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Integration and Deployment of Educational Games in e-Learning Environments: The Learning Object Model Meets Educational Gaming

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ABSTRACT

Game-based learning is becoming popular in the academic discussion of Learning Technologies. However, even though the educational potential of games has been thoroughly discussed in the literature, the integration of the games into educational processes and how to efficiently deliver the games to the students are still open questions. This paper addresses the aspects of integration and automatic deployment of educational games in Learning Management Systems. This integration simplifies the introduction of games in educational settings, leveraging the pre-existing technological infrastructure. Our approach is based on the automatic packaging and exportation of games as self-contained Learning Objects that can be easily distributed through any LMS compliant with the current interoperability standards. We thus inherit the advantages of the Learning Object model in terms of interoperability and, when supported by the LMS, in terms of student tracking and assessment.

Keywords

Educational games, Learning Objects model, Learning Objects meta-data, Learning Management System interoperability

Introduction

Ever since videogames were born, they have been identified as potential learning tools (Malone 1981b; Malone 1981a). Since then, there has been a sustained academic discussion of their educational applicability (Leutner 1993; Rieber 1996; Papert 1998; Prensky 2001; Gee 2003; Mitchell and Savill-Smith 2004; Squire 2005; Michael and Chen 2006). This discussion has grown and evolved along with the maturity of the videogame industry, which has now become one of the most relevant businesses in the entertainment sector. After years of discussion and debate, the benefits of applying digital games, although lacking enough proof of the results sometimes (Hays 2005), have at least caught the attention of a great part of the academic community (Van Eck 2006). However, this does not mean that we are ready to massively adopt game-based learning in the educational system. The discussion has now moved on to other aspects such as pedagogically sound game design, student tracking and assessment, cost-effectiveness, and integration aspects (de Freitas and Oliver 2006; Van Eck 2006; Burgos et al. 2007b; Torrente et al. 2008a).

In this work, we will not be focusing on the strictly pedagogical aspects of game-based learning (referring interested readers to detailed literature reviews on the topic), but on some technical issues perceived as a barrier in the adoption of educational games that are hindering further research in this area. Two of these issues are how the games are delivered to the students and how to track the performance of the students in the game experience. A possible approach to tackle these issues is the integration of the games as a new type of content in e-Learning systems, thus taking advantage of the current widespread infrastructure provided by the modern Learning Management Systems (LMS). However, commercial videogames are difficult to deliver through these systems mostly due to their significant technological requirements (e.g. specific operative system or specific hardware) and due to an inherently complex distribution process. On the one hand, instructors need to address the packaging and distribution of games and, on the other hand, the students need to obtain the game, install it and then execute the game on their computers, which need to meet the technical requirements.

In this regard, the <e-Adventure> platform overcomes the technical issues related to installation, distribution and platform-dependency by providing an educational game engine that can be distributed via web (Moreno-Ger et al. 2008b) through the use of Java™ technologies. Although, the Java-based approach alleviates the interoperability and execution issues, it does not adequately address all the distribution issues that instructors have to face. The instructor still needs to cope with the integration in the educational process. For this reason we propose an approach that takes advantage of pre-existing e-Learning environments. This approach relies on the production of educational videogames as self-contained distributable Learning Objects (LO) following the principles of the LO model (Polsani 2003; Balatsoukas et al. 2008). This model envisions the learning contents as small self-contained objects that can then be combined in larger units (i.e. courses). In addition, there are standardized formats to store and distribute learning objects, allowing the content to be reused across platforms and contexts. This standardization guarantees the simplicity of the deployment of these contents in heterogeneous LMS.

Therefore the paper is structured as follows: firstly we discuss aspects related to the domains of e-Learning and educational gaming, as well as present some of the issues concerning their integration. Then we contextualize this contribution by analyzing related work. Finally, we describe the <e-Adventure> platform and how it facilitates the aforementioned integration, illustrating the process with a case study in which we test and analyze the integration of an <e-Adventure> game in some commercial and open source LMS.

E-Learning and Videogames

In this section we provide a general overview of both e-learning and educational gaming and discuss some issues that need to be addressed to simplify the use of games in education.

Current trends in online learning: developing standards and specifications to promote content interoperability

The e-Learning field is an industry on the rise that is beginning to be considered a mature technology. The initial excitement about the possibility of accessing content anytime and anywhere was hindered by simplistic e-learning systems that were essentially repositories with vast amounts of content and very basic facilities (e.g. management or communication) (Weaver 2002; Zemsky and Massy 2004). However, modern e-Learning systems are more comprehensive and try to mitigate the problems of the separation between students and instructors, such as the lack of motivation or the high drop-out rates. Modern Virtual Learning Environments, often labelled as Learning Management Systems (LMS), provide facilities for the interaction between instructors and students, detailed tracking of the students' progress, and a simple path for the delivery of content through the web. In addition, their use is getting more and more generalized in diverse contexts, not only as an alternative to face-to-face learning, but also as a rich complement (e.g. most universities are using an LMS to complement and support their lectures). This approach has been called b-Learning (Osguthorpe and Graham 2003; Garrison and Kanuka 2004).

However, as e-Learning has become an important aspect of many learning experiences, there is a broad range of competing platforms. Additionally, we cannot simply throw any kind of content at the students and expect them to learn. There is a need for high quality content, built with solid educational principles. This means that the authoring and maintenance costs for this content are becoming huge, and the variety of competing platforms may put the investment at risk if those expensive contents are not interoperable.

The Learning Object (LO) model (Polsani 2003; Balatsoukas et al. 2008) addresses these issues by proposing a development strategy of learning content based on self-contained pieces that can be assembled into courses, supported by standardized interchange formats to simplify the interoperability of contents among systems and avoid vendor lock-in. With this objective, the e-Learning arena has been immersed in a process of standardization and specifications development to support the interoperability between diverse LMS and content repositories.

Thus far, some specifications and standards are gaining acceptance in the e-learning market. Regarding the encapsulation of content, the effort carried out by the IMS Global Consortium has achieved a high impact with the IMS Content Packaging (IMS CP) specification (IMS Global Consortium 2004). The specification establishes a standardized format for the packaging and distribution of LO. According to the IMS CP specification, contents should be packaged in a zip file containing all the learning contents, along with a *manifest* file which provides information about the structure of the learning contents and additional information about how to deploy and deliver the content. Most of the commonly used LMS have facilities to import and export IMS CP contents, such as Moodle (Dougiamas and Taylor 2003), Sakai (Farmer and Dolphin 2005) or WebCT/BlackBoard (Goldberg and Salari 1997). This widespread adoption suggests that IMS CP can be taken as a preferred standard when it comes to packaging content.

In addition, the IMS CP specification is flexible and can be customized to specific scenarios through the so-called Application Profiles. One such profile is the Shareable Content Object Reference Model (SCORM) Content Aggregation Model (ADL 2006), created in the context of the Advanced Distributed Learning (ADL) initiative.

ADL SCORM not only covers the packaging of learning objects, but also provides a communication protocol between an LMS and the Learning Objects. This communication protocol allows the LMS to gather tracking and assessment information generated within the LO. In addition, the latest version of the ADL SCORM reference model introduces the concepts of Sequencing and Navigation (SCORM SN). SCORM SN allows content developers to create activity sequences and to define the interaction mechanisms to navigate through them. Thereby the interaction between the student and an LO can affect the sequencing process through the aforementioned communication mechanism (Gonzalez-Barbone and Anido-Rifon 2008).

This notion of having complex learning sequences that vary depending on the outcomes of the individual activities is also present in another IMS specification: IMS Learning Design (IMS LD) (IMS Global Consortium 2003). In IMS LD, the LOs are part of the *environments* provided to the student during the exposition of activities and their outcomes can affect future branching decisions during the learning experience.

On the other hand, in order to address the aspects of storage, search and retrieval of LOs in content repositories, content developers are encouraged to describe and annotate with metadata their LOs (Anido-Rifón et al. 2002). This annotation process also requires a standardization effort in order to define how the objects should be described. One of the most commonly used metadata specifications in this context is the IEEE Learning Object Meta-Data standard (IEEE 2002). This standard specifies a wide range of metadata that can be used to describe LO characteristics. The data is organized in categories concerning diverse aspects (general data, technical and educational features, etc.).

The potential of videogames for education

The academic interest in studying the educational potential of computer and videogames has rapidly increased in the last few years. The trend started with some seminal works about the relation between the motivation and engagement provided by games and learning, such as (Malone 1981a) or (Lepper and Cordova 1992). From these works, many authors have highlighted how games can keep people of different conditions focused and concentrated on a task during long periods of time. In fact, further studies about what make learning fun have identified aspects that are aligned with learning principles (Jenkins et al. 2003; Aldrich 2004; Becker 2007; Gee 2007), favoring the development of skills and competences rather than fact memorization.

However, as some recent meta-analyses and literature reviews (Hays 2005; Dondlinger 2007) reveal, the conclusions of the research on game-based learning are disparate. Although multiple authors identify signs to argue in favor of the benefits of this approach, its effectiveness has not been demonstrated thoroughly yet. Some researchers reached no significant conclusions, others could not prove game-based learning to be better than other instructional approaches, and others are some times questioned because of the methods used in their experiments (Hays 2005).

However, even if this line of research is still under discussion, there are enough evidences and cases of successful (past and present) applications of instructional videogames and game-like simulations in real contexts, which indicates a high interest in this approach (Aldrich 2004; Lunce 2006; Michael and Chen 2006; de Freitas and Jarvis 2007). From this perspective, the main objective of this work is not to further elaborate on the pedagogical discussion, but to study some of the technical issues that represent a barrier for the introduction of game-based learning initiatives in our educational processes. Reducing these barriers should facilitate further research about the specific educational values of game-based learning.

The problem of delivering the games

One of the main barriers that hinder the adoption of educational games is the complexity that they introduce in the learning process. While a lecture does not require any technology investment, videogames require up-to-date computers and controlled environments. Schools usually lack this kind of equipment: In a literature review on game-based learning presented in 2004, Kirriemur and McFarlane (2004) listed a number of concerns impeding the development of educational games including, among others, "*the almost total lack of video gaming equipment in schools, as opposed to home*s". Moreover, even when this kind of equipment is present in the schools, they usually lack the staff preparation and/or the time required to organize educational gaming sessions. Similarly, Rosas et al. (2003) identified as main issues preventing the use of game-based learning the resistance of teachers towards new technologies and the complexities of *edutainment* along with, again, the lack of technological infrastructure.

To tackle this aspect, an effective mechanism to distribute the games to the students would be to deliver them through a LMS. Delivering a game through a LMS is more effective than other approaches, like handing out CD-ROMs to the students in class or arranging in-school game sessions. Additionally, the tracking and assessment features of some modern LMS would give the instructor more power to control aspects of the learning experience such as when the students accessed the game, the time each student spent playing it and the outcomes of the game session. However, deploying a game in a LMS is still a complex task that demands specialized knowledge from instructors, as previously mentioned.

Another key issue is the philosophical difference between videogames and modern LMS, two completely different industries. On the one hand, e-Learning technologies have been developed around the web following a philosophy of interoperability between platforms, simplicity for the instructors, making contents available anytime and anywhere, etc. Modern LMS have been devised for the distribution of online courses that are mainly based on web contents (not only html documents but also richer formats such as PDF or multimedia resources) that are packaged and distributed according to a set of standards and specifications, as it was mentioned in the previous section.

On the other hand, commercial videogames are usually one of the most resource-consuming products of the software industry. As a proof of this claim, the videogame industry is pointed out because of the key role it plays in the promotion of technology (both hardware and software) innovation (Crandall and Sidak 2006). This fact, along with the inherently high development cost of commercial games (currently averaging in the range of $10M-$25M), forces developers to follow a design strategy in which runtime performance is a key aspect. Hence videogames are usually closed products, difficult to deploy in heterogeneous environments (videogames are rarely cross-platform), and hardly ever designed to be deployed directly from the web. That makes their integration in current LMS a big challenge.

Considering this, it is mandatory to find solutions for the development of educational videogames that can be easily integrated in online systems, and that follow the current trends in standardization described previously. For that purpose, we propose a simple methodology for the development of educational videogames targeted to web-based learning environments composed of two steps: First, we need to tackle the technological barrier between the e-Learning and videogames fields (i.e. produce web-oriented videogames). Then, we need to package, describe and deliver the games using the same standards and specifications that are currently being used in those web-based learning environments.

Related work

Game-based learning is a very broad field, with varied initiatives and heterogeneous approaches. An exhaustive analysis is beyond the scope of this work, but we will compare our approach with some initiatives that we consider especially relevant to the e-learning domain because they specifically address authoring or deployment issues.

Tools for the creation of educational videogames

Focusing on the instructors who demand the ability to create and modify their own games to suit their specific needs (Torrente et al. 2008b), there are some author-friendly environments specially oriented to facilitate the construction of videogames. Some examples are the initiatives led by *The Game Creators* (http://www.thegamecreators.com) a company that provides commercial authoring tools for the creation of all kinds of videogames at a reasonable cost. Perhaps their two most representative products are *The FPS Creator* (http://www.fpscreator.com) (an environment for the creation of First-Person-Shooter games with amazing results) and *The 3D Game Maker* (http://t3dgm.thegamecreators.com). In this line, most products are focused on a single game genre which simplifies both the cost of the tool and the complexity of its use. Probably the most represented genres are adventure games and interactive fiction, represented by tools like *Adventure Maker* (http://www.adventuremaker.com) or *ADRIFT* (http://www.adrift.org.uk/cgi/new/adrift.cgi). Some examples of more complex tools (probably beyond the skill level of most instructors, but which still simpler than fully-featured programming environments) would be projects like *Mission Maker* (http://www.immersiveeducation.com/MissionMaker) or *Alice* (http://www.alice.org), both specifically purposed for education.

Integrating games into learning experiences

There is also some existing research about how to deliver educational videogames and game-based simulations. Given that most studies are focused on studying the pedagogical aspects, few works actually reflect on the mechanisms for delivering the games to the students.

The problem of delivering the games is, in fact, closely related to the integration of these games with other learning contents (traditional materials or other educational games) in bigger courses. In this line, some interesting approaches have been proposed, relying on game-based environments (which are usually friendly for students) not only for playing, but also as interfaces for browsing other materials (Chao 2001; Christoffel and Schmitt 2002). For instance, *Quest Atlantis* (Barab et al. 2005) is a 3D multi-user environment mostly used to immerse children (ages 9-15) combining educational gaming with other lessons defined by teachers. The environment supports large courses in the form of *quests* that the student must accomplish by carrying out diverse tasks (game-based and not game-based) without leaving the game world. *River City* (Ketelhut et al. 2006) follows a similar pattern. However, these approaches are self-contained and are not focused on the reuse of the learning content produced.

Focusing on the delivery of games as Learning Objects, the proposal in (Burgos et al. 2007b) contemplates the inclusion of the games in IMS Learning Design-based Units of Learning (Koper and Tattersall 2005), which is a very similar approach to our proposal. However, it does not contemplate the encapsulation of the games themselves as self-contained Learning Objects for their direct deployment in e-Learning environments or their individual storage in content repositories. The games are described as *activities* within the Unit of Learning. Thus these works should be complemented with the proposal of more fine-grained packaging and annotation mechanisms for individual games, which should facilitate the actual integration of the games into those game-based Units of Learning. In addition both works are also complementary in terms of enabling the games to affect the behaviour of the learning experience. In their work, Burgos et al. identify as a key unsupported feature the possibility of allowing the outcomes of the games to affect the inner state of the Unit of Learning that is used to make branching decisions.

Production of educational videogames as Learning Objects: the <e-Adventure> platform

The <e-Adventure> platform is an environment for the development of educational *point-and-click* adventure videogames that addresses the technical and distribution issues described previously, covering both the development (and maintenance) of the games and their execution (Moreno-Ger et al. 2008a). As stated previously, we propose to develop educational videogames as web content in order to facilitate the delivery of the games to the students through online LMS. To facilitate this process, the <e-Adventure> platform was developed using *Java*^{TM} technologies, which were designed bearing in mind their application in web environments.

In order to reduce the technical requirements of the games and retain both student interest and educational value, the genre of *point-and-click* adventure games was chosen. The low technical complexity of these games does not imply an excessive reduction in the advantages of using videogames in education, as the genre supports all the features that are relevant from an educational point of view and still manages to provide a fun approach to learning (Ju and Wagner 1997; Van Eck 2007). Besides, narration is a key aspect of adventure games, which can be used effectively from an instructional point of view (Dickey 2006).

Development of <e-Adventure> games as Learning Objects

However, as previously mentioned, the creation of web-deliverable learning objects is just one half of the problem. Game-based content is complex and expensive to produce, and this increases the need of interoperability between different learning platforms. For this reason, <e-Adventure> games can be exported as self-contained Learning Objects (LO) following the IMS Content Packaging specification (IMS Global Consortium 2004). The process is straightforward: instructors use the <e-Adventure> editor to create and modify the game and then the editor offers the possibility of exporting the executable game as a LO.

Additionally, following the notion of active LOs that exchange information with the LMS for tracking and assessment purposes, <e-Adventure> games can communicate at runtime with the LMS host. Whenever an <e-Adventure> game is launched, the game engine tests if it is possible to communicate with the host LMS (Martinez-Ortiz et al. 2006). If the test is successful, the game engine periodically communicates with the LMS notifying any value update of a ser of educational properties defined during the creation of the game by the instructor. If no communication link can be established, the engine works in a disconnected mode.

<e-Adventure> games support two protocols for the communication with the LMS host. The first approach is to use the IEEE ECMAScript API for Content to Runtime Services Communication (Richards 2004). If this protocol is not supported by the LMS, the engine also tries to establish a link using an *ad hoc* protocol developed as part of the <e-Adventure> platform. The standardized approach uses the same set of specifications as the ADL SCORM reference model, thus being compatible with SCORM-compliant LMS. On the other hand, the proprietary protocol was developed to enable the communication with IMS Learning Design (IMS Global Consortium 2003) environments, and has been successfully tested with the CopperCore IMS LD (Burgos et al. 2007a) and the .LRN platform (Moreno-Ger et al. 2008a).

The aspect of allowing the annotation of the LO with technical and educational metadata is covered according to the IEEE Learning Object Metadata (IEEE 2002) standard. Due to the scope of the <e-Adventure> editor, the objective was not to provide a full IEEE LOM editor. Instead, we have focused on a minimal subset of the standard that fits game-based educational contents. Special attention has been given to those categories we considered more relevant in this context: Educational metadata and technical characteristics. Table 1 summarizes the different categories from the IEEE LOM standard directly supported inside the editor.

Table 1. Subset of IEEE LOM elements supported as meta-data in <e-Adventure>, adapted from the original specification

Category	Element	Explanation
1. General	1.2. Title	Name given to this LO
	1.3. Language	The primary human language of the content (e.g. en_EN)
	1.4. Description	A textual description of the content of this LO
	1.5. Keyword	A keyword or phrase describing the topic
2. Life Cycle	2.1. Version	The version of this LO
4. Technical	4.4. Requirement	Technical capabilities necessary for using this LO
	4.4.1.3.Min Version	Lowest version of the <e-Adventure> engine required
	4.4.1.4. Max. Version	Highest version of the <e-Adventure> engine supported
5. Educational	5.1. Interactivity Type	Predominant learning mode (active, expositive or mixed)
	5.2. Learning Resource Type	Specific kind of LO (exercise, simulation, exam, self-assessment or lecture)
	5.3. Interactivity Level	The degree of interactivity characterizing this LO (very low, low, medium, high or very high)
	5.4. Semantic Density	The degree of conciseness of the LO (very low, low, medium, high or very high)
	5.5. Intended End User Role	Principal user(s) for which this LO was designed (teacher, author, learner or manager)
	5.6. Context	The principal environment of application (school, higher education, training or other)
	5.7. Typical Age Range	Age of the typical intended user.
	5.8. Difficulty	How hard it is to work with or through this LO (very easy, easy, medium, difficult or very difficult)
	5.9. Typical Learning Time	Approximate or typical time it takes to work with or through this LO (duration in hours and minutes)
	5.10. Description	Comments on how this LO is to be Used
	5.11. Language	The primary human language of the content (set with 1.3)

In order to simplify as much as possible the work of the content author, the metadata annotation process is done in a semi-automatic way. The <e-Adventure> editor harvests as much as possible metadata from the game description simplifying the instructor’s task. All the technical metadata are also automatically generated, and the instructor can focus on the definition of metadata related to educational aspects.

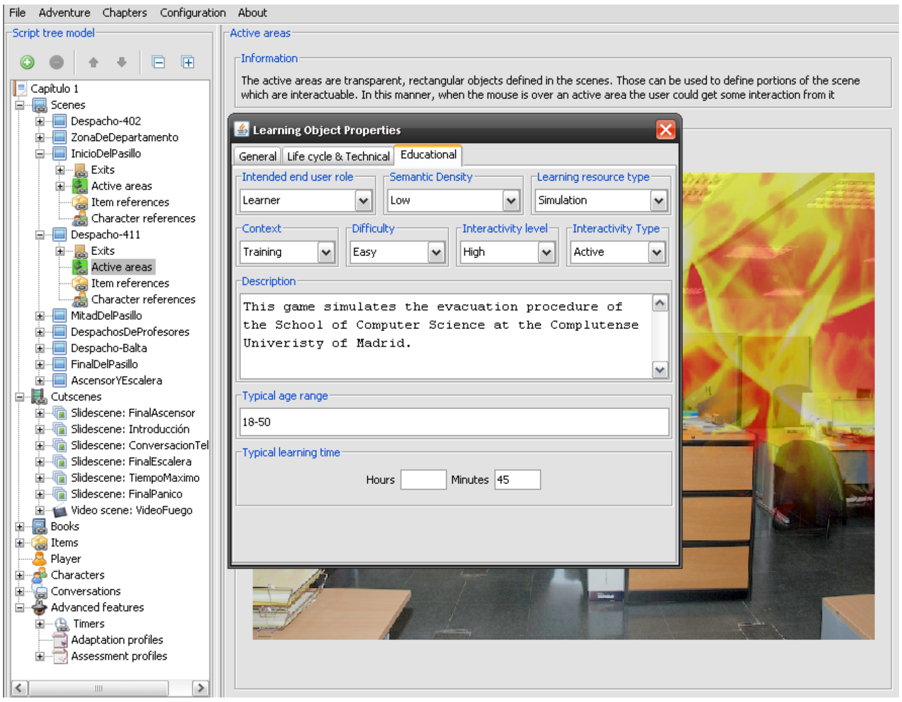

Figure 1. Screenshot of the annotation with IEEE LOM metadata in <e-Adventure>

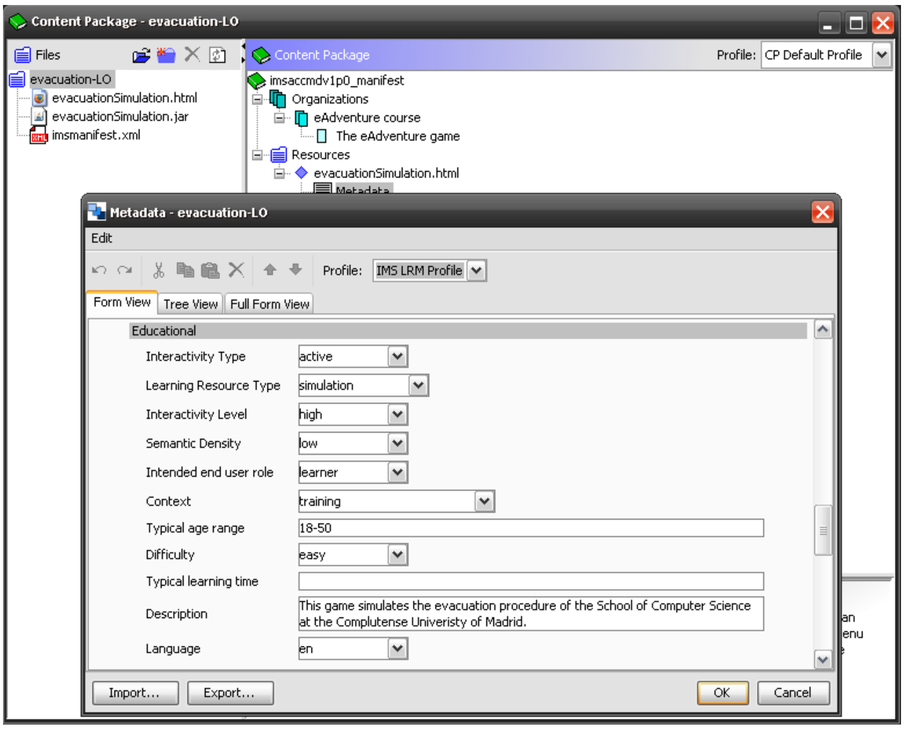

Figure 2. Screenshot of an <e-Adventure> LO package loaded in the Reload Editor application, displaying part of its metadata section

The exportation process of the game creates a minimal self-contained LO. The instructor uses the editor to create an IMS CP bundle that includes: the game itself (including assets), its metadata, a streamlined version of the <e-Adventure> game engine, a simple html page used to launch the game and a *manifest* file used to describe the bundle content. The generated LO contains a single course with a single educational resource (the game), however the LO may be refined or integrated with larger courses using tools that comply with the selected specifications. For example, as seen in *Figure 2*, the LO can be edited using the Reload Editor (http://www.reload.ac.uk), which allows its integration with bigger pre-existing courses and or refinement of the original metadata included by the <e-Adventure> platform.

In summary, with <e-Adventure> it is possible to package the games according to the IMS CP specification and annotated with meta-data following the IEEE LOM standard. The result is a shareable and reusable educational videogame packed as an LO and ready to be deployed in any IMS-compliant LMS. In the next section, we analyze the actual level of compliancy and how this approach facilitates the deployment and delivery process for educational games.

Case Study

In order to test the compliancy of the proposed solution in terms of content interoperability, we have conducted a local case study focused on the problem of game delivery through different LMSs. Additionally, the possibility of having a connection established between the games and the LMS and using that communication channel to exchange tracking and assessment information has also been evaluated. The objectives were thus the following:

1. To test the successful integration of a real <e-Adventure> game in a broad sample of LMS as a) a single-content course and b) a complex course combining both game content and traditional (i.e. web-based) content.
2. To test the compliancy of the automatic assessment engine in the same sample of LMS (i.e. determine which LMS could successfully process the statement of results produced by the game and attach it to the profile of the student to be used in the future).

On the other hand, it was required to specify selection criteria to determine which LMS would be selected to take part in the test in a manner that the results obtained could be significant. Covering every single available LMS was deemed impossible, as new tools are emerging constantly. We made a selection covering some widely extended open source tools and complemented it with commercial products such as the two versions of BlackBoard's WebCT currently being used in our university: WebCT versions 4 and 6. We also tried to make special emphasis on tools that currently support communication with interactive LO using either the ADL SCORM reference model or the IMS Learning Design specification. The complete list of evaluated products can be found in Table 2.

For each individual LMS we performed three different tests: The first test was the deployment of an <e-Adventure> game embedded in a web document without any attention to specific standards. In order to reflect the usual skill set of instructors and, in most cases, their actual access rights, this integration should be possible using the LMS interface, instead of requiring an FTP connection to upload the contents or any form of server-side modification. The second test was the deployment of the game as a standardized LO packaged according to the IMS Content Packaging specification. Finally, we also reported on the possibility of establishing a communication link between the game and the LMS, using any of the two communication protocols supported by the <e-Adventure> platform.

Presentation and discussion of the results obtained

The next table (Table 2) summarizes the results obtained in all the tests performed. For each LMS the table depicts if it was possible to deploy the LO as a single web document (column 2), into a structured course according to the IMS CP specification (column 3) and if the automatic assessment mechanism worked properly (column 4).

As the table shows, the standardized LO could be successfully deployed in all the LMS, but in some cases the integration of the game "as is" was not possible without low-level access to the server given the way in which some systems treat the inclusion of files and/or downloads (CopperCore/SLeD is a special case, given that by design they do not support content that is not part of a standardized Unit of Learning). This highlights the importance of packaging the games according to the current standards and specifications. Both CopperCore (with the SLeD frontend) and .LRN (with its IMS-LD module (Escobedo del Cid et al. 2007)) can establish a communication link using the proprietary protocol defined in <e-Adventure> and special plug-ins. With LAMS it is also possible to establish a proprietary communication link.

Table 2. Summary of the results obtained in the integration and deployment process of the LO-game in the diverse LMS

Environment	Web document	Standard LO	Tracking support
CopperCore / SLeD	N/A	Yes	Proprietary protocol
LAMS	Yes	Yes	Proprietary protocol
.LRN	No	Yes	Proprietary protocol
Moodle	Yes	Yes	SCORM 1.2
Sakai	Yes	Yes	Experimental SCORM 2004 support
WebCT 4	No	Yes	No
WebCT 6	No	Yes	SCORM 1.2

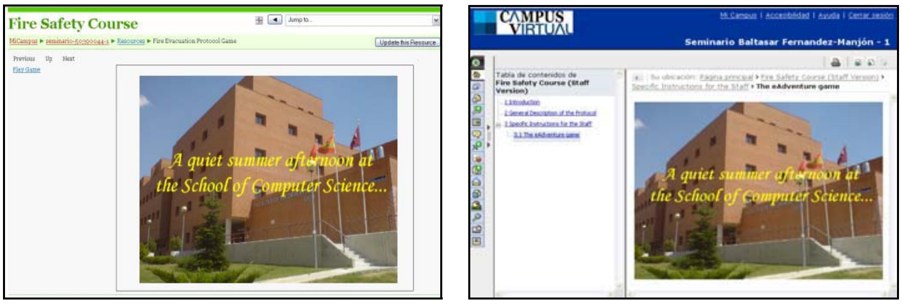

Figure 3. Screenshots of the sample game deployed in Moodle (left) and WebCT (right)

Applications

As described in the previous subsection, the main objective of the experiment was to test the integration of <e-Adventure> games in educative contexts through their deployment in LMS as LOs. The available systems are in constant evolution, and so are the needs of the application environments. It is not uncommon to see an institution that changes the technology of their LMS, for example alternating between proprietary and open source tools.

Having observed poor performance during an evacuation drill, the Dean's Office at the School of Computer demanded an investigation to identify and improve all the issues identified during the drill and the implementation of a training program to ensure both staff and students know the evacuation protocol. However this is not an issue easy to address. Memos about how to proceed in these evacuations have been proved useless in the past because most people simply do not take the time to read the instructions, and fire safety briefings for personnel or students register low attendance rates. For that reason we developed a low-cost game-like simulation of the evacuation procedure using <e-Adventure> (Moreno-Ger et al. 2008a) as a mechanism to capture both staff and student attention.

Figure 4. Screenshots of the evacuation procedure game-like simulation implemented with the <e-Adventure> platform

This case exemplifies the problem of how to deliver educational videogames to the students that has been described all along the paper. The high number of users of the game difficulties its delivery through a traditional delivery channel (e.g. through CD-ROMs). To tackle this issue, the game is to be delivered through the LMS currently available at Complutense University, which is based on WebCT 4. All the teachers, staff and students have access to this system, so it could be a good controlled distribution channel for the game.

However, the university is currently considering alternative systems to cover the online support for the courses. Apart from a potential upgrade of the current WebCT platform, different open source tools are also being considered (such as *Moodle* and *SAKAI*). As the results of our test show, the investment in the development of the game is safe regardless of the final decision, as the game can be seamlessly integrated with any of the environments currently being considered.

Conclusions

So far, the research community broadly accepts the potential benefits of educational videogames, even when such benefits have not been properly and empirically demonstrated yet. However, the actual application of educational videogames is limited due to a number of factors, including the difficulty of integrating the games into ongoing educational processes (McFarlane et al. 2002; Kirriemur and McFarlane 2004). Our proposal is to take advantage of the current LMS infrastructure and their instructor-oriented content deployment tools, following the Learning Objects Model supported by standards and specifications.

As the case study proves, using the <e-Adventure> platform for the creation of educational *point-and-click* adventure games packaged as IMS-CP Learning Objects instructors can successfully deploy the games in several of the LMS with more extended use. The packaging effort is very low (just select the appropriate option on the <e-Adventure> editor) and the deployment is straightforward using the content importation facilities of most LMS. Therefore the games can be easily delivered to the students without requiring additional installation and deployment efforts as it was the case in some of the examples mentioned in the related work section.

Additionally, in some environments it is possible to use the communication between the LMS and the game engine to produce an automatic evaluation of the activity within the game and attach it to the profile of the student. However the results of the case study suggest that the compatibility degree with ADL SCORM must be taken into account when considering this approach. Most systems offer different degrees of compatibility with this reference model, although most systems only comply with SCORM 1.2. In terms of tracking and assessment, this means that the LMS can gather data submitted from the games, but cannot use it to affect sequencing decisions. In contrast, the environments that use the proprietary communication protocol or SCORM 2004 can get more value from this information.

In addition, the approach also facilitates the integration of the games with other LOs containing web-based content (using the deployment tools of LMS or standards-compliant content authoring tools like the *Reload Editor*). This could be used to create mixed courses (combining games and other content) which has an important application potential, for instance to provide alternative paths to students that would not benefit from a pure game-based learning approach (Torrente et al. 2008a). However, an interesting alternative not explored in this study is how to connect diverse games in the same course, in a manner that the results of a game could affect the behaviour of the next one, thus supporting the creation of complex courses as game-based trees. A priori, such connection between games could be achieved acting the LMS as intermediary by using the assessment engine and the adaptation mechanism described in (Moreno-Ger et al. 2007). Nonetheless this has not been empirically tested yet and further research should be conducted.

The proposed approach does not force educational institutions to install any specific software, as it takes advantage of the existing LMS infrastructure. In addition, this approach promotes reusability of contents, protecting the investment against possible LMS replacements. On the other hand, the educational videogames produced can be stored in public LO repositories to promote the exchange of contents. We are thus inheriting all the benefits of the LO model.

Next steps in the project are to test the educational outcome of using games and simulations in an actual University course. We are currently collaborating with researchers from the Complutense School of Medicine to create educational games to support the practical exercises performed by the first and second year students. The games will be delivered to the students through the Complutense's e-Learning environment (Virtual Campus), integrated with the rest of the online content that supports the corresponding subjects.

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References

ADL (2006). *Advanced Distributed Learning Sharable Content Object Reference Model (ADL-SCORM)*, Retrieved January 28, 2009 from http://www.adlnet.gov/.

Aldrich, C. (2004). *Simulations and the Future of Learning: An Innovative (and Perhaps Revolutionary) Approach to e-Learning*, San Francisco, CA: Pfeiffer.

Anido-Rifón, L., Fernández, M. J., Caeiro, M., Santos, J. M., Rodríguez, J. S., & Llamas, M. (2002). Educational metadata and brokerage for learning resources. *Computers & Education, 38* (4), 351-374.

Balatsoukas, P., Morris, A., & O'Brien, A. (2008). Learning Objects Update: Review and Critical Approach to Content Aggregation. *Educational Technology & Society, 11* (2), 119-130.

Barab, S., Thomas, A., Dodge, M., Carteaux, R., & Tuzun, H. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development, 53* (1), 86-108.

Becker, K. (2007). Pedagogy in Commercial Video Games. In D. Gibson, C. Aldrich & M. Prensky (Eds.), *Games and Simulations in Online Learning: Research and Development Frameworks*, Hershey, PA: Information Science, 21-47.

Burgos, D., Moreno-Ger, P., Sierra, J. L., Fernández-Manjón, B., & Koper, R. (2007a). Authoring Game-Based Adaptive Units of Learning with IMS Learning Design and <e-Adventure>. *International Journal of Learning Technologies, 3* (3), 252-268.

Burgos, D., Tattersall, C., & Koper, R. (2007b). Re-purposing existing generic games and simulations for e-learning. *Computers in Human Behaviour, 23* (6), 2656-2667.

Crandall, R. W., & Sidak, J. G. (2006). *Video Games: Serious Business for America's Economy,* Entertainment Software Association Report, Retrieved January 28, 2009, from http://www.theesa.com/newsroom/seriousbusiness.pdf.

Chao, D. (2001). Doom as an interface for process management. *Proceedings of the SIGCHI conference on Human factors in computing systems*, New York: ACM, 152-157.

Christoffel, M., & Schmitt, B. (2002). Accessing Libraries as Easy as a Game. *Lecture Notes in Computer Science, 2539*, 25-38.

de Freitas, S., & Jarvis, S. (2007). Serious games - Engaging Training Solutions: A Research and Development Project for Supporting Training Needs. *British Journal of Educational Technology, 38* (3), 523-525.

de Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & Education, 46* (3), 249-264.

Dickey, M. D. (2006). Game Design Narrative for Learning: Appropriating Adventure Game Design Narrative Devices and Techniques for the Design of Interactive Learning Environments. *Educational Technology Research and Development, 54* (3), 245-263.

Dondlinger, M. J. (2007). Educational Video Game Design: A Review of the Literature. *Journal of Applied Educational Technology, 4* (1), 21-31.

Dougiamas, M., & Taylor, P. (2003). Moodle: Using Learning Communities to Create an Open Source Course Management System. *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Chesapeake, VA: AACE, 171-178.

Escobedo del Cid, J. P., de la Fuente Valentín, L., Gutiérrez, S., Pardo, A., & Delgado Kloos, C. (2007). Implementation of a Learning Design Run-Time Environment for the .LRN Learning Management System. *Journal of Interactive Media in Education, 2007* (07), Retrieved January 28, 2009, from http://www-jime.open.ac.uk/2007/07/.

Farmer, J., & Dolphin, I. (2005). Sakai: eLearning and More. *Proceedings of the 11th European University Information Systems (EUNIS 2005)*, Manchester, UK, 22-27.

Garrison, D. R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *Internet and Higher Education, 7* (2), 95-105.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*, New York: Palgrave Macmillan.

Gee, J. P. (2007). *Good videogames and good learning: collected essays on video games*, New York: Peter Lang.

Goldberg, M. W., & Salari, S. (1997). An Update on WebCT (World-Wide-Web Course Tools) - a Tool for the Creation of Sophisticated Web-Based Learning Environments. *Proceedings of NAUWeb '97 - Current Practices in Web-Based Course Development,* June 12-15, Flagstaff, AR, USA.

Gonzalez-Barbone, V., & Anido-Rifon, L. (2008). Creating the first SCORM Object. *Computers & Education, 51* (4), 1634-1647.

Hays, R. T. (2005). *The effectiveness of instructional games: a literature review and discussion*, Naval Air Warfare Center Report, Retrieved 28 January, 2009, from http://adlcommunity.net/file.php/36/GrooveFiles/Instr_Game_Review_Tr_2005.pdf.

IEEE (2002). *IEEE Standard for Learning Object Metadata,* Retrieved 28 January, 2009, from http://ltsc.ieee.org/wg12/index.html.

IMS Global Consortium (2003). *IMS Learning Design Specification, Version 1.0 Final Specification*, Retrieved January 28, 2009 from http://www.imsproject.org/learningdesign/index.html.

IMS Global Consortium (2004). *IMS Content Packaging Specification, Version 1.1.4 Final Specification*, Retrieved January 28, 2009 from http://www.imsglobal.org/content/packaging/index.html.

Jenkins, H., Klopfer, E., Squire, K., & Tan, P. (2003). Entering the Education Arcade. *ACM Computers in Entertainment, 1* (1), 17-17.

Ju, E., & Wagner, C. (1997). Personal computer adventure games: Their structure, principles and applicability for training. *The Database for Advances in Information Systems, 28* (2), 78-92.

Ketelhut, D. J., Dede, C., Clarke, J., & Nelson, B. (2006). A multi-user virtual environment for building higher order inquiry skills in science. *American Educational Research Association Conference*, San Francisco, CA, USA.

Kirriemur, J., & McFarlane, A. (2004). *Literature review in games and learning,* NESTA Futurelab Report, Retrieved January 28, 2009, from http://www.futurelab.org.uk/resources/publications-reports-articles/literature-reviews/Literature-Review378/

Koper, R., & Tattersall, C. (2005). *Learning Design - A Handbook on Modelling and Delivering Networked Education and Training*, Heidelberg: Springer Verlag.

Lepper, M. R., & Cordova, D. I. (1992). A desire to be taught: Instructional Consequences of Intrinsic Motivation. *Motivation and Emotion, 16*, 187-208.

Leutner, D. (1993). Guided discovery learning with computer-based simulation games: Effects of adaptive and non-adaptive instructional support. *Learning and Instruction, 3* (2), 113-132.

Lunce, L. (2006). Simulations: Bringing the benefits of situated learning to the traditional classroom. *Journal of Applied Educational Technology, 3* (1), 37-45.

Malone, T. (1981a). Toward a Theory of Intrinsically Motivating Instruction. *Cognitive Science, 5* (4), 333-369.

Malone, T. (1981b). What makes computer games fun? *Byte, 6* (12), 258-276.

Martinez-Ortiz, I., Moreno-Ger, P., Sierra, J. L., & Fernández-Manjón, B. (2006). Production and Deployment of Educational Videogames as Assessable Learning Objects. *Lecture Notes in Computer Science, 4227*, 316-330.

McFarlane, A., Sparrowhawk, A., & Heald, Y. (2002). *Report on the educational use of games*, Retrieved January 28, 2009, from http://www.teem.org.uk/publications/teem_gamesined_full.pdf.

Michael, D., & Chen, S. (2006). *Serious Games: Games that Educate, Train, and Inform*, Boston, MA: Thomson.

Mitchell, A., & Savill-Smith, C. (2004). *The Use of Computer and Videogames for Learning: A Review of the Literature*. Trowbridge, Retrieved January 28, 2009, from http://www.lsda.org.uk/files/PDF/1529.pdf.

Moreno-Ger, P., Blesius, C., Currier, P., Sierra, J. L., & Fernández-Manjón, B. (2008a). Online Learning and Clinical Procedures: Rapid Development and Effective Deployment of Game-Like Interactive Simulations. *Lecture Notes in Computer Science, 5080*, 288-304.

Moreno-Ger, P., Burgos, D., Sierra, J. L., & Fernández-Manjón, B. (2008b). Educational Game Design for Online Education. *Computers in Human Behavior, 24* (6), 2530-2540.

Moreno-Ger, P., Sancho Thomas, P., Martínez-Ortiz, I., Sierra, J. L., & Fernández-Manjón, B. (2007). Adaptive Units of Learning and Educational Videogames. *Journal of Interactive Media in Education, 2007* (05), Retrieved January 28, 2009, from http://www-jime.open.ac.uk/2007/05/.

Osguthorpe, R. T., & Graham, C. R. (2003). Blended learning environments: Definitions and directions. *The Quarterly Review of Distance Education, 4* (3), 227-233.

Papert, S. (1998). Does Easy, Do It? Children, Games, Learning. *Game Developer Magazine, June*, 87-88.

Polsani, P. (2003). Use and Abuse of Reusable Learning Objects. *Journal of Digital Information, 3* (4), Retrieved January 28, 2009, from http://jodi.tamu.edu/Articles/v03/i04/Polsani/.

Prensky, M. (2001). *Digital Game Based Learning*, New York: McGraw-Hill.

Richards, T. (2004). *IEEE Standard for Learning Technology - ECMAScript API for Content to Runtime Services Communication*, Retrieved January 28, 2009, from http://www.ieeeltsc.org/standards/1484-11-2-2003.

Rieber, L. P. (1996). Seriously considering play: Designing Interactive Learning Environments based on the Blending of Microworlds, Simulations and Games. *Educational Technology Research and Development, 44* (2), 43-58.

Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., Grau, V., Lagos, F., López, X., López, V. n., Rodriguez, P., & Salinas, M. (2003). Beyond Nintendo: design and assessment of educational video games for first and second grade students. *Computers & Education, 40* (1), 71-94.

Squire, K. (2005). *Game-Based Learning: An X-Learn Perspective Paper,* MASIE center: e-Learning Consortium Report, Retrieved January 28, 2009, from http://www.masieweb.com/research-and-articles/research/game-based-learning.html.

Torrente, J., Moreno-Ger, P., & Fernández-Manjón, B. (2008a). Learning Models for the Integration of Adaptive Educational Games in Virtual Learning Environments. *Lecture Notes in Computer Science, 5093*, 463-474.

Torrente, J., Moreno-Ger, P., Fernández-Manjón, B., & Sierra, J. L. (2008b). Instructor-oriented Authoring Tools for Educational Videogames. *Proceedings of the 8th International Conference on Advanced Learning Technologies*, Los Alamitos, CA: IEEE Computer Society, 516-518.

Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. *EDUCAUSE Review, 41* (2), 16-30.

Van Eck, R. (2007). Building Artificially Intelligent Learning Games. In D. Gibson, C. Aldrich & M. Prensky (Eds.), *Games and Simulations in Online Learning: Research and Development Frameworks*, Hershey, PA: Information Science, 271-307.

Weaver, P. (2002). Preventing e-learning failure. *Training and Development, 56* (8), 45-50.

Zemsky, R., & Massy, W. (2004). *Thwarted Innovation: what happened to e-learning and why*, A report for The Weatherstation Project of The Learning Alliance at the University of Pennsylvania, Retrieved January 28, 2009, from http://www.irhe.upenn.edu/Docs/Jun2004/ThwartedInnovation.pdf.