Mobile Game Development for Multiple Devices in Education

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***Abstract*—Mobile learning and educational gaming are two trends that are rapidly having an increasing impact in Technology-Enhanced Learning. However, both approaches present significant technological challenges. Mobile technologies are very diverse and the market pressure pushes the continuous development of new technologies and features. On the other hand, game-based learning needs to deal with enormous development costs and the problem of allowing instructors and experts to actively participate in the game development process. Moreover, there are numerous situations where bringing both approaches together could be very useful, but this combination magnifies the technological barriers previously described. In this work we present <e-Adventure>, an authoring environment for educational adventure games that supports the production of both desktop and mobile games. This framework provides a graphical environment that allows instructors to create their own educational games with a low cost. Then, the games can be exported to multiple formats, including support for diverse types of mobile platforms. This is achieved through a modular semi-automated exportation process, which is based on mobile device profiles.**

***Index Terms*—game-based learning, m-Learning, mobile games.**

I. INTRODUCTION

The concept of m-Learning (learning with the help of mobile devices) is not as new as it could be imagined. The lack of quality of the early devices, with reduced computational power and small displays which were merely able to render text strings, constituted a severe barrier for the deployment of rich educational materials. In addition, the devices were expensive and the connection costs, when available, enormous. Only communication via SMS messages seemed to be an affordable way for supplying educational contents and allowing a communication between teachers and students [1, 2]. These conditions prevented the academic and commercial sectors from investing time and money on the investigation of new m-Learning-based educational experiences.

However, in the last three years, mobile technologies have dramatically evolved, promoting the interest in m-Learning systems. Such evolution has brought new mobile devices with higher computing power, affordable and pervasive Internet connections and high quality displays which can render complex learning contents. This technological evolution comes along with a great reduction in the prices of the devices and the cost of the connection services, making the purchase of a last-generation cell-phone or PDA (Personal Digital Assistants) no longer an unaffordable luxury. From an educational perspective this new situation has sparked the interest for educational experiences that take advantage of mobile devices.

However, even though mobile technology has evolved and now can support the investment on m-Learning, there are still technological issues that need to be addressed. The current market of mobile devices is extremely dynamic, populated with a broad range of heterogeneous devices with different operative systems and capabilities. This variety of mobile platforms implies new challenges to the designer of mobile applications as the success of a mobile application is directly related to the number of devices it can run on.

On the other hand, another trend that is having a significant impact on technology-enhanced learning is the notion of using computer and video games in education [3-5]. Even though the discussion is still open to debate, the academic community is beginning to accept the educational benefits of this paradigm [6], Among the characteristics that make games an interesting option for learning, we find arguments such as the increment of the motivation that games can supply or how they provide immersive worlds that promote reflection, situated reasoning and problem-solving [7, 8].

The potential of game-based learning can also be enhanced when mobility is introduced [9]. For instance, the games can relate to their environments, introducing in the game the location of the player, providing versatile learning systems including mixed or augmented reality.

In this work we study the possibilities, advantages and also the challenges of combining game-based learning and m-Learning paradigms. To deal with such problematic blend we describe <e-Adventure>, an educational game platform that reduces the complexity and cost of developing educational videogames [10]. The platform has been extended targeting diverse mobile platforms, offering a centralized user-friendly editor that can export the games in different formats. Using this tool, a user with none or very little game production knowledge will be able to design and developed his or her own custom educational videogame and to export this videogame for execution on a computer or a number of mobile platforms.

The document is structured as follows: in section 2 m-Learning and game-based learning are analyzed, studying the possibilities offered by them and the challenges which they present, especially when combined. Then, in section

3 we study one of the main problems of designing new m-Learning activities: the diversity of devices and platforms. The <e-Adventure> authoring tool, with a description of its exportation method based on device profiles, is presented in section 4. Finally, in section 5, we discuss some conclusions and outline future lines of work.

II. MOBILE LEARNING AND GAME-BASED LEARNING

As we previously mentioned *m-Learning*, and game-based learning are two trends which are experimenting a broad interest coming from both the educative community and commercial sectors. This section provides a deeper description of the characteristics that make these trends especially attractive.

A. M-Learning

m-Learning stands for the learning achieved through the use of mobile devices, such as PDAs, mobile phones, portable video players, TabletPCs, low cost laptops or even portable gaming devices, usually including the notion of having the capability of getting connected to the Internet.

The mobility factor is the key characteristic of m-Learning systems, making possible the improvement of the learning experience in several ways. In some cases, mobile devices are included in a learning experience to work as a reference tool, allowing the user to interact at the same time with the *virtual world* and the *real world.* This approach has special interest for “in field” training, allowing users to interact with the real elements they are learning about. For instance, think about a visit to a place with archeological ruins where the students could have access to hyper-media information about how those edifications were centuries ago. The use of this kind of devices allows students to access digital contents in places with no connection facilities or when computers can not be accessed such as disfavored locations [11].

In this line, mobiles devices open the gates for the so called Just-In-Time learning experiences, or learning right when the knowledge is needed. This characteristic, for example, might allow a professional who works with complex machinery to lookup some information about an infrequent task right before performing it, thus reducing the chance of causing any damage. The mobility factor also allows students to improve their knowledge or skills of a subject in moments typically wasted, like waiting in a queue or while travelling by public transport.

Some other interesting possibilities of m-Learning systems come out thanks to the newest features of these devices. The new mobile devices now include features caught from other device families, such as GPS (Global Positioning System) receptors, digital cameras, Bluetooth/Wi-Fi connections, audio/video players or even anemometers. These new features open new possibilities for enriching the educational experience with elements such as the use of GPS positions to provide the user with a deeper feeling of immersion (e.g. a virtual museum guide, which offers contents depending on the position of the user as described in [12]). In this line, another example would be digital cameras, which are very frequently embedded in new mobile devices. They can be used to take pictures of an unusual event or even for enriching the image of the real surroundings with digital data generated by the device [13, 14].

However, designing good m-Learning systems is not a simple task. m-Learning has been generally considered as an evolution of e-Learning only channeled through a smaller device. Consequently the first development efforts in the m-Learning field were invested on the adaptation of existing e-Learning environments to fit in a smaller screen. However, these approaches did not take into account other features of mobile devices, like the low memory capacity and runtime performance. Wrong decisions in design time about the contents presented on the display, the amount of data on the screen or the interaction procedure with the user can reduce the advantages offered by the inclusion of mobile devices in the activity [15, 16], leading to rough and inefficient systems.

In addition to this shortcoming, we must seriously consider the diversity of the field previously described. In this regard the absence of common standards for manufacturers and developers describing the main characteristics of the devices and operative systems plays a key role. In this context, the size and characteristics of the display are especially relevant. As a consequence of this scenario, developers must produce applications with different settings to run on each device and the content must be adapted to fit in very diverse displays. This is one of the major challenges in the development of mobile applications, as supporting any possible platform and device might increase dramatically the development cost of the system.

B. Game-Based Learning

During the last decades a growing interest has risen concerning the idea of how computer and videogames, as well as game-like simulations can provide benefits to learning experiences [5]. This interest was initially sparked by authors that identified the engagement and motivation provided by games as a force that could improve learning almost as soon as the first videogames were born [17-19]. Since then, many authors have highlighted how games can keep people of different conditions focused and concentrated on a task during long periods of time [20]. In addition, further studies have pointed out aspects of videogames very related to constructivist principles, which can be used to promote students to play active roles and learn through experience rather than fact memorization [7, 8, 21-23].

Some of these works not only discuss the benefits of game-based learning but also the aspects of videogames which can be the cause of those benefits. Among them, the immersion in the game world experimented by players is perhaps one of the most relevant [24]. While users play they feel as an active element, free to explore the in-game world, which can help in the acquisition of deep knowledge about the domain of study.

However, even if the academic community is starting to see games as a valid medium [6], there are still barriers that hinder their real application in large-scale environments. Among those barriers, the high development costs of videogames along with the need of getting instructors effectively involved in the production of educational videogames are probably two of the most relevant issues to be addressed [10].

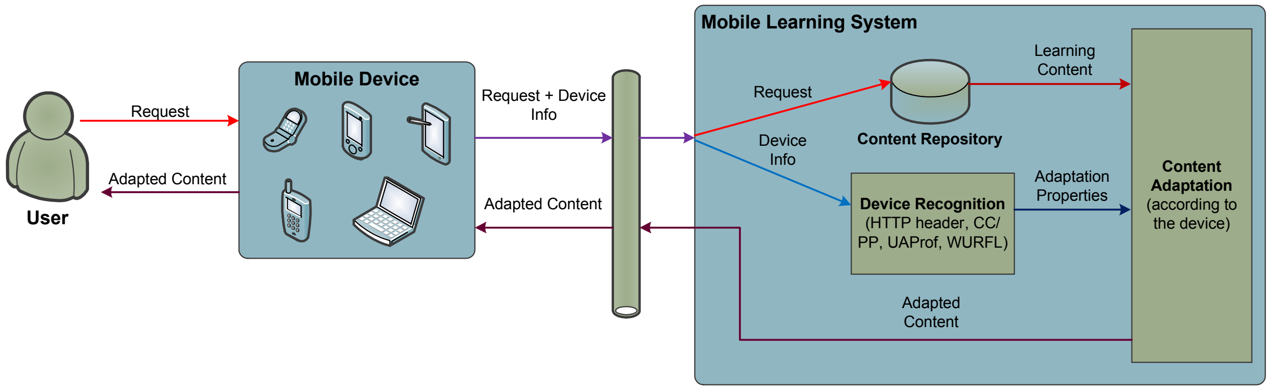

Figure 1. Scheme of a device feature recognition module integrated in an m-Learning system.

C. *Game-Based Mobile Learning*

Both m-Learning and game-based learning provide advantages for technology-enhanced learning. However we want to highlight the broad range of possibilities offered by the combination of both approaches from an educational point of view. When both approaches are combined, the advantages offered by either approach are improved.

The current technological development in our society has brought new mobile devices and better connectivity that are perceived by many consumers as a “cool gadget”. This perception, on its own, can act as a motivating factor towards the use of mobile-based learning contents for a certain population segment, but not to everyone. Additionally, once the novelty wears off, the result is some times just the same content on a more uncomfortable device.

However, videogames can provide an additional motivation that would engage a greater segment of the population. The initial idea of students reading content while commuting to their schools cannot compete with the impact of mobile game platforms, a far more common sight in public transportation systems.

Additionally, there are situations where game-based learning can improve the benefits of m-Learning. This is especially applicable in training scenarios where a game-like simulation deployed in a mobile device could provide students with the benefits of practicing in a safe test environment and at the same time in the real working place. For instance, think about chemistry students who could check the results of a certain chemical reaction before they carry it out during a practical lab session.

Mobile devices can also contribute to the immersion which the player experiments while playing a videogame. The new features present in some mobile devices, like GPS receptors or Bluetooth connections can add new parameters to be taken into account by the system (e.g. the position of the user) improving the feeling of immersion. The users feel that they are a part of the experience since their actions in the real world have an effect in the virtual world. Additionally, the embodiment factor, i.e. the use of more senses, improves de educational activity achieving better long term learning [25].

Moreover, another positive factor of game-based learning often discussed is the stimulation of the cooperative and competitive attitudes. However, when users play they experiment some social relations in the virtual world while they are physically isolated in the real one. With the introduction of m-Learning systems, these relationships can be transported to the real world since the game is not linked to a concrete location but travels with the user.

III. THE DIVERSITY OF MOBILE TECHNOLOGIES

The rapid growth in the field of the mobile technologies has resulted in the development of high quality devices. PDAs and mobile phones have become scaled computers, with 32-bit processors and memories measured in Megabytes. However, most of these devices use proprietary operative systems and different hardware architectures.

During the last years a new market war is going on, with different firms trying to set their platform in a privileged position developing new devices and technologies.

Three companies, Nokia, Microsoft and Blackberry have led the market for the last few years with their respective operative systems: *Symbian*, *Windows Mobile* and *Blackberry’s OS* (characterized by the active mail technology known as push). During the last year, Apple is also becoming a strong new competitor with the *iPhone*, and Google is getting ready to enter the market with *Android*.

This variety means that mobile system designers must consider both the platform and the range of devices that the application will be oriented to. Even devices belonging to the same platform show different features and characteristics, such as the size of the screen or the availability of special features like GPS receptors or Bluetooth connections.

In order to deal with this challenge, there are some tools that the system designer can use to get knowledge of the features and characteristics offered by the devices. Fig. 1 shows a scheme of how the learning system selects the information to be supplied depending on the device profile.

To recognize the capabilities of the mobile device which produced the content request there are some different techniques. HTTP User-Agent Header is the older recognition method, based on the exchange of data between web browsers and servers while connected via HTTP protocol. The HTTP request sent by client devices contains the *Accept* and *User Agent* headers which give

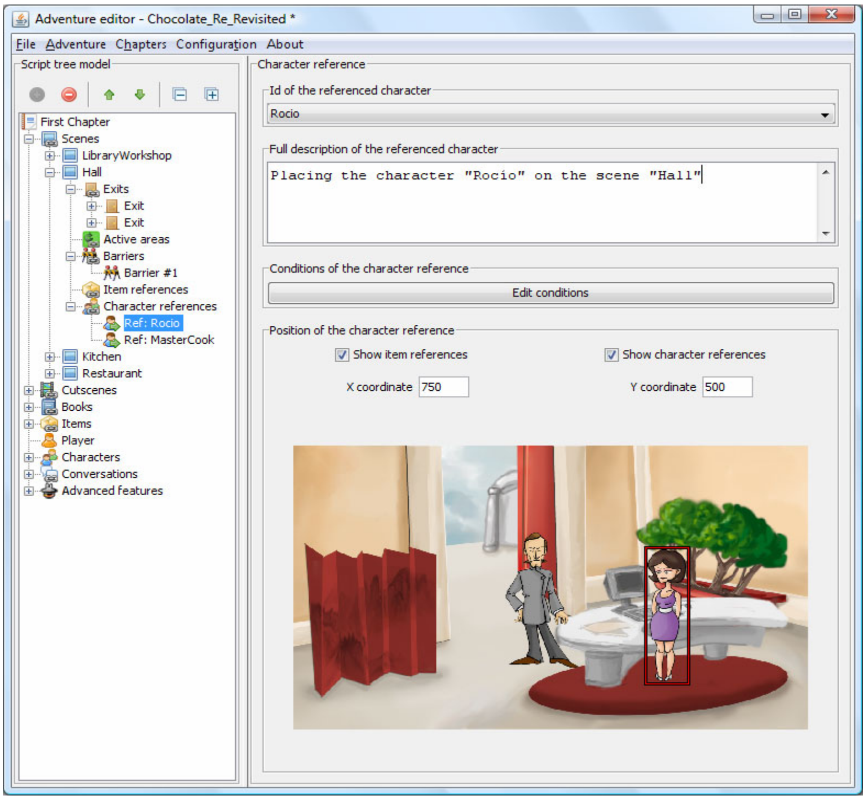

Figure 2. Screenshot of the <e-Adventure> game editor.

information about the kind of data acceptable by the device and describing the device itself respectively. Unfortunately, the amount of data supplied is too small for the current heterogeneity of devices and features.

CC/PP (Composite Capabilities Preferences Profile) is a World Wide Web Consortium (W3C) specification for expressing the capabilities of the devices[1]. This technology can also represent information about user preferences or special needs. The main advantage of this method is its device independency.

Another device recognition method is UAProf (User Agent Profile), promoted by the Open Mobile Alliance[2] based on the detection of the user agents. It uses the CC/PP language specification for defining a device dictionary with the features of the subscribed devices. The main disadvantage of this method is that some old devices might not support this technology and that the profiles must be updated to describe the real features of the devices.

WURFL[3] (Wireless Universal Resource File) based on the existence of a descriptor file located in a server belonging to the system. Since the server is not managed from a third party, the information supplied is more accurate and complete. Besides, WURFL allows to the user to insert additional information not supplied by the manufacturer. As a last characteristic, WURLF presents a hierarchical structure based on families. In this manner devices belonging to a family inherit the features of the own family, which reduces considerably the size of the descriptors.

[1] http://www.w3.org/Mobile/CCPP/
[2] http://www.openmobilealliance.org/
[3] http://wurfl.sourceforge.net/index.php

IV. THE <E-ADVENTURE> PLATFORM

A. A simple authoring environment for instructors

The <e-Adventure> platform is an authoring environment for the production of *point-and-click* adventure games. The choice of this game genre was influenced due to the educational traits of these games [23, 26, 27]. The platform was devised to facilitate the introduction of game-based learning in the educational system by tackling some of the most relevant issues that are preventing such integration [28]. Those issues are mainly concerning (but not limited to) the high development costs of videogames (unaffordable for educational budgets), the difficulty of getting instructors actively involved in the production of educational games and the need of education-specific features (usually not present in commercial videogames).

Thus, the platform consists of two applications: a instructor-oriented game editor for the creation of the games [10] (shown in Fig. 2) and a game engine, which facilitates the deployment and distribution of the games to the students. The editor facilitates the implication of instructors with no programming background in the development process, keeping them focused on the achievement of the learning value.

B. Game exportation for multiple platforms

<e-Adventure> currently has two different versions of the game engine (the application that executes the games). Once the creation of the game is finished (a process which

includes the definition of the story, the production of the art assets and the final assembly of the adventure [29]), the author must select the target platform: mobile or desktop.

If the educational adventure is to be executed on a computer, the videogame will need no adaptation since there are no technological restrictions for running this kind of low-cost videogames on computers.

If the selected target is the <m-Adventure> engine for mobile platforms, an adaptation process will be necessary to make sure that the engine on the concrete device will be capable of executing the videogame. As we will detail on the next subsection, during the exportation process the editor checks the descriptor of the target device (or device family) to retrieve its technical features. If necessary, the editor will take care of some automatic transformations (e.g. scaling the images and relocating the elements in a smaller canvas) and will warn the author with possible sources of incompatibility. With this information the game author can change the conflictive elements for others more suitable for the target platform.

To facilitate the platform-interoperability of the <m-Adventure> engine, it was written for the Java 2 Micro Edition (J2ME) platform. Fig. 3 and 4 show two screenshots of the same game exported for desktop and mobile platforms.

C. *Profile-based exportation for mobile devices*

<e-Adventure> aims to help mobile developers by reducing the time and knowledge required to get an adventure game running on diverse mobile platforms. The challenge here is that mobile game developers just need to create the game once, and then the system adapts that game to the diverse target platforms. As described in the previous section, once the authors have finished defining the different elements which make up the educational adventure, they have to choose the execution platform: the <e-Adventure> engine for desktop applications or the <m-Adventure> engine for mobile applications. In the second case the user must specify the concrete mobile device or device family to export the adventure to. We focus on this

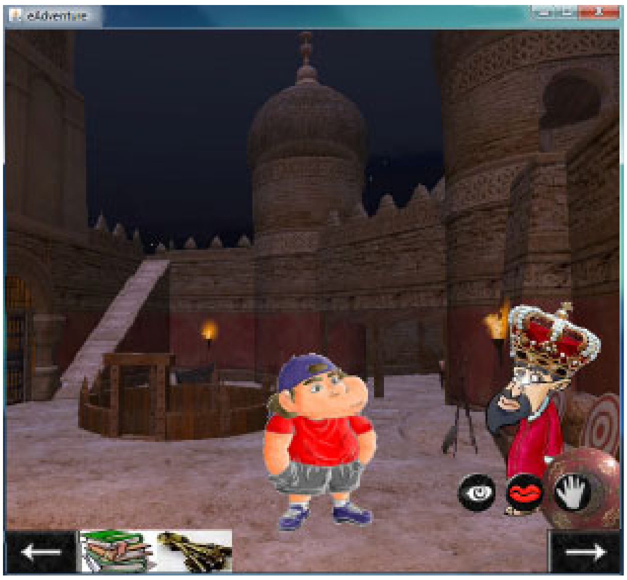

Figure 3. Screenshot of the <e-Adventure> version of the 1492 game.

Figure 4. <m-Adventure> version of 1492.

paper on the mobile approach since the computer one is straightforward and does not imply any adaptation procedure.

The <e-adventure> editor has its own device profile database based on WURFL description files. Thus the different descriptions of the devices can be updated by the users, without relying on third persons to get the profiles updated. One extra advantage of this approach is the possibility of categorize devices in families according to common features, which allows choosing the target device in base of the characteristics it should have instead of looking for a concrete profile. Presently this is especially relevant, as new devices with new features are coming up almost every day. Such continuous evolution makes having an updated device database an arduous task. Besides, new features are usually added to devices belonging to a family but keeping the same general characteristics. Once the user has selected the target device, the adaptation process takes place.

The adaptation process offers two different behaviors: an active approach and an informative approach.

On the active approach, once the author confirms the operation the system performs some adaptation activities such as scaling the art assets to the size of the new display and relocating those elements in a smaller canvas. The results of the process are two products. Firstly, the game file (containing the descriptor) to be executed on the <m-Adventure> platform. Secondly an adaptation report containing log information about the tasks performed by the system and some warning data about the produced game. This warning data consist, in first place, on possible conflict sources in the adventure game. Those could be, for instance, videos or audio tracks, or could even be related to the absence on the device of concrete features such as a Bluetooth connection. On the other hand it also reports the adaptation tasks which could not be performed automatically by the system so the user will required to be solved manually.

The informative behavior of the exportation system produces the same products but does not carry out any

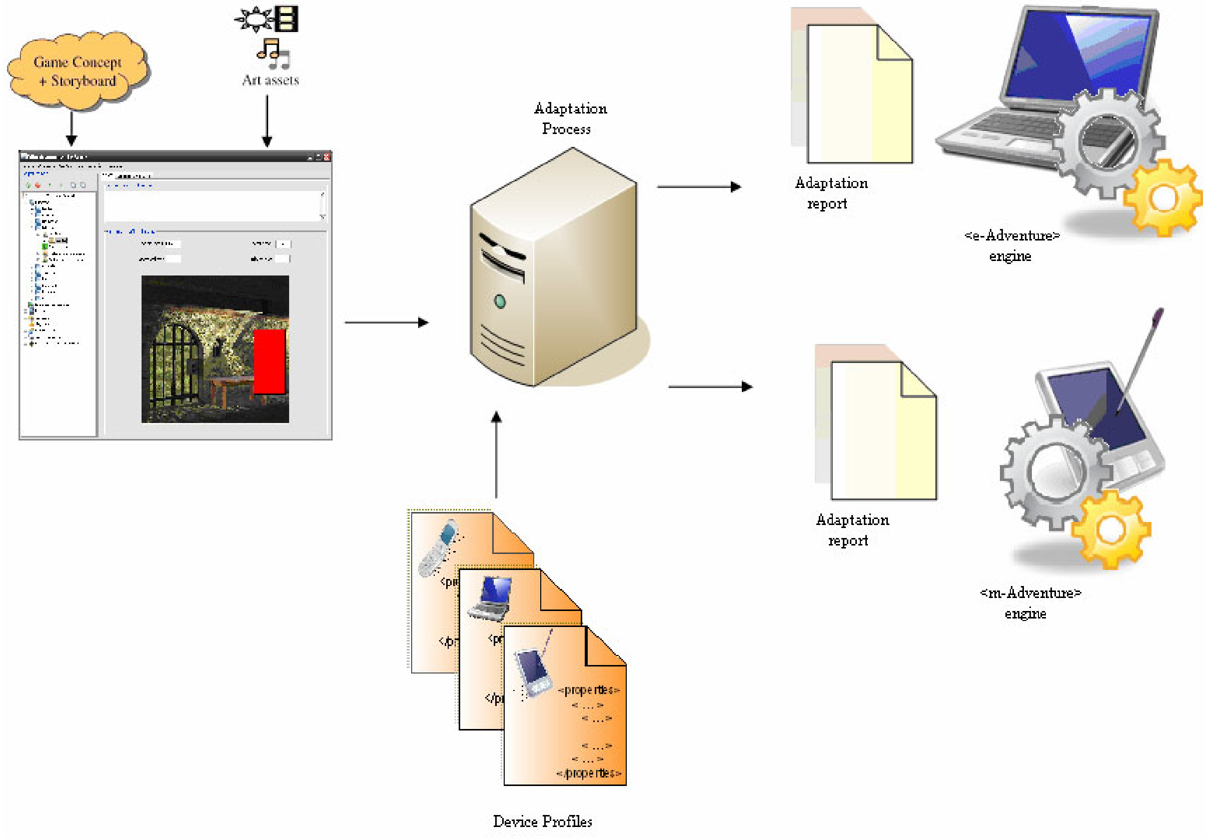

Figure 5. Scheme of the exportation procedure in <e-Adventure>

adaptation task, so it is the user who must solve those issues logged on the adaptation report.

This adaptation process facilitates the development of mobile applications for different platforms which can run the <m-Adventure> execution engine by taking on consideration the possibilities and features offered by any mobile device. This approach might be extended in the future to include user preferences which would help the developer to introduce adaptations for users with functional diversity. A scheme of this exportation procedure can be observed on Fig. 5.

V. CONCLUSIONS AND FUTURE WORK

As it has been described in this paper, m-Learning approaches are gaining momentum due to the new possibilities they offer. Mobility allows users to access the contents exactly at the moment desired (Just-In-Time Learning), no matter when or where. On the other hand, game-based learning is another interesting branch in Technology-Enhanced learning. The benefits provided by this paradigm are mainly concerning the impact on the motivation of the students, but also include positive effects such as the promotion of constructivist principles, short and effective feedback cycles, and a deep immersion feeling facilitating the development of reflexion, analysis and problem-solving skills.

However, both paradigms can profit from their mutual combination, mixing the benefits provided by each one along with some interesting by-products. First, videogames can augment the entertainment provided by m-Learning systems and thus promote their use between all kinds of learners, solving (at least partially) the problem of bringing students to the learning. Besides, game-like simulations, along with other game-based contents, can be used as safe test environments convenient for training situations such as practical lab sessions. In addition, when put onto mobile devices, those contents could be accessed in learning contexts where desktops are not available, blending the *virtual* and the *real* world by interacting with both at the same time. Finally, videogames can benefit from mobile devices, improving the immersion feeling of the games and promoting collaboration and competition between students, which permits real social interaction rather than a mere remote communication. In summary, the combination of m-Learning and game-based learning can not only improve the attractiveness of the educational activities, but also add new values and offer new opportunities and scenarios for learning. Finally, it separates learning from concrete places and times.

But to combine both paradigms is not easy. Mobile devices are very diverse, covering a wide range of manufacturers, platforms, operative systems and mechanisms for their communication with no standards guaranteeing the interoperability of the parts involved. This is a serious burden for mobile-game designers who need to adapt the games for all these devices. When it comes to the educational field, such extra development cost along with the difficulty of getting instructors involved in the development of the games makes this approach much less affordable.

The <e-Adventure> platform tries to contribute in this regard. The instructor-oriented editor provided allows instructors with no technical background to produce their own educational games, and then export them to be played not only on desktops but also on a wide range of mobile platforms. Relying on a WURLF-based device descriptor, which can be directly edited by the user or just selected from the database distributed along with the platform, the editor tool carries out the necessary adaptations to produce a game which could be run on the selected device.

Although <m-Adventure> has been written in J2ME, which a priori guarantees that the games produced with the platform will be platform-independent, further testing is needed. The edition of the games with the authoring tool, as well as the exportation and adaptation mechanism has been successfully tested, although further refinements will be required to achieve a product-like quality. In terms of runtime performance, the mobile games produced have been mostly tested in simulation environments, where the results where at least promising, but very few small tests have been performed in very concrete, real mobile devices (actually mobile phones). In the next future it will be indispensable to carry out a final testing stage on the broadest possible set of real devices. This will probably lead to further refinements of the platform to make the range of supported devices as wide as possible. However, we are first targeting high-performance mobile devices such as PDAs, PocketPCs and some top mobile phones, which ship with J2ME and CDC profile, to ease this process. Besides, the eventual performance results of the games produced with this platform will strongly depend on their complexity, which cannot be determined beforehand. Thus game developers may need to keep this in mind when developing complex games for low-capacity devices.

Another future line of research will be to test our approach in real courses. Presently we are collaborating with the School of Medicine of the Complutense University in Madrid to produce mobile game-based simulations that students of first grades could use during practical sessions. A thorough analysis of the results obtained will help us to improve the platform and determine more accurately the benefits of this approach.

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