Coordinating Heterogeneous Game-based Learning Approaches in Online Learning Environments

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Abstract. Game-based learning is quickly becoming a popular trend in Technology-Enhanced Learning. However, the field is very broad with many different initiatives being classified as game-based learning. On the other hand, instructors are demanding effective ways to track the interaction of the students with the games and to assess the learning process. The diversity is a major issue in this regard, requiring instructors to understand each game and to evaluate different kinds of games in different ways. In this work we present a unified mechanism to gather tracking and assessment information from different and varied games. All the information is stored in an online learning environment, where the instructor can consult it. The keystone of the approach is a tracking and assessment API that can be implemented by different games on the client-side and by diverse online learning environments on the server-side. This approach is illustrated with the <e-Adventure> family of educational platforms, which support this interoperable API.

Keywords: Game-based learning; adventure games; authoring tools; learning management systems; in-game assessment; adaptation; mobile learning.

1 Introduction

The notion of using videogames for education, although not new, is gaining momentum and becoming an established trend in the field of Technology-Enhanced Learning [3, 22, 36]. Even though a complete discussion of the educational benefits of game-based learning would be beyond the scope of this work, it is to be noted that the reasons behind this approach have evolved and matured, abandoning the initial position in which videogames were used in education just because kids enjoy them. Games have become an established entertainment industry, engaging people of all kinds of age, gender, race or social status [10], which makes them a good way to enhance the fun factor of the learning experiences, augmenting in this manner the motivation of all kind of learners. Besides, videogames (even entertainment-driven videogames) are built on principles related to constructivist learning [11], setting the

player into an active and exploratory role instead of the passive "sit-and-listen" method. Additionally, games promote situated-learning, allow the players to explore the rules of the game world by trial and error (with a very short and effective feedback cycle [18]) and, if set in an appropriate domain, they can be an effective tool to understand determined fields of knowledge [12, 37].

However, even if the academic community is beginning to accept the educational benefits of this paradigm [21, 36], not every game has educational value and there are a number of instructional aspects that must be taken into account when designing game-based learning experiences. One of the most important aspects is how to make sure that the students are actually learning while interacting with the game [20]. It is important to track the activity of the students, making sure that they are learning the right lessons, preventing them from making wrong assumptions, and promoting reflection about the contents and mechanics of the game.

A basic approach would be to organize play sessions in which the instructor is present, watching and guiding the students. However, this method is not scalable in traditional schooling, and mostly impossible in online learning environments. A more sophisticated alternative for these environments, as proposed in [24] would be to take advantage of the closed interaction between student and game to track the activity of the student and send the information to an online Learning Management System (LMS) where the instructor can check the tracking information gathered.

But the field of game-based learning is very wide [33] and still very young and mutable, just as the videogame industry itself. First, many approaches can be labelled as game-based learning [17]. From simple *edutainment* games for young children that sugar-coat educational content with popular cartoon characters, to high-end 3D massively multiplayer educational gaming for corporate environments, it becomes hard to define and measure the characteristics of the field.

Additionally, different situations may require different types of games. Firstly, not all the genres and types of games are adequate to learn in all the domains of study. Moreover, even in a single domain, diverse target audiences or educational contexts may also demand different types of games, even to the point of some cases requiring a non-game-based alternative [34]. Some students/domains may favour simpler 2D games which are simpler to use and have less technical requirements for their execution. Some other cases may require more advanced 3D games, either to increase the immersive factor or to grasp the attention of students with gaming habits (who are probably used to state-of-the-art commercial games). In some situations it may even be possible to explore the possibilities of mobile gaming for Just-In-Time learning situations or to really achieve the learning anywhere and anytime motto of traditional e-learning approaches [14].

Thus, in a mainly game-based online learning environment, we may find that a unique type of videogame could be insufficient. This would lead to complex heterogeneous game-based learning systems with diverse (game-based and/or traditional) learning materials in which students choose (or are assigned) the approach that is more appropriate according to their profile.

This diversity represents a challenge when it comes to tracking the activity of the students and controlling whether they are learning the appropriate concepts (i.e. the learning goals are being successfully accomplished). With different game-based learning approaches being put into practice at the same time on the same

environment, there is a need of an entity able to coordinate all of them and register the results of the games for assessment purposes without involving an extra burden for the instructor.

In this work we show our approach for the management of this complex scenario. This approach is exemplified through the <e-Adventure> family of educational game platforms, which put this principle into practice. It is a set of educational game platforms supporting the production of multiple types of games for diverse learning scenarios, including 2D and 3D adventure games for either desktop or mobile devices (Pocket PCs, PDAs, mobile phones, etc.). All these platforms implement a common tracking and assessment API that gathers information from the interaction with the learner and connects them to an online Learning Management System (LMS). This common gateway allows the integration of different heterogeneous games in the same learning environment, which is coordinated and controlled by a "central entity" (the LMS) that can be managed by the instructor. Thanks to this structure the scheme is not limited to games of the <e-Adventure> family, as any game implementing the Assessment API could interoperate with the LMS.

Thus, the document is structured as follows: in section 2 the diverse field of game-based learning is analyzed in terms of the possible approaches and situations covered in the field. Then, in section 3 some issues regarding the integration of game-based learning in on-line environments are discussed. The <e-Adventure> family with a description of the common tracking and assessment API is presented in section 4. In section 5, a case of application is given, in which a course with four different learning approaches (game-based and web-based) ruled by a LMS was developed. Finally, in section 6, we discuss some conclusions and outline future lines of work.

2 The Diversity of Game-Based Learning

As previously mentioned, Game-Based Learning is a broad term that would include any initiative in which any kind of computer or videogame is part of a learning process. This section provides an informal classification of the initiatives found in academic discussions in terms of their complexity, target audience and situations of applicability in order to give a general scope of the field.

2.1 Edutainment

In spite of its etymology (combining the words education and entertainment), the term *edutainment* is often used in the literature to describe those products in which play, fun and game design take a secondary role [32]. These products are often interactive multimedia presentations of the regular school content, targeting young children and using popular cartoon characters as a motivating aspect.

The *edutainment* market has been (and still is) very profitable, with hundreds of titles published yearly. However, its peak was mostly in the 90s, along with the popularization of multimedia computers, and was motivated mainly by the engagement of parents and tutors who thought these approaches could help their children to improve their school results. However, many of these products had a

relatively low quality as they do not get a proper balance between fun and learning value (in many cases, the outcome has the learning value of a bad learning experience and the fun factor of a bad game), loading the term *edutainment* with a negative value [22].

2.2 2D Educational Games: Low Costs and Low Technical Requirements

One of the key challenges preventing the application of game-based learning approaches is their cost. Michael & Chen, during a session on *serious games* in the 2005 Game Developers Conference ran a survey to estimate the average development cost of a serious games project [22]. The result was that more than 52% of the projects had a cost above $100.000. Similarly, [3] estimates the development cost for a next-generation simulation between 15 and 30 persons-year.

These numbers are far beyond the budget of most educational projects. For this reason, many educational game proponents advocate for simpler games that can be developed at a more reasonable cost [20]. In this case, game authoring platforms such as the *Game Maker*[1], or genre-focused tools such as *Adventure Maker*[2] and *Adventure Studio*[3] are often mentioned in the literature [1] as an effective method to reduce the development costs of the games.

These games also have other advantages. First, their technical requirements are far lower than those of modern commercial games. This facilitates the distribution of game-based contents to broader audiences without demanding a constantly updated (and expensive) computer. Additionally, their simpler interfaces may be more comfortable for mature students who are not always used to the more dynamic and complex commercial games.

Indeed, in the last few years it has become obvious that simpler games appeal to broader audiences. The boom of the Internet-based casual gaming market, or the huge success harvested by Nintendo in both the DS™ (platform in which learning products such as *Brain Age*™ or *English Training*™ are at the top of the best-selling games) and the Wii™ consoles should be enough proof of that.

However, these games always run a risk of being perceived by certain student populations as dated and excessively simplified, loosing the motivation and immersion characteristics of game-based learning [28].

2.3 3D and Multiplayer Games: Catering for Discerning Students

The commercial game industry is in a process of constant and extremely fast technological innovation, always trying to capture the attention of the players with more impressive graphics, physics and other aspects that enhance the realism. This adds a great pressure to the educational gaming field. Will these hard-core gamer populations accept simpler educational games as real games?

[1] http://www.yoyogames.com/gamemaker
[2] http://www.adventuremaker.com/
[3] http://www.adventuregamestudio.co.uk/

Of course, modern technology comes at a cost, and this requires special considerations: Is the target audience big enough so as to justify the investment? In some cases, the best approach might be to seek relatively modern 3D games, but one or two generations behind the current state-of-the-art and with the support of specialized easy-to-use authoring tools such as *The 3D Game Maker*™[4] or the *Homura IDE* to keep the development costs at reasonable levels [7].

However, the perception of avid gamers is not the only reason why some educational games must innovate technologically. Some domains may require a higher level of immersion and/or realism than the offered by 2D games, making 3D games a better alternative. In this line, when realism is an important factor in the learning process, state-of-the-art graphics may also be required.

Other modern aspects, such as multiplayer (or massively multiplayer) features may also be required in determined circumstances. This is the case, for example, in the ongoing efforts to train emergency services that employ realistic 3D multiplayer environments to rehearse emergency planning including interaction among the players [16]. In such scenarios, the stakes are sufficiently high so as to justify the increased development cost.

2.4 Mobile Games: Learning Anytime and Anywhere

Now the number of mobile devices (PDAs, cell phones, portable game consoles, pocket PCs, etc) available in the market is increasing exponentially with a special success among teenagers. The use of mobile devices opens a wide range of possibilities, reaching even the educational field, in what has been called m-Learning [19]. The main characteristic of m-Learning is the mobility factor which makes possible the improvement of the learning experience in different ways. As the simplest approach mobile devices can be used as reference tools, allowing the user to interact in the real world with the elements he or she is learning about, improving in this way the "in field" work (e.g. think about a botanic course where students could access the web-based documentation of the plants while they see them during a visit to a botanical garden or a natural place). Some other studies show the advantages of using this kind of devices in disfavoured locations or wherever computers can not be accessed [14].

One of the main possibilities offered by the inclusion of mobile devices in educative experiences is the so called Just-in-Time learning. This is the possibility of accessing the knowledge at the moment and the place where it is necessary. This characteristic, for example, might allow a professional to learn how to use a lorry without the chance of causing any damage with a wrong action. Arguing in the same line m-Learning can be useful for students which wanted to improve their skills when they are travelling, waiting for someone, or just in their spare time (this can be particularly relevant when the learning content is game-based).

Moreover, modern mobile phones and PDAs usually include extra features typical of other kind of devices, such as GPS receptors or Bluetooth connections. The use of

[4] http://t3dgm.thegamecreators.com/

these features offers new possibilities for educational experiences. Among these, the possibility of developing location-based applications deserves to be highlighted. In these systems the movement or the position of the user is another input for the system, improving in this way the user's feeling of immersion [25, 31]. Besides, some other devices (which use is very extended in some cases) such as digital cameras have yielded a number of initiatives for the development of mobile augmented reality systems (also known as Mobile AR) [8]. These systems merge the physical and the virtual worlds, enhancing the environment which surrounds the user with computer-made virtual elements.

In spite of the advantages offered by m-Learning, this approach on its own would be insufficient in some situations and should be complemented with other approaches. For example, students could get tired rapidly playing long videogames on a mobile device. A desktop version of the game would be desirable in order to alternate playing with the computer and the mobile device. Besides m-Learning educational experiences must be designed specifically with the particularities of these devices in mind, which affect both the contents and the interface. This is a complex but relevant process in order to reduce the negative effects due to the reduced display and the computational limitations so the advantages offered by these systems are not dimmed [6, 27].

3 Game-based Learning and E-Learning

Another key issue in game-based learning is how to distribute the content to the students. In this sense, a possible approach is to use online learning platforms for this distribution [34], allowing the students to play the games at home (or, in the case of the mobile versions, on the move) and at their own pace.

E-learning applications have evolved from the passive content repositories in the 90's into comprehensive web-applications that manage all aspects of the learning experience. The new Learning Management Systems (LMS) offer communication mechanisms, provide student tracking and evaluation tools for the instructors and keep a profile with the progress of each individual student. Additionally, they are no longer reduced to distance education, with many educational institutions (including almost all the universities) deploying these systems as an extra support for their traditional teaching models.

Additionally, there is an important line of research in adaptive online learning environments that tries to adapt or select the content that is more appropriate for a particular student (taking into account the student's profile) [5, 15, 26]

This approach would be especially suited for dealing with heterogeneous game-based learning approaches. The same system can host different courses with different types of educational games. Indeed, even the same course could include several alternative types of games for different types of students or contexts. Moreover, the same LMS can also host the contents in traditional (web-based) formats for those students that do not like educational games and prefer to follow a more traditional approach [34].

Having alternative web-based content is important not only for those students that do not like games. In some cases, due to time or environment constraints, playing a game may not be an appropriate learning activity. More importantly, games are probably one of the media forms posing more accessibility challenges [13]. On the other hand, web-based content has been the subject of accessibility studies for many years. Therefore, in game-based learning, a web version of the content can serve as a more accessible alternative for people with special needs or functional diversity.

We can thus find complex heterogeneous learning systems in which game-based and traditional approaches coexist. The adaptation layer decides which is the more adequate depending on the profile of the student, the learning context, the situation, etc.

But simply delivering all the games through the LMS does not solve the main problem of how to integrate and coordinate all the alternative learning paths and how to verify that the learning goals are being accomplished in each case. This integration is a key problem to be addressed in a manner that at the same time the system scalability and interoperability issues are also guaranteed.

4 The <e-Adventure> Family

The <e-Adventure> family is a set of platforms devised for the production and execution of educational videogames. Those platforms are specifically focused on the low cost production of games of the adventure genre (games like those in the Monkey Island™ series), due to the good educational traits of this kind of games, which have been broadly identified and analyzed in the literature [4, 37].

The objective is to provide diverse solutions to cover the needs and requirements of the widest possible range of students and situations. Therefore, the family is compounded of 3 platforms, which are described in the next three subsections: the <e-Adventure> platform, devoted for the creation of common point-and-click adventure games using 2D world representations (section 4.1); the <e-Adventure3D> platform, which follows the same idea but focused on 3D worlds (section 4.2); and finally a mobile version of <e-Adventure> specially devised for mobile learning (section 4.3).

However, what makes this family of products especially relevant to cover the issues previously highlighted, is that they all implement a common in-game Tracking and Assessment API which connects all of the platforms to a centralized Learning Management System where the instructors can consult the gathered data (section 4.4).

4.1 The <e-Adventure> Platform

The original <e-Adventure> platform is compounded by two applications: a game editor and a game engine. The game editor is instructor-oriented so a typical instructor with neither programming background nor game-making skills can produce their own educational point-and-click adventure games [35].

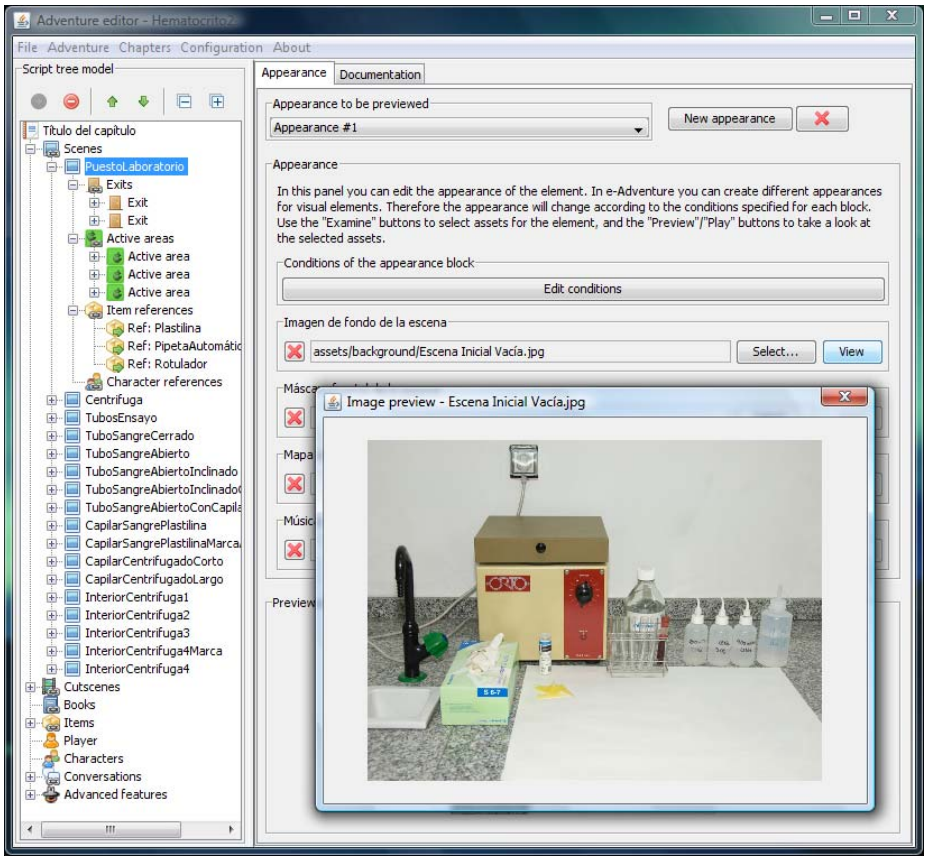

Fig. 1. Screenshot of the edition of a medical procedure game-based simulation with the <e-Adventure> game editor.

The low development costs of these games, along with the narrative-centric nature of the adventure genre make the <e-Adventure> platform adequate for a wide range of contexts and situations (e.g. procedural simulation). For instance, <e-Adventure> is adequate for game-like training simulations. Firstly, work environments (such as labs) can be represented in <e-Adventure> with little effort by taking photos of the real location (Figure 1), which helps students to get used to the machines and tools they will find there. Secondly, the activity of the students can be tracked while they play thanks to the assessment engine, checking in this manner if the stages of the simulation are completed correctly and in the right order (especially useful when the simulation is about a complex procedure with many stages to be completed in a certain order).

Actually the effectiveness of the <e-Adventure> games has been proved in several applications, among which we can highlight some medical procedure simulations [23].

Moreover, it is possible to take advantage of the importance that the narration (i.e. the storyboard) has in these games for the teaching of long pieces of theory or facts sequences through a good story (as the case of study in section 5 depicts).

4.2 The <e-Adventure3D> Platform

In spite of the promising results obtained with <e-Adventure>, we cannot ignore that there is a public that may find the genre of point-and-click adventure games as dated and uninteresting. As it is discussed in section 2.3, some students with gaming habits find these games too "old-fashioned" and therefore not attractive. For that reason we developed a platform for the creation of more modern-looking 3D adventure games following the same principles as in the original <e-Adventure> platform (i.e. instructor-oriented, education-specific traits, etc.). It is true that the development cost of these games is higher due in part to the high cost of the 3D resources, but it is a good approach to capture the interest and attention of a public which is expecting from a game more than a simple 2D world. Besides, the interaction with a 3D world seems to be more appropriate for simulations requiring an extra dose of realism and precision.

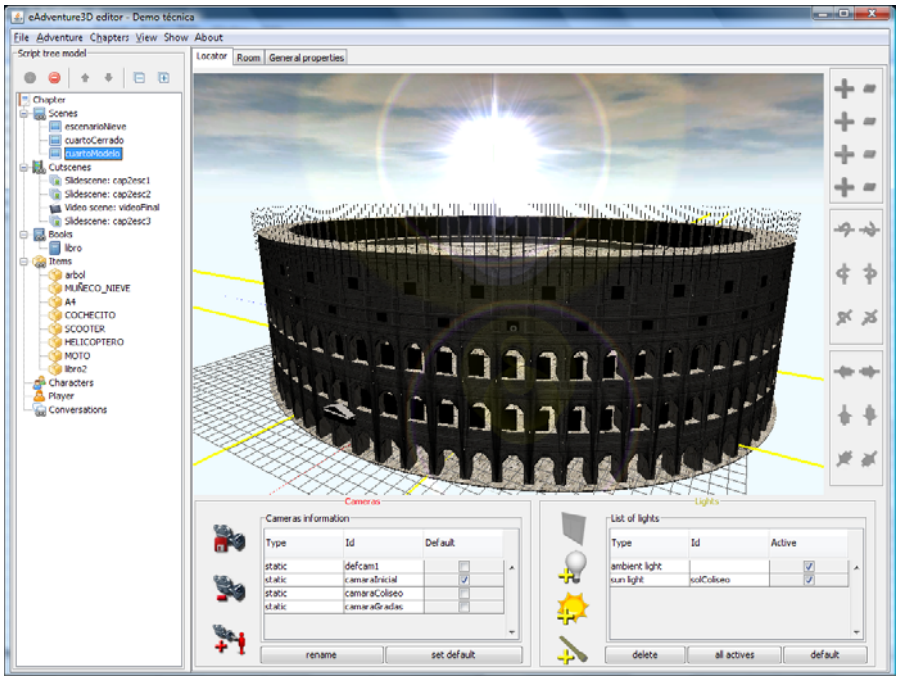

Fig. 2. Screenshot of the edition of a 3d adventure game for the teaching the history of Rome.

As seen in Figure 2, the creation of a 3D adventure game with the <e-Adventure3D> editor is similar to the creation of a 2D point-and-click adventure game, once the artistic resources are provided.

4.3 The <m-Adventure> Platform

Due to the increasing success of the mobile gaming platforms and the possibilities offered by the new mobile devices, we also decided to extend <e-Adventure> platform with a new mobile engine, called <m-Adventure>.

The main idea is that the <m-Adventure> engine can use the same videogames generated by the original <e-Adventure> game editor. However, before the games are executed on the mobile device, some necessary modifications need to be carried out to get it running under the restriction of the device (e.g. resizing of the images, removing of any resources not allowed by the device, etc). Despite the special needs of these devices, the use of this platform allows the users to access the content at the moment they desire.

As the videogames developed by the <e-Adventure> editor do not require a critical response speed, those are especially suitable for mobile devices with low performance speed and limited resources (e.g. mobile phones). On the other hand, the <e-Adventure> platform has been proved to be very useful for the learning of complex procedures, as it has been previously described. Bringing this platform to mobile devices gives users the possibility of accessing the game content during these procedures and to practice certain actions in a safe system (e.g. lab sessions). In such situations it can be a great reviewing tool instead of consulting a heavy manual, as on the display of the device the user can observe the same tools or even locations than in the real action. In this sense we can say that the <m-Adventure> platform provides the user with a quality Just-In-Time Learning, accessing the contents exactly when they are needed.

4.4 The Tracking and Assessment API

As it has been described in the previous three subsections, the <e-Adventure> family provides diverse solutions for game-based learning. Instructors will choose the more appropriate option according to the needs and preferences of the students and the learning context.

Using all these tools, it is possible to create diverse game-based materials for the same course, providing a scenario with various “learning paths”. However, those paths are disconnected, which brings some disadvantages to the instructors. It is not only the extra effort required to create the content of the different paths, but also how to coordinate them. From a pedagogical point of view instructors must check that, regardless of the learning path followed by the student, the learning goals are being attained successfully, a task which gets even harder when you have to pay attention to several game-based and web-based learning paths. Besides, instructors need to find a solution to problems such as the delivery and deployment of the games to the assorted platforms involved (mobile devices, desktop computers with different system features, etc.).

In <e-Adventure> these issues are addressed by providing a common API for assessment and tracking purposes. The API works as a middleware between the games and a LMS. In this manner, the game engine can be used to gather the results of the game; produce a detailed assessment report with partial or final grade according

to a set of assessment rules defined by the instructor; and, finally, send a machine-readable version of the report to the LMS to be attached to the profile of the student.

As it can be observed in Figure 3, the API manages the communication between a game being executed in the student's computer and the LMS. This means that the API needs to be implemented in both the server-side and the client side.

Some LMS already support the SCORM (*Sharable Content Object Reference Model*) set of specifications [2], promoted by the U.S. Department of Defense in order to unify how the educational contents are packaged, distributed and executed. In particular, SCORM defines a mechanism for the communication between active content and the server, allowing the content to submit information to the server such as the completion status of the content.

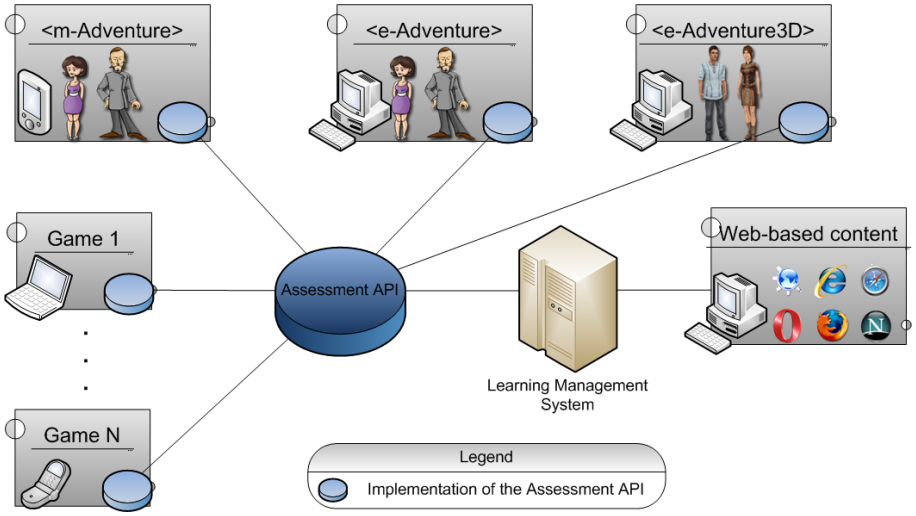

Fig. 3. Scheme of the communication between the elements of a heterogeneous game-based learning system through an assessment and tracking common API.

The API proposed in <e-Adventure> is based on SCORM's communication specifications. This means that, in those cases in which the server supports SCORM, there is no need of implementing the server-side of the API. On the other hand, if the target LMS is not SCORM-compliant, the server-side API must be implemented and connected to the LMS.

Regarding the client-side, all the products in the <e-Adventure> family implement the API. However, it should not be restricted to these platforms. The API is open and based on SCORM's communication specifications: the *IEEE Data Model for Content to Learning Management System Communication* [29] and the *IEEE ECMAScript API for Content to Runtime Services Communication* [30]. This means that an educational game developer can implement this API in other game engines, yielding a truly scalable approach that allows multiple kinds of games to be integrated in the same system.

5 1492: Case of Study of a Heterogeneous Game-based Learning System

In order to evaluate the Tracking and Assessment API and its educational advantages, we created a heterogeneous on-line game-based course, as it is described in this section. It must be noted that this case study focuses on testing and validating the flexibility and LMS compatibility of the tracking and assessment API. It is not our intent to compare the performance of the different game-based learning approaches, or to validate the very concept of game-based learning. As a consequence of the same arguments, the games implemented are just introduced in this section but the design and implementation details (usability, instructional design, development costs, etc.) are not in-depth analyzed; however, a brief explanation of the learning context is given to exemplify a possible scenario where the ideas presented in this paper could be applied.

5.1 Application Context and Target Audience

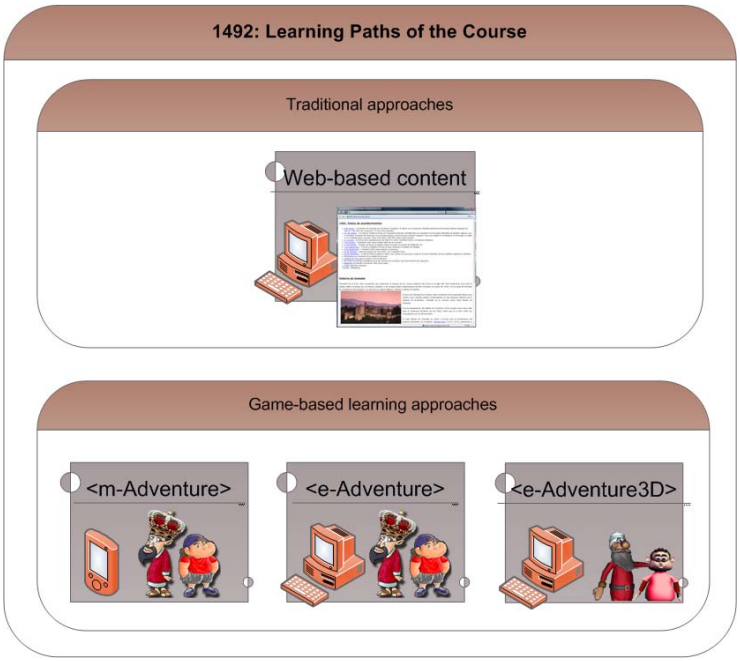

Fig. 4. Different materials (i.e. learning paths) of the heterogeneous game-based learning system.

Due to the narrative orientation of the <e-Adventure> games (which are really adequate for story-telling) we decided to focus the course on the Spanish History subject, present in almost all the years of the pre-higher Spanish educational system. Besides, the broad target audience was a solid reason in favour of a heterogeneous

system with different learning approaches in order to satisfy the prospects of most of the audience.

The contents of the course are diverse episodes of the Spanish History. In particular, one of the topics focuses on the events that happened in the year 1492, one of the most active and influential years in the beginnings of the Spanish Kingdom. Among the numerous events and changes experienced by the country in that year, two are considered to be especially important. First, 1492 is the year in which the alliance of northern kingdoms finished the conquest of the south regions they started centuries ago thanks to the capture of Granada. As a result, the Spanish Kingdom closed their main front of war and concentrated its attention in exploration, financing Columbus' expedition to America and starting the Imperialistic era of Spanish History. These events make this year a compulsory topic of discussion and study in all the Spanish History courses for students in primary and secondary school, making it an interesting topic for the game-based learning portion of the course.

5.2 General Structure and Materials of the Learning System

The game-based portion of the course is implemented as three distinct games covering the same topic: The Conquest of Granada in 1492. The story is set around a boy, Cristobalín, who is told by his history teacher to write an essay about the year 1492 to improve his knowledge of the subject. When the student starts reading for his essay he falls asleep, immersing in a dream where he relives the events leading to the Conquest of Granada.

Fig. 5. Screenshots of the <e-Adventure> (left) and <e-Adventure3D> (right) versions of the 1492 game.

Using all the products of the <e-Adventure> family, three different games were created: The original game –a 2D adventure game-, an improved and more appealing 3D adventure game and a simplified version for execution in mobile devices. In

addition, a web-based (more traditional) approach is also available for those students for which a game is not desirable.

The course was deployed in a LMS based on the open source tool Moodle [9]. In order to better illustrate that the approach is not restricted to SCORM-compliant environments (and given that SCORM support in Moodle is still an open issue), we extended the environment with a server-side implementation of the tracking and assessment API.

5.3 Description of the Learning Paths

The first learning path is based on a *point-and-click* adventure game developed with <e-Adventure> (Figure 5 left). The simplicity of these games and low technical requirements make it a good choice for most of the students trying to complement their knowledge of the subject at home with any or few guidance of the teacher.

The second alternative in the system is a 3D version of the first game developed with the <e-Adventure3D> platform (Figure 5 right). Basically the storyboard of the game is the same (the boy Cristobalín is told to produce a research essay about the year 1492), but enhanced with the possibilities offered by a 3D-based in-game world. This game could attract the attention of those students expecting something next to current commercial approaches. Probably this will be the choice for teenagers, which in many cases are used to play videogames more often in they free time.

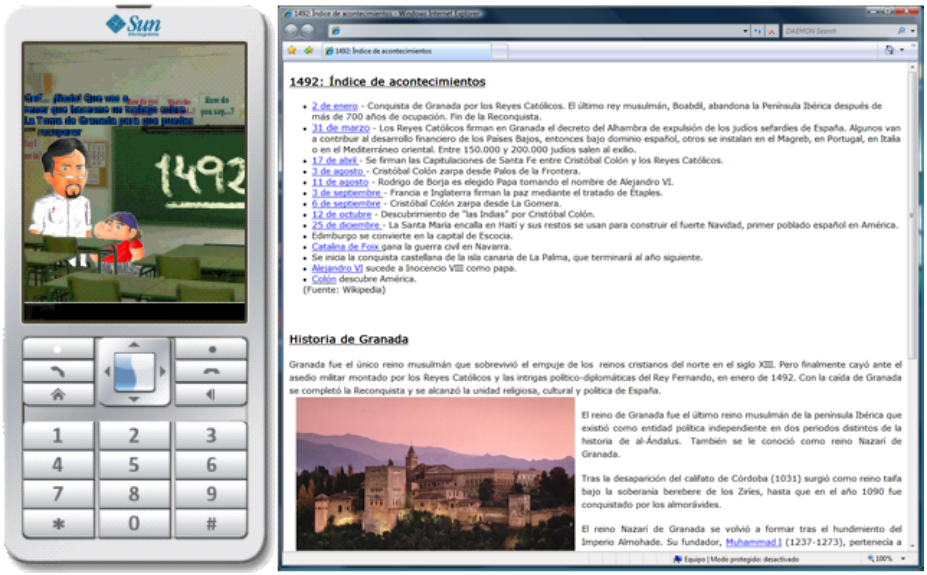

Fig. 6. <m-Adventure> version of 1492 (left) and a fragment of the web-based content of the course (right).

The third game-based approach is basically a mobile version of the <e-Adventure> platform. The purpose of this approach was to attract some young students who use

their mobile phones frequently and not only for making and receiving calls and messages, but for gaming as well (Figure 6 left).

Finally, the last learning path is a web-based alternative (Figure 6 right), more adequate for those students presenting difficulties in self-study and which perhaps would require further guidance instead of the freedom of interaction that a videogame provides. This last approach is basically a compilation of all the facts occurred on 1492 in Spain, gathered from diverse sources such as Wikipedia.

5.4 Assessing the Performance of the Students

The learning process in any of the four available paths is evaluated with a different test, adapted to the characteristics of each format.

The 2D version and the mobile version of the game include a final scene in which the student interacts with a virtual teacher, who asks a number of test questions about the content. The student answers using the multiple-response mechanism supported by the in-game conversations and the grade is computed. The 3D version uses a more sophisticated approach, computing a grade as the student plays the game. All the game versions, in addition to the grade, prepare a tracking report as indicated using the tracking features offered by the tracking mechanisms offered by the <e-Adventure> platforms as described in [24].

On the other hand, the traditional (web-based) version includes a typical multiple-choice test (with an additional free-text question) to be answered by the student within the system.

The grades computed through any of the three version of the game are processed by the Tracking and Assessment API, normalized, and submitted to the LMS.

The grades are stored in the LMS along with the traditional grades obtained by the students following the web-based path. When the instructor accesses the LMS to check the grades, all the student-grades are stored together (see Figure 7). The detailed tracking reports from the game versions are stored in the free-form text question from the traditional exam. This gives the instructors a unified interface to follow the progress of their students, regardless of the type of game they used to follow the content.

6. Conclusions and Future Work

Game-based learning is a very active and diverse field with promising educational benefits. However, due to the wide range of approaches, systems and target audiences there are some issues that need to be addressed.

In this paper we propose to deal with these inconveniences through an LMS. To connect the games with the LMS those need to implement a common Assessment API. In this manner games can track and evaluate the activity of the students according to the rules determined by the instructor, and produce an assessment report which is sent to the LMS. On its side, the LMS processes the report and attaches it to the profile of the student. In addition, this principle has been exemplified with the <e-

Adventure> family of platforms for the production of educational adventure games for diverse contexts and target audiences.

Fig. 7. Assessment record of the course in a Moodle LMS.

This approach guarantees the interoperability and scalability of the system, as any game or platform implementing the API could be introduced.

The SCORM-oriented approach taken when creating the Tracking and Assessment API means that several LMS will be almost automatically compliant with these games, although more research is required to systematize a process to widen the spectrum of different LMS which can communicate with the assessment API. We also intend to provide implementations of the client-side API for different popular game engines and platforms. According to this idea, a future line of research will be to develop a more refined communication layer not only for assessment but also for adaptation purposes, allowing in this manner that any standard LMS can communicate with any videogame implementing the common API in both directions.

The final objective of this line of research is to rationalize the use of games in education by providing a solid ground that allows these games to be introduced in pre-existing educational environments. In our view, the modern LMS can be the foundation on which to build game-based learning experiences. But the diversity of game-based learning approaches and the variety of competing LMS implementations

requires unification efforts. Our work tries to facilitate the interoperability, trying to allow any educational game to communicate with any LMS.

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