (e.g. going from one place to another, or searching for evidence in one place) are oriented towards the content of the story (i.e. who killed Hanne). Thus, in this case, acquaintance with the city of Aalborg seems to come as a side effect of following the killer of Hanne.

In conclusion, the fiction tradition, like the cultural heritage one, balances the pleasure of following an interesting story with the knowledge acquired from the experience of discovering the related interesting places in which the story is staged. This is a relatively new genre and a lot of experimentation is expected as well as studies on the process of authoring mobile fiction and evaluating the user experience.

6 Conclusions

In this paper, we studied the field of location-based games and their possible contribution towards learning. We discussed the key concepts of this new genre, which involves interleaving of physical and virtual spaces, and through these key concepts, we defined a study framework. This has been used for reviewing existing

cases and ultimately, increasing our understanding in order to shape our insights into designing the next generation of applications of this kind. A first step has been the derived classification scheme of location based games, shown next.

In the context of this area of research, there are various issues that need to be addressed: Are all physical spaces adequate for location-based games? And are all different kinds of narratives suitable for successful games with learning potential? With regards to the spaces that are used as settings, and which participate in the activities, these need to be carefully selected in terms of joyful user experience with learning potential. A site of an ancient temple or a museum may have more stories to tell us and enhance visiting experience, provided that a good storyteller is involved. It was observed in the survey that games that seemed to focus on learning outcome are usually designed for specific rich information places (museums or other cultural heritage sites) or places in which the action was well situated, like in city games.

Another issue is related to the design of such games. How open can they be? What is the role of the players in defining the story and the game rules? And what is the role of the story author in this new setting [Wiesner, 09]? The possibility of user participation in defining the story has already been studied in the case of computer games, as [Jenkins, 04] observes in relation to the popular computer game The Sims: "*It is a sandbox in that it should be understood as a kind of authoring environment within which players can define their own goals and write their own stories*". These are termed emergent narratives. Another example of user participation in defining the narrative of a certain space is the merging of media like social media and location-aware experiences (e.g. mobile blogging as discussed by [Walker, 07]). The social dimension, very strong in these games, supports the view that these games are particularly suitable means for teaching skills that mostly needed in our times [Schrier 06], like interpretation, multimodal thinking, problem solving, information management, teamwork, flexibility, civic engagement, and the acceptance of diverse perspectives, as, they often produce learning that is social, experiential and situated [de Souza, 06], as shown in many examples in this study.

The issue of selection of the most appropriate stories suitable for these games also needs to be studied extensively. [Neitzel, 05] distinguishes among mythological, gnoseological and ideological stories and relates them to action, adventure and strategy computer games. However, we need to further study how these kinds of games and relating narratives map to location-based physical activities.

Finally, the continuously shifting technological ground (e.g. presentation media, connectivity and mobile devices) needs to be further studied and related to this genre and further investigation into the impact on user experience and learning is also needed. For instance, the new generation of ebook readers needs to be studied in terms of their role in location-based games, as new devices come out with new affordances.

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