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# Experiencing the Past through the Senses: An M-Learning Game at Archaeological Parks

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M-learning—the combination of e-learning with mobile technologies—captures the very nature of e-learning by providing users with independence from the constraints of time and location.[1] To exploit the potential of mobile technologies for learning, researchers must define new teaching and learning techniques.[2] The Explore! m-learning system implements an excursion-game technique to help middle school students (ages 11 through 13) acquire historic knowledge while playing in an archaeological park.

Traditional visits to such parks tend to generate little interest in young students, especially when they are faced with the ruins of ancient settlements whose current appearance no longer reflects their initial purpose. Explore! is designed to help students learn history while playing a game, thus transforming a visit to an archaeological park into a more complete and culturally rich experience. We structured the game to be like a treasure hunt: it combines the excitement of the chase and solving a mystery with the joy of exploring and discovering a place's hidden secrets. This type of game is perfectly suited to the archaeological park context. Students can move about freely in such a location; by observing the park and memorizing places, names, and functions, they can use their intelligence and imagination to conjure up how life was once lived. Explore! requires minimal investment because it runs on commercial mobile phones equipped with GPS receivers.

Our field studies with several classes of students have shown that Explore! is capable of arousing students' emotions and stimulating their imagination and curiosity while still keeping them focused on the learning task. The multimedia features of Explore! are designed to make this possible. The game gives students the opportunity to explore 3D reconstructions of historical buildings, objects, and places, and also provides contextual sounds that recreate the historical atmosphere and enhance the overall user experience.

## The game

The game implemented in Explore! consists of three main phases. In the introduction phase, the game master gives a brief description of the park and explains the game. In the game phase, groups of students explore the park, searching for key sites by following clues. Finally, in the debriefing phase, participants review and share the knowledge learned during the game.

Explore! currently presents *Una Giornata di Gaio ad Egnathia* [Gaius' Day in Egnathia], a game designed for a visit to the archaeological park of Egnathia, an ancient Roman city in the Apulia region in Southern Italy. Each student group impersonates Gaius, a citizen of Egnathia, and receives two mobile phones, a paper map of the park, and a backpack carrying a pair of loudspeakers (see Figure 1). The loudspeakers on the backpack are connected to the first phone and provide contextual sounds (that is, background noises, readings of the text displayed on the phone, warning sounds, and so on). The group must discover the given sites in the park following the indications provided by the first mobile phone. If players need help finding a place, they can ask the Oracle, a software module providing game hints, that is available on the second mobile phone (see Figure 2). We implemented the Oracle as a small video game on the phone's screen where Gaius is represented by an avatar that approaches one of six temples (see Figure 2a). Each temple contains



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clues about a specific place of interest (see Figure 2b).

At the end of the game, each group receives Gods' gifts, which consist of 3D reconstructions of the correctly identified places. The students can interact with the 3D reconstructions (see Figure 3a, next page) and visually compare the possible ancient appearance with the existing remains (see Figure 3b). If, instead, the group has not correctly identified the places, the group members will be able to review the 3D reconstructions only during the debriefing phase. The proposed 3D models are scientifically correct; we designed them in collaboration with archaeologists from the Ancient History Department at the University of Bari, Italy.

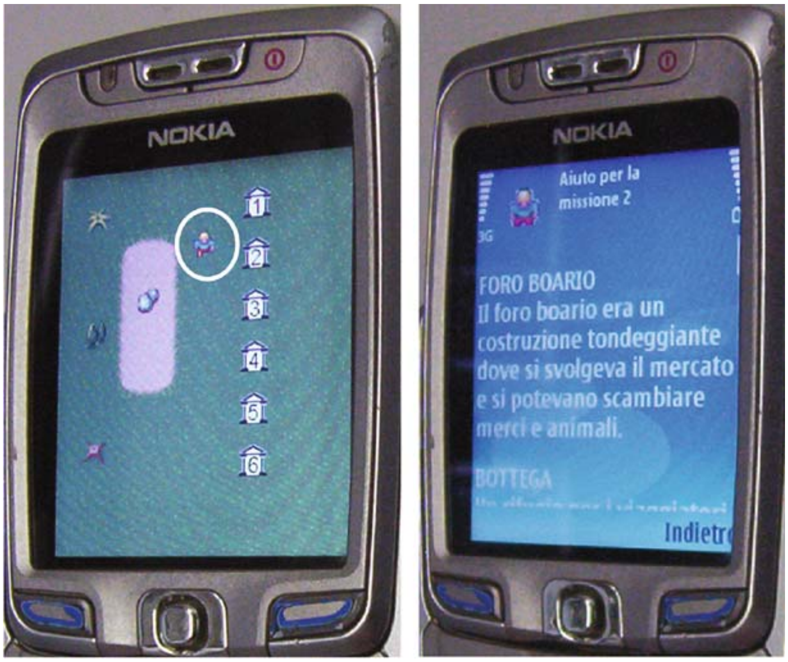
In VR applications, a sound component added to a virtual scene can help users with navigation, orientation, and execution of tasks, making the whole experience more enjoyable.[3] Explore! emits multiple sounds during the game to ensure a realistic and engaging environment. Figure 4 shows a map of the Egnathia park that indicates the various sounds produced at each meaningful place. The intensity of each sound source changes dynamically according to the players' physical position, acquired from GPS. For example, if the players are in position A in Figure 4, they hear sounds such as the noise carts make on a paved road—the Trajan Way—and the cows lowing in the Foro Boario market.

The use of contextual sounds in Explore! has several advantages. By implementing the acoustic environment of the ancient city, the system immerses players more fully in their impersonation of Roman citizens. The contextual sounds also provide clues that help to identify the game targets.

## The user experience

The user experience with an interactive system depends on various issues, such as the system's characteristics (complexity, usability, and so on), a user's personal factors (expectations, needs, motivation, satisfaction, and so on), and the context or environment where the interaction occurs.[4] Interaction with mobile systems poses challenges because the user might be affected by outside influences, such as noise, distractions, or other people. Therefore, to fine-tune the system and to evaluate the Explore! game, we carried out field studies

*Figure 1. A group performing the game in the Egnathia archeological park. The student on the left carries the first mobile phone with the information about the places to locate and a backpack with the loudspeakers, the next student holds the paper map, and the third student from the left holds the second mobile phone displaying the Oracle.*




**(a)** **(b)**

*Figure 2. The Oracle as displayed on the mobile phone: (a) as Gaius (the circled icon) approaches one of the six temples, (b) he receives clues about the associated site of interest (in this case, the Foro Boario, which was a market where animals were sold).*


**(a)** **(b)**

*Figure 3. (a) The 3D reconstruction of the furnace and (b) its current appearance in the archaeological park.*

rather than controlled experiments in a laboratory. Study participants were middle school students (age 11–13). Other involved stakeholders were schoolteachers, history experts, archaeologists, and curators of the archaeological park.

We performed two extensive field studies. In the first study, we compared the students' experience playing the Gaius' day game on mobile phones with the experience of playing a previous paper-based game. The study and its results are described in detail elsewhere.[5] Participants in the mobile game groups expressed excitement about the opportunity to use technology during their visit and commented on how nice it was to use a mobile phone for the game and to see the 3D reconstructions. Moreover, the mobile game groups appeared concentrated on their tasks and exchanged comments with other competing groups only to acquire useful information, whereas the paper-based groups were more talkative and tended to engage in jokes and irrelevant chit chat whenever they met. We found no significant differences between the two game conditions for learning effectiveness, which shows that students aren't distracted by the technology and that e-learning is valuable provided that appropriate techniques are used.

Our aim for the second field study was to evaluate how the introduction of contextual sounds would affect students' experience and learning. We compared the current version of the Gaius' day game, which includes contex-

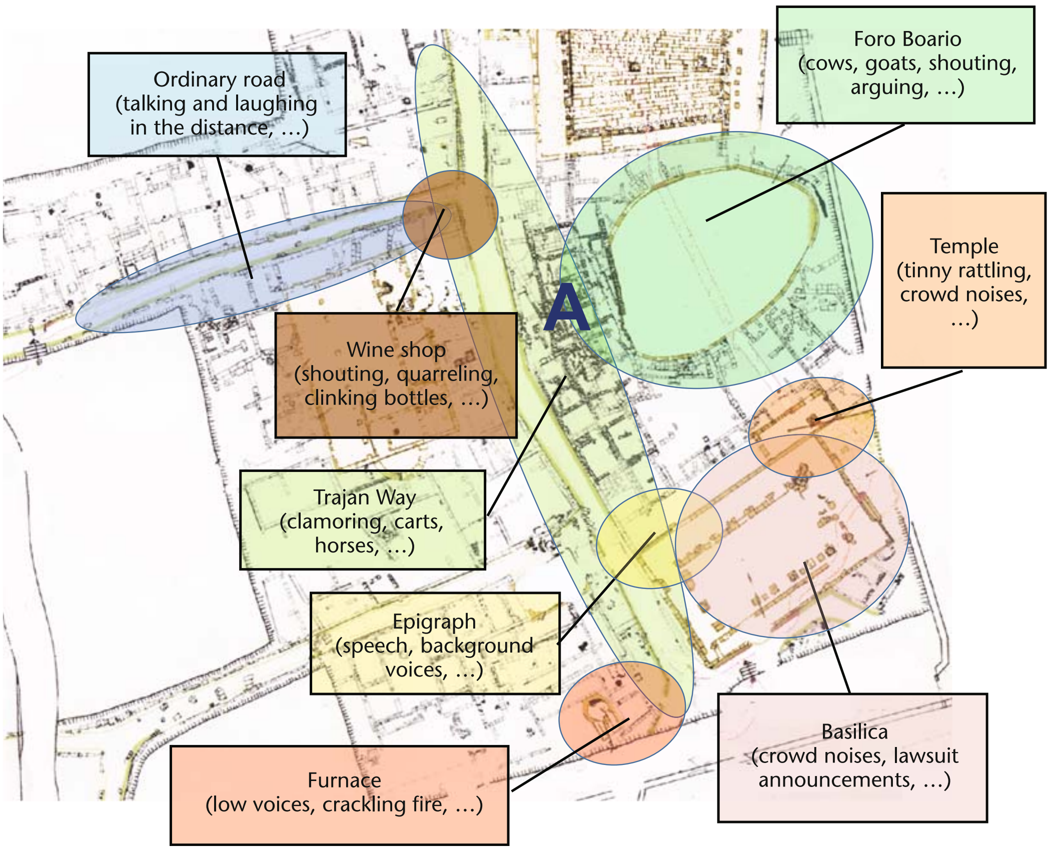



*Figure 4. Sound source locations in the Egnathia archaeological park. Here, sound sources often overlap (as they do in real life).*

tual sounds, with the previous version of the electronic game. Preliminary analyses of the collected data show that students appreciated the integration of sounds. This is an important result because satisfaction is a significant component of the user experience.

## Architecture and implementation

Striving for a simple, inexpensive digital-gaming infrastructure, we designed Explore! with mobile phones in mind, using compatible memory cards containing the game software. Visitors can use their own mobile phones so the archaeological park doesn't need to provide any hardware infrastructure. To reduce costs and architectural complexity, no data are transmitted from or to the mobile phone during the actual game; all data exchange takes place between the phone and the memory card. A notebook and a projector are used for the debriefing phase: the notebook is equipped with a memory card reader for retrieving the game log files, which are stored in the mobile phones as the group visits different parts of the park and answers questions. In the debriefing phase, students and the game master play a collective memory game, where monuments and archaeological objects must be placed in the correct location on the park map shown on the projected screen. The activities of any group can be replayed on the projected screen, showing the path the group took across the archaeological park.

We designed Explore! to be as device independent and modular as possible, with a clear distinction between game content (historical information, 3D reconstructions, sounds, and so on) and game logic. The system consists of three main modules. The first one, Game Application, relies on an XML file that describes the game content (easily authored for each archaeological park) and an XML file stating the layout and relationships among the various audiovisual elements of the user interface. The second module, Hint Application, provides the game cues, which also are represented in XML. The third module, Debriefing Application, runs on a notebook and retrieves the game's XML log files from the memory cards on the mobile phones. The XML-based design makes the Explore! system independent from mobile platforms. Our current implementation is based on a combination of Microsoft .NET (for both Game Application and Debriefing Application) and Java 2 Micro Edition (for Hint Application).

Three-dimensional graphics on mobile devices is not yet widely supported, although software libraries and APIs connected to mobile, 3D hardware are continuously improving. Due to current mobile technology limitations, we chose to substitute the actual 3D files with a sequence of snapshots of the 3D models, taken while rotating the viewpoint 360 degrees around the object. The version most appreciated by our users consists of a total of 16 snapshots: eight snapshots taken in 45-degree increment steps at a close distance from the reconstructed historical monument, and the other eight taken in a similar way at a greater distance. This 3D visualization method trades off users' navigation flexibility for computational simplicity and image detail quality. By restricting navigation to left rotation, right rotation, and limited zoom, the image quality is only constrained by the mobile phone display resolution. As shown in Figure 3, the result is acceptable. We tested a version in which we provided 16 snapshots taken at the same distance from the monument in a 22.5-degree interval, resulting in the same computational complexity and data size but without the possibility of zooming. This solution appeared to be inferior, possibly because zoom was considered more valuable than a smoother rotation experience.

We provided 3D reconstructions of the places in the first version of Explore![5] The current version implements sound, thanks to the Contextual Sounds Application, an Explore! software module that defines the user's position and produces a virtual sound environment. This module can be included easily in any system that needs to generate a contextual sound environment in outdoor settings. It behaves in a way that is similar to the Java Specification Request 234 DistanceAttenuationControl interface available on the Java 2 Micro Edition platform, which controls how the sound originating from a source fades as the distance from the user grows. The DistanceAttenuationControl is based on the distance gain formula; the distance is calculated using the GPS coordinates of the sound sources (coded in an XML file) and the current GPS coordinates of the mobile phone.

Virtual sound sources have been placed in various locations at the Egnathia archaeolog-

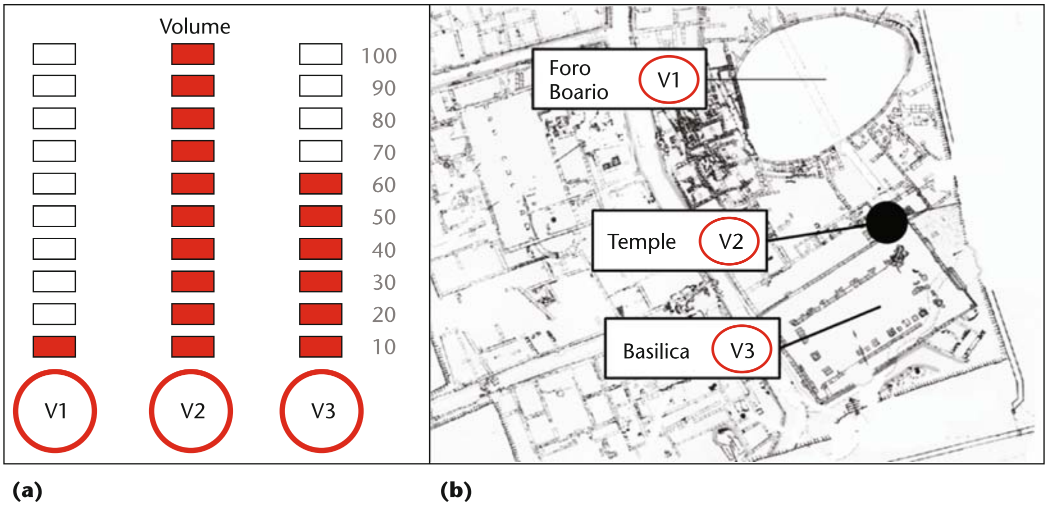



*Figure 5. (a) The volume of sound sources changes according to (b) the player's position, represented by the black dot close to the V2 sound source.*

ical park. When game players walk across the park, they hear the sounds originating from the virtual sources. The perceived sound volume changes according to the distance between the player and each source. In the example shown in Figure 5, the player (indicated by a black dot) is close to the temple. The player hears at maximum volume the sound of tinny rattles emitted by the virtual source indicated as V2. In addition, the player can easily hear the crowd noise and the lawsuit announcements coming from the basilica emitted by the V3 source—although these sounds are fainter than V2. Given the player's position, the lowing of the cows in the Foro Boario, emitted by the V1 source, is barely perceivable.

### Future work

A practical advantage of Explore! is that it lets experts who teach history easily adapt the game to different archaeological parks, without the assistance of a software engineer. We are implementing a tool to allow such experts to create and manage the XML representation of the game content without writing any code.

The deployment of mobile multimedia in collaborative activities depends on a close analysis of important space and time factors to establish the appropriate interaction modalities. Unlike text on a mobile phone display, sound effects can be heard by everyone nearby. We are currently enhancing the game with additional context-aware features, such as a Bluetooth-based mechanism to detect dispersal of the group. This function will delay providing information to the group until all the members are gathered together. **MM**

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## Learning while Having Fun

The use of computers in education has escalated rapidly during the last two decades. At the same time, technology advances have opened a new field of use, namely computer-based edutainment—education in the form of entertainment—where learners can achieve their learning goals while having fun.[1] By meeting some of their psychological needs, computer games, if adequately designed, can motivate children to learn.[2] Research on this approach has paved the way for the use of electronic games not only for pure entertainment but also as education tools.

The deployment of location-based multimedia services is continuously expanding from its early use in tourist guide systems[3] and art installations[4] to current, widespread applications such as vehicle navigation assistance and mobile gaming. Games on mobile phones, more than other interactive technologies, have become a significant part of the contemporary culture experienced by young people. Mobile games that associate real-world elements with the virtual objects on the phone, as occurs in augmented reality[5] and context-aware systems,[6] open up a wider game design space by exploiting multimedia and multimodal features of real-world elements. A representative example on how ubiquitous and mobile technologies can provide opportunities for novel learning experiences out of the classroom is discussed elsewhere.[7]

The use of mobile games as learning tools is gaining increased support for several reasons: mobile devices are associated with low cost, accessibility, flexibility, and portability.[8] Furthermore, mobile games are engaging, and inspire curiosity and increased motivation.[9] In addition, mobile games as educational media are supported by pedagogical theories, including constructivism, in which learners actively construct their own knowledge instead of passively receiving information from a teacher or guide, and situated cognition, in which students draw on real-world situations and become immersed in particular circumstances.[9] Empirical studies have shown evidence that educational electronic games promote effective learning, primarily of mathematics, science, physics, music, game accessibility guidelines, and history.[7,10,11]

M-learning games, such as the one presented in the main article, imbue young students with a better understanding of history, helping players to acquire deeper knowledge while playing in an archaeological park. The gameplay method offers several benefits. Firstly, play is fun and amusing. Because it's enjoyably, players are less likely to forget learned facts and skills; hence, this property of the gameplay method brings obvious pedagogical benefits. A second positive aspect of play is that different skills can be practiced simultaneously. In a group-based game like Explore!, each player contributes with her or his most congenial skills. Finally, play is a relational activity, stimulating collaboration and encouraging interaction within and among groups.

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