Deploying and Debugging Educational Games Using e-Learning Standards

Ángel del Blanco, Javier Torrente, Ángel Serrano, Iván Martínez-Ortiz, Baltasar Fernández-Manjón
Complutense University of Madrid
School of Computer Science, Department of Software Engineering and Artificial Intelligence
C Profesor José García Santesmases sn, 28040 Madrid, Spain
{angel.dba, jtorrente}@fdi.ucm.es, aserrano@e-ucm.es, {imartinez, balta} @fdi.ucm.es

Abstract—**Development, packaging and deployment of educational games following e-Learning standards has benefits, such as improved reusability and interoperability of contents. Moreover, standards can facilitate that games exchange data with other software agents (e.g. Learning Management Systems - LMS) in a standardized manner, which opens up a wide range of possibilities for next generation Game-Based Learning experiences. However, the application of standards to games poses a technical challenge. There is a clear need for tools that simplify this process for teachers and educators with limited technical background. In this paper we present how the <e-Adventure> platform is addressing this problem, with special focus in the exchange of data to/from the games. Tools being developed for facilitating packaging, deployment and debugging of educational games with standards are described. On the one hand, these tools facilitate testing and debugging since they allow simulation of game deployment with active communication without needing a back-end LMS. On the other hand, they smooth the learning curve that is needed to understand the standards and their possibilities when combined with games. Finally a case study focusing on the SCORM standard is presented.**

Keywords-<e-Adventure>; educational games; SCORM; standards.

I. INTRODUCTION

Current research in e-Learning is now trying to determine new ways to use serious games for education that take advantage from all their potential, assuming that their value as learning tools is no more under discussion, thanks to recent works in the field [1-4].

In this line, there is interest in exploring the application of e-Learning standards to educational games [5], [6]. Publishers, teachers and educational organizations can expect benefits from development, packaging and deployment of educational games following e-Learning standards, like the improved reusability and interoperability of Game-Based learning courses, protecting the investments in contents that are expensive to produce compared to other materials [7].

There are also works pushing this research line forward by addressing the active communication between games and Learning Management Systems (e.g. Moodle, Sakai or Blackboard) [8], [9]. The argument is that as games are highly interactive, they can be used for student tracking and assessment, if they are connected to a back-end (LMS) that allows educators to access the information. Also the games can use relevant data that is available in the LMS (e.g. student profile and achievements) to improve the game experience. For these purposes educational gaming stakeholders can profit from standards like ADL SCORM, that specify communication protocols and data models between contents and LMS, thus investment is still protected.

But e-Learning standards are technically complex, especially if they also address active communication like SCORM. To fully exploit these opportunities, teachers, educators and other stakeholders need specialized tools that simplify packaging, deployment, debugging and testing the educational games with standards.

This paper is structured as follows: section II provides a brief overview of current research in games and e-Learning standards. Section III introduces the <e-Adventure> game authoring platform, its current compliance with e-Learning standards (e.g. IMS Content Packaging [10], ADL SCORM v1.2 and 2004 [11]), and integrated tools for testing and debugging game deployment with communication. Section IV exemplifies these ideas through a case study. Finally section V provides conclusions and future work.

II. EDUCATIONAL GAMES AND E-LEARNING STANDARDS

Section II.A provides a short introduction to recent research in the field of educational games. This section is linked to II.B, which covers the e-Learning standards that are particularly relevant to the reuse of educational games.

A. Educational Games

The interest in the application of digital games to education is not new, with first experiences and seminal works dating from the 70's and 80's [12], [13]. However, it has grown exponentially in the last decade, both at research and market levels, aiming at providing students with more attractive, engaging and meaningful content.

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Although using games for education does not always mean an improvement in learning [14], and no few scholars have pointed out barriers that limit the potential of Game-Based Learning [15-17], recent research proves that educational games can improve both students' motivation [18] and learning outcomes [3].

So, now that the community starts to accept games' educational potential, other authors have started to consider multiple ways to enhance education with educational games. In this line, the potential of games to support adaptive learning and improve personalization in learning is an active topic [19]. Besides, other authors are interested in using the valuable user-interaction information that games can generate to evaluate student knowledge and skills put into practice as part of the game play [20], [21].

B. e-Learning Standards

A key aspect for the success of the learning process in e-Learning courses is the availability of good quality materials. However, the creation of high-quality digital contents usually requires the involvement of technical experts, educators and domain-experts, thus increasing the development costs. This situation is even worse for educational games, where game developers and graphic artists are also required. So, finding ways to ensure the reuse of the contents developed while reducing the risks presented by future platform migrations becomes a problem of the utmost importance.

The Learning Object paradigm [22] opened a broad range of opportunities to facilitate the distribution, sharing and reuse of learning materials, at least from the technical point of view. As a result of this new paradigm, several specifications and standards were proposed in order to avoid a vendor lock-in to a specific platform or tool, and to facilitate the interchange of the learning contents between tools.

As part of the implementation of this LO development model, content developers must deal with the proposed e-Learning specifications and standards. The e-Learning specifications and standards deal with different interrelated aspects of the LO model, in particular:

- **Packaging**. This aspect is related to the creation of interchangeable content units that can be understood by different tools and platforms, thus facilitating the migration of content between platforms, or the collaboration of tools made by different vendors.
- **Tagging**. Learning content repositories were created in order to facilitate the interchange of learning materials among educators. In order to facilitate content classification and retrieval, it is needed to associate metadata information to the learning materials describing different aspects like the educational purpose, the target audience and technical requirements, among others.
- **Learning Management System communication**. Some educational contents can extract assessment information about student performance. Besides, some contents can adapt its content to specific student needs using the student's profile. For these reasons, a communication link between content and LMS is needed to exchange this kind of information.

There are different specifications and standards that cover the different aspects described above, some of them are: IMS Content Packaging (IMS-CP) [23], IEEE Learning Object Metadata (IEEE LOM) [24] and ADL Shareable Content Object Reference Model (SCORM) [25].

The IMS Content Packaging specification (IMS CP) [23] defines a means for packing self-contained educational resources as LO. IMS CP is flexible enough to allow the packaging of educational resources of different levels of granularity. Particularly, version 1.2 has been taken as starting point for the ISO/IEC 12785 standards family for content packaging.

The IEEE Learning Object Metadata (LOM) standard is part of the IEEE 1484.12 standards family [24] and defines a common set of metadata categories and vocabulary that can be used to describe and catalogue learning resources.

The ADL Shareable Content Object Reference Model (SCORM) [25] is an application profile of other e-Learning specifications, particularly IMS-CP and IEEE LOM. This specification has strongly focused on active content. The ADL SCORM 2004 3rd edition has been actually adopted as technical recommendation (de-facto standard) by the ISO/IEC JTC1 SC36 committee in the form of ISO/IEC TR 29163 family. The SCORM specification covers the three aspects of packaging, tagging and communication above described.

However, there is no wide accepted specification or standard that deals with the integration of educational games in general and in particular when games are used in collaboration with a LMS.

III. <E-ADVENTURE>

<e-Adventure> is an educational game authoring platform developed by the e-Learning research group from Complutense University of Madrid (http://e-adventure.e-ucm.es). Although it was originally focused on *point-and-click* adventure games and simulations [26], it has evolved and matured allowing the development of other 2D highly interactive contents (Figure 1) [27], [28].

The core of the <e-Adventure> platform is the game editor (Figure 2), that allows the development of games and simulations in a teacher-oriented way. In this manner games can be developed without coding. Besides, games' educational value can be enhanced by configuring education-oriented features like assessment and adaptation profiles.

The assessment profiles are the means for filtering the large amount of information produced by the tracking system that <e-Adventure> includes. The assessment profiles use this information to generate two assessment reports: one is human-readable that can be delivered to the teacher or the student as feedback; the second is designed to be easy processed by an application like a LMS [29].

The adaptation profiles allows to customize the game experience for the student according to data gathered from outside the game (e.g. from a LMS) [30].

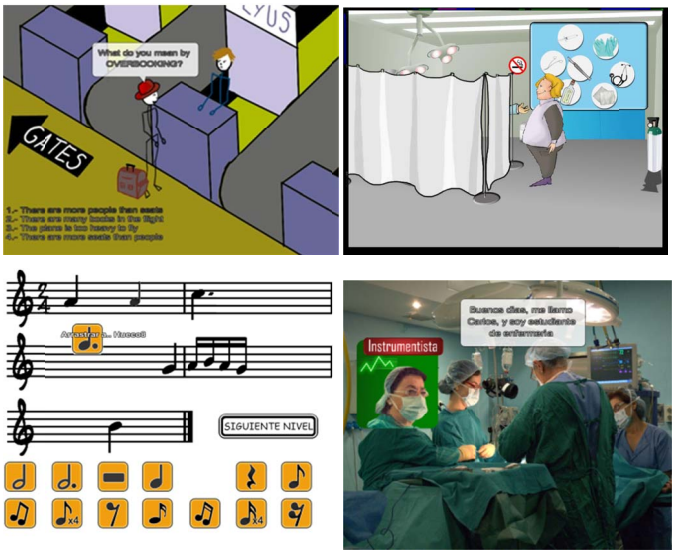

Figure 1. Screenshots of four different <e-Adventure> games. Top to bottom, left to right: *Business Trip to London* (subject: English); *Visit to the Hospital* (subject: English); *The music notation game* (subject: music composition) and *Clinical Surgery* (subject: introduction to the surgery room).

<e-Adventure> has became a consolidated product, which also allows us to use it as a test environment for exploring other GBL-related research lines, like mobile learning [31], narrative-centered visual languages for games [32] or accessible game design and implementation [28].

A. Standards supported in <e-Adventure>

The <e-Adventure> authoring tool allows users to export games as LO. To achieve this objective a set of standards are implemented, in particular: IMS-CP, IEEE LOM, LOM-ES (Spanish standard and *application profile* of IEEE LOM) [33], ADL SCORM 1.2 and 2004 3rd Edition. In addition, the <e-Adventure> authoring tool implements *application profiles* of the previous specifications in order to provide support for specific platforms like LAMS and AGREGA.

From a user point of view the <e-Adventure> authoring tool abstracts the exportation process providing a set of exportation profiles:

- **IMS CP**. This exportation profile just packages the game as a basic IMS-CP compliant LO, but also including the metadata following the IEEE LOM standard.
- **SCORM 1.2 and SCORM 2004**. These exportation profiles package the game as a Shareable Content Object (SCO) following the rules of the SCORM Content Aggregation Model 1.2 or 2004 respectively, includes the game metadata using IEEE LOM and follows the communication protocol with the LMS following the rules of SORM Runtime Environment 1.2 or 2004 respectively.
- **AGREGA**. This exportation profile is specific to the AGREGA repository, but it is a Spanish application profile of SCORM 2004 that uses the LOM ES standard.
- **LAMS**. This exportation profile is specific to the LAMS platform (version 2.3.5 onwards) and but it is an application profile of IMS-CP.

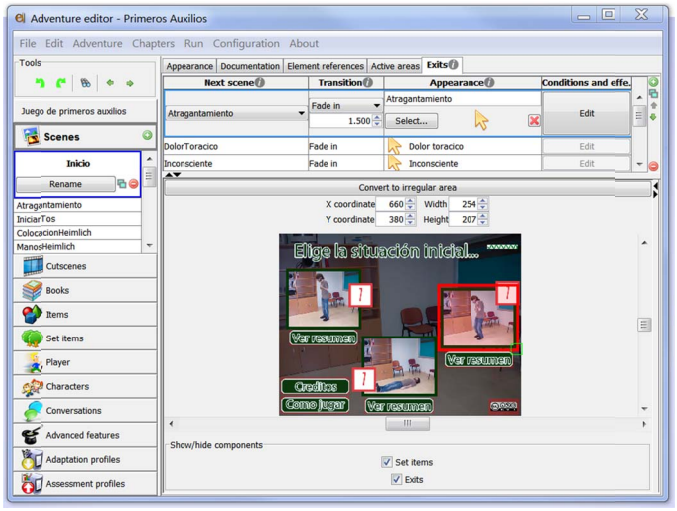

Figure 2. Screenshot of the <e-Adventure> game editor, version 1.3.

These different exportation profiles are presented to the user by using a wizard, where the user is asked the minimal information needed (Author name and Author institution) and the LO package is generated. However there are two aspects that are related to the exportation process and needed a separate explanation: metadata tagging and game communication with the LMS.

During the game creation process, metadata for the game can be added (not required, but recommended) with an included meta-data editor. There are tailored metadata editors for the different metadata profiles supported by <e-Adventure>.

When the game requires active communication with the LMS, certain modifications to the adaptation and evaluation profiles of the game are needed. The <e-Adventure> authoring tool allows the user to create different communication protocols, particularly SCORM 1.2 and 2004 versions, where the user will be provided with a tailored user interface to map the assessment rules to a data model element of the selected protocol. During the exportation process, the authoring tool checks that the selected assessment and adaptation profiles fit with the selected exportation profile, and in addition generates all Javascript files needed to allow the communication between the game and the LMS.

B. Debbuging games with <e-Adventure>

The <e-Adventure> editor offers a debug interface that allows teachers to:

- Debug the game behavior from the editor, allowing the teacher to inspect the internal game state [34].

- Test the communication protocol with a LMS from the web browser. The communication debugging mode, provides *online* and *offline* modes in order to facilitate the tasks of defining and testing the communication between games and LMSs (see Figure 3).

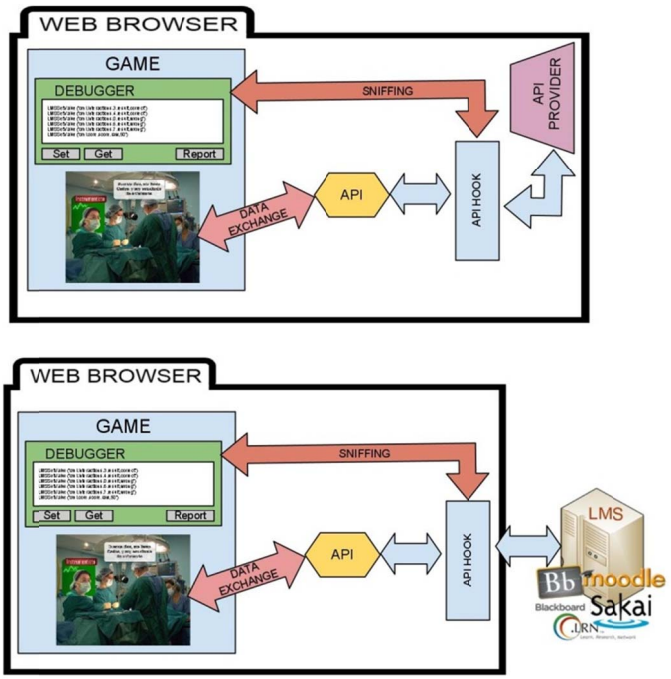

Figure 3. The two debugging modes: simulation and real communication.

The *online* debugging mode allows teachers to check if the game properly communicates with a back-end LMS. Moreover, this *online* mode allows the teacher to explore how the standard actually works, getting quick feedback in order to reduce the creation-test cycle, and thus improving the game design and integration with the LMS. If the game is integrated in a learning sequence with other activities, the *online* debugging mode allows the teacher to explore how the game outputs impact the sequence flow.

The *offline* debugging mode allows teachers to test the games with communication without needing to deploy the game in a real LMS, which also is useful to shorten the creation-test cycle. In the *offline* mode, the game is launched in the web browser where an API provider has been developed to simulate the communication mechanisms. The API provider has been developed in Javascript and provides the same functionality as the selected standard or specific LMS.

The debugger gives the teacher full control over the communication protocol. In both modes, the debugger acts as an sniffer, logging all the communication events between the game and the API. Besides, the debugger allows for manual API calls to check and change the data model state. If the communication protocol is bound to a particular data model (e.g. SCORM), the teacher is constrained to follow it; otherwise (e.g. LAMS exportation profile) any input is accepted.

The debugger also notifies the teacher of all communication (input/output) events, showing the attribute-value pairs that game and LMS have exchanged. It also includes the possibility of showing the assessment report in a pop-up window upon the teacher's request.

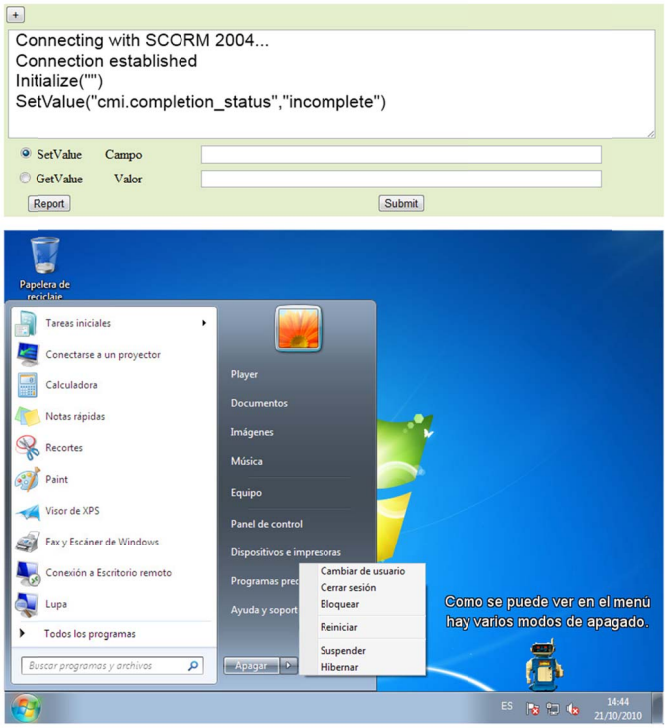

Figure 4. The game and the SCORM debugger. The text shows the initialization values. The text has been augmented for better readability.

IV. Case Study: Introducing Microsoft Windows 7

As a case study a Game-Based course using SCORM and Moodle was developed. The goal of the course was to introduce the Microsoft Windows 7 Operative System, and included an <e-Adventure> game. The game was deployed in a Moodle LMS (1.9.5) as a SCORM 2004 package. The game used an <e-Adventure> assessment profile to communicate the results of the game to Moodle. In addition a SCORM debugging console, developed using Javascript and HTML, was integrated in the web page that launches the game within the SCORM package.

This game was developed using screenshots of the Windows 7 user interface. A little robot serves the purpose of in-game tutor, setting short-term and long-term goals and guiding the student as needed.

The game also considers student evaluation, including a short multiple-choice exam that has to be completed at the end of the game. In this exam the robot (i.e. tutor) describes items of the OS interface and the student has to identify them. The student needs to answer 5 of the 10 questions to pass the test.

Through the assessment profile, several SCORM 2004 data model fields were used to track students' activity in the game. When the game starts the value "*incomplete*" is sent to the

"*completion status*" field to notify the LMS that the activity (game) was started but not completed yet. When the student completes the test, we the field is set to value "*complete*". If the student answered correctly at least 5 questions, the value "*passed*" is sent to the field "*success status*". An "*objective*" field was used to represent the general learning objective of the game (get to know the main elements of Windows 7 UI). Finally, the game sets a *score*, adding 10 points per each questions correctly answered (maximum value: 100 points).

The *interactions* array is used to track detailed information for each answer provided by the student in the final test (Figure 5). For each response to a question an *interaction* record is created, storing the id, the timestamp, the description and the objective that is related to the interaction (only one goal in this case study). Other sub-fields are also used:

- *Type*: Multiple-Choice.
- *Correct responses*: the correct option among the possible responses.
- *Learner response*: students' input.

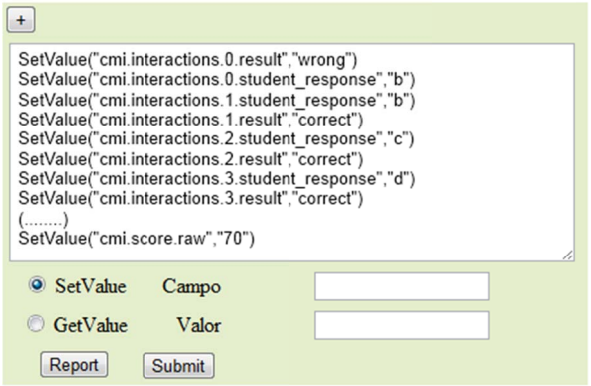

Figure 5. An excerpt from the debugger console, showing communication after the test.

Upon game completion, the assessment report produced by <e-Adventure> in human-readable format is sent to the LMS through the field "*comment from learner*". SCORM does not include a field that is adequate for storing detailed assessment reports, so we decided to use *"comments from learner"* for two reasons: 1) it can store long pieces of text and 2) we checked that Moodle 1.9.5 actually allocate spaces in its database for it. However, to facilitate testing and debugging this report can also be accessed on a pop-up window by hitting the "*report*" button in the debugging console.

The course developed was used to train professionals in the e-Learning field in the use of SCORM for games. Both the game and the debugging console were very useful to teach participants:

- How SCORM actually works.
- How SCORM is actually implemented in Moodle 1.9.5 and how the information that the game produces can be retrieved from the LMS.
- What are the more appropriate fields in the SCORM data model for tracking students' interaction in games.

V. CONCLUSIONS AND FUTURE WORK

The Game-Based Learning field is starting to explore new research lines. Among these new lines, how to use students' interaction data gathered from the games is under discussion. These data can be very useful for assessment purposes and for controlling the flow of learning sequences. It is desirable that data extracted from the game is handled in compliance with e-Learning standards to foster content interoperability. In this paper we discuss the need of tools that facilitate development and smooth the curve of learning the standards, especially for non-technical professionals.

We have implemented a standard debugging system in the <e-Adventure> platform, as a new tool for educational game creation. The debugger allows teachers testing and debugging the defined communication in *offline* mode without the need of using an LMS for that matter. Besides, the debugger presents an *online* mode that can be used not only to ensure that the LMS correctly handles the data transmitted, but also to check how the game outputs affect the development of other activities if it is integrated into a broader learning sequence. Furthermore, the debugger can be useful to analyze and understand game packages developed by other authors.

The debugger has not been included in official <e-Adventure> release yet. It still needs further testing before it becomes publicly available. As possible lines future work, we are studying the possibilities of using other standards for video games integration (e.g. IMS Learning Information Services, IMS Learning Tool Interoperability and IMS Common Cartridge), including new ideas such as mashups and cloud applications. We also are planning to evaluate this approach with more teachers that enroll in <e-Adventure> training courses that we usually run periodically.

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