Enhancing Adaptive Learning and Assessment in Virtual Learning Environments with Educational Games

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ABSTRACT: *The rising acceptance of Virtual Learning Environments (VLE) in the e-Learning field poses new challenges such as producing student-centered courses which can be automatically tailored to each student's needs. For this purpose digital games can be used, taking advantage of their flexibility (good video games always try to adapt to different players) and capabilities to stealthily track players' activity, either for producing an accurate user model or enhancing the overall assessment capabilities of the system. In this chapter we discuss the integration of digital games in Virtual Learning Environments and the need of standards that allow the interoperable communication of games and VLE. We also present a middle-ware architecture to integrate video games in VLEs that addresses the technical barriers posed by the integration. We present a case study with the implementation of the architecture in the <e-Adventure> game authoring platform, along with three examples of video game integration in educational settings.*

Keywords: Educational video games; Virtual Learning Environments; Adaptive Learning; Assessment; SCORM.

INTRODUCTION

Schools, universities and corporations are becoming increasingly dependent on e-Learning systems for their distance or blended learning programs. State-of-the-art e-Learning systems are no longer mere content repositories but fully featured Virtual Learning Environments (e.g. *Moodle*™ (Dougiamas & Taylor, 2003), *Sakai*™ (Farmer & Dolphin, 2005)) that support all the activities related to learning. Modern VLEs comply with different e-Learning standards to ensure content interoperability (e.g. SCORM (ADL, 2006)), which is important to protect investments in content production. Therefore the courses created may combine VLE's built-in tools (e.g. chat, forum, questionnaires, etc.) with a wide range of learning contents. However, in many cases standards only cover content deployment, leaving the active integration of tools and contents to VLE developers' own judgment.

Among the new **educational tools** to be used in education, **video games** and **simulations** are gaining acceptance as learning tools as contents that foster learning by doing (Aldrich, 2005), problem solving skills (Rieber, 1996) and improve motivation and engagement (Garris, Ahlers, & Driskell, 2002). Video games has also potential because of their high level of interactivity, which allows providing fine-grained adaptive experiences, and player's activity tracking capabilities (Tang, 2007; Moreno-Ger, Burgos, & Torrente, 2009). Ideally these features could be used to enhance what the VLE knows about the student. This opens new possibilities for improving the **assessment** methodologies and to adapt the learning process for each student.

Nevertheless, for this to be a reality games and VLE need to establish an active and bidirectional **communication** that can cope with an intense exchange of interaction data. Current e-Learning standards were not designed to support this kind of communication. Some e-Learning standards address the communication between VLE and content (e.g. SCORM) or the adaptation of the learning flow (e.g. IMS Learning Design (IMS Global Consortium, 2003) but we still need to deal with the current diversity of VLE and with a lack of specific standardization support for the peculiarities of game-based learning.

In this chapter we present a general architecture to integrate games in VLE specifically focused on supporting **adaptation** and **assessment** features. Through the use of a middle-ware, game designers can develop adaptive educational **games** defining the interaction with the VLE without committing to any specific VLE or standard and without the need of technical knowledge on this matter. Thus the games created could be integrated in different VLEs and contexts, even if they support different families of standards (or even no standards at all). To test the feasibility of this approach, we've implemented the architecture in the <e-Adventure> game authoring platform. For the last two years we have evaluated the implementation and the conceptual framework in the development of several games for different educational settings.

In this chapter we first identify the barriers and the state of the art of the e-Learning field focusing on assessment, adaptation and standards; second, we discuss how video games can contribute to assessment and adaptation in e-Learning and the challenges behind this approach. Then we describe the proposed architecture and its implementation in the <e-Adventure> platform as a case study and three experiences of video game integration in VLE and finally, we present some conclusions and outline future lines of work.

VLEs: ASSESSMENT, ADAPTATION AND STANDARDS

Current VLEs aim to provide support tools for all aspects of the teaching-learning process, from course creation to student evaluation features (Govindasamy, 2002). Common **assessment** tools include tests and questionnaires. However, there is a lack of well-defined methods to assess student progress from how the student interacts with content. While the VLE can usually know when a user accessed the content, in many cases contents behave as black boxes for the VLE.

An additional notion is how to establish relations among the activities in a course so that they can result in an adaptive learning flow in which the outputs of some activities affect the behavior of the learning experience (Henze, 2000). Even though there are several examples of systems that include **adaptation** features (e.g., AHA, ALFANET, etc.), mainstream student-centered VLEs do not tend to include adaptation capabilities (Hauger & Köck, 2007). The new VLEs need to facilitate tasks such as tracking the progress and the skills acquired by the student within highly interactive contents, as well as to adapt the learning experiences to the specific needs of each student.

Another important issue in e-Learning is the **interoperability** of contents. E-Learning standards try to deal with the different aspects of e-Learning processes, mostly content delivery but also some of them deal with **communication** with VLE or definition of paths in the lessons. At the present time, compliance to e-Learning standards is a crucial factor when selecting a new VLE implantation in a corporate or educational environment. This allows the reutilization of existing contents and protects the investment in developing new contents against future platform migrations.

E-Learning specification and standardization initiatives are numerous and diverse, involving different organizations and consortiums such as the IEEE or IMS Global Learning Consortium. Most of these contributions target the concept of allowing the creation of courses as aggregations of simple units of content, an approach usually referred to as the Learning Objects Model (Balatsoukas, Morris, & O'Brien, 2008). To achieve this kind of aggregation, it is important to package the contents in a standardized format (using for example IMS Content Packaging (IMS Global Consortium, 2004)) and to annotate the contents to facilitate their management (using for example the IEEE Learning Object Metadata standard (IEEE, 2002)).

Even though the use of the aforementioned standards to package and distribute the content is well established in many available VLEs, these standards do not simplify the widespread adoption of **student-centered** approaches with **adaptation** and performance tracking (Graf, Lin, & Kinshuk, 2005). Nonetheless, there are some efforts to support adaptive learning through e-Learning standards and specifications.

In terms of **assessment** and gathering the students' performance SCORM (ADL, 2006)defines a data communication model that allows the interchange of information between the (potentially interactive) content and the VLE in a standardized way. Melding this fact with packaging, content structuring and labelling turns SCORM into a singular specification. SCORM also includes basic branching capabilities in an activity sequence, although it was not intended for highly interactive contents and thus its potential is limited (Shute & Spector, 2008).

IMS-Learning Design (IMS Global Consortium, 2003) could support **adaptive** learning flows due its flexibility by which it allows educators to define virtual courses following any pedagogical approach (Van Es & Koper, 2006). However, there are few systems that fully implement IMS-LD and the effective use of the supporting IMS-LD editors still requires significant knowledge about the specification. LAMS is a system that has been developed based on IMS-LD ideas, focusing on course development and execution but without complying with the full specification (Dalziel, 2003).

A very promising set of three specifications in the field is being developed by IMS Global Learning Consortium, which tries to provide solutions for the incipient needs of the e-Learning business. The first specification available is IMS Common Cartridge (IMS-CC) (IMS Global Consortium, 2011), which covers packaging, organization and delivery of educational content. IMS-CC also presents improvements in user authentication and provides a simple protocol for accessing tools remotely, known as IMS Basic Learning Tool Interoperability (IMS-BLTI) (IMS Global Consortium, 2010), allowing the creation of mash-ups in the VLE. BLTI is also strongly related to the second specification, which is still unpublished, being developed by IMS: Learning Tools Interoperability (IMS-LTI), which will eventually push forward the concept of mash-ups with an agreement about security and run-time services. The last specification, also unpublished, is IMS Learning Information Services (IMS-LIS), which will define an interoperable way to communicate information between different VLEs and between contents and VLE as well. IMS-LTI and IMS-LIS are expected to be a significant improvement in the active integration of interactive content and tools, but in the meantime SCORM still represents the state-of-the-art for video games integration.

Therefore, the adoption of this type of advanced VLEs demands dealing with a diversity of standards that may put the investment at risk. Given that developing interactive and adaptive content requires a significant budget, this can potentially become a major issue.

GAME-BASED LEARNING AND E-LEARNING

As it has been widely discussed in the literature during the last years, the use of video games can enhance the **learning processes** in many aspects (Gee, 2003). Traditionally the most frequently benefit associated to game-based learning in the literature is that it can increase students' motivation (Lepper & Cordova, 1992; Malone, 1981), which recent research has backed-up (Papastergiou, 2009; Liu & Chu, 2010; Sancho, Torrente, & Fernández-Manjón 2009). The relation between video games and constructivists theories (Gee, 2007), their support for collaborative/competitive learning (Squire, 2003), or their alignment with 21st century skills (Annetta, Cheng, & Holmes, 2010) are other benefits of game-based learning, according to recent literature. Furthermore, video games encourage the adoption of problem solving skills (Van Eck 2007) and “learning by doing” (Aldrich, 2005), while keeping the students engaged (Shute, Rieber, & Van Eck, 2011). However, the full potential of video games in adaptable student-centered online learning is almost unexplored and requires further research.

Videogames, Adaptation and Assessment

The adaptation of educational content to suit different target audiences with different levels of initial knowledge is a common feature in **student-centered** learning, although it is difficult to achieve. Meanwhile, personalization and challenge adjustment are pervasive features in video game products. Game developers and publishers include mechanisms in their video games to **adapt** the game experience to suit the requirements of the widest possible range of users (Moreno-Ger, Burgos, & Torrente, 2009). The most obvious type of adaptation in video games is the inclusion of different levels of difficulty, trying to adjust the challenge to different levels of skill.

However, the potential is even bigger thanks to the high interactivity of games, which can be used to implement much more fine-grained **adaptation** mechanisms. Some advanced games can even carry out this adaptation transparently to the user. For example, the *MaxPayne*™ video game incorporates Dynamic Difficulty Adjustment techniques (Robin, 2005) that alter the game execution depending on the actual performance of the user. More recent titles apply similar techniques to personalize different aspects of the game. For example, the *Left4Dead™* saga (http://www.valvesoftware.com/games/l4d2.html) includes an AI engine that customizes elements like pathways through the game world, enemy populations and also the game atmosphere and environment through adaptive music, sound and visual effects according to the player's style of play (http://www.valvesoftware.com/publications/2009/ai_systems_of_l4d_mike_booth.pdf).

On the other hand, getting to know the student in a virtual learning setting is also a significant challenge (Ahmad, Basir, & Hassanein, 2004). Typical approaches collect data by asking the user directly, although there are research initiatives that try to infer information about the students by observing their interaction with the system (Charles, et al., 2005). The fine-grained interactivity provided by games can produce more detailed information about the interaction of the students that any other kind of non-interactive content. Gathering and processing this information can open up new opportunities in terms of automatic **assessment** and student profiling. Nonetheless, how to track students' performance from games is not a trivial matter and further research is also needed (Del Blanco, Torrente, Marchiori, Martínez-Ortiz, Moreno-Ger, & Fernández-Manjón 2010;,Shute, Rieber, & Van Eck, 2011).

Current Challenges Integrating Game-Based Learning in VLEs

From the previous discussion, we derive that educational **games** can be an ideal medium to deliver **student-centered** content in VLEs, and a new way of extracting detailed information about students' performance. However, some issues should be addressed to successfully exploit the potential synergies between adaptive game-based learning and e-Learning.

One concern is the flexibility and maintainability of the content, a key issue in e-Learning but which is rarely tackled in video games. While typical educational content such as text, presentations or multimedia files can be easily edited, video games are usually sold as closed products which cannot be modified. Other aspect is that games must behave more openly in order to become a more useful tool in student-centered VLEs, allowing the instructor to know what happens during the game sessions and to modify the behaviour of the game as desired. This requires the definition of specific models that allow the instructor to interact with the game experience remotely. This can be done using the currently existing standards mentioned in the previous section, but this approach presents two main issues.

On the one hand, a game developer who wants to integrate a game into a VLE must identify which standard/specification will be used in the VLE to store the data and how the games will exchange information with the VLE. Given the current situation, with diverse (and evolving) standards available, this does not guarantee the full interoperability of the contents, leaving the investment unprotected. Besides, educational game developers must implement in each game the selected set of standards from scratch, which requires great efforts due to the inherent complexity of these standards.

On the other hand, when developing adaptive and **assessable** educational video games, it is necessary to maintain a model of each student persistently, and to define how to **adapt** the game experience according to that user model. If these behaviours are programmed ad-hoc in the game, the investment could become useless if instructors need to modify the adaptive and assessable behaviour of the game (for instance, if the educational video game is to be used in a new educational context). This could be solved if instructors could directly set up the adaptation and assessment configuration of the game and connect the video game with a VLE to solve the problem of the student model persistence.

The integration of video games or 3D immersive virtual worlds is not new, as several initiatives have combined VLEs and interactive content to get the best of both worlds (Chen, Wang, Chang, Chao, & Shih, 2009; Rey-López *et al.*, 2008). For instance, *SLOODLE™(Kemp, Livingstone, & Bloomfield, 2009) and NUCLEO™*(Sancho, Fuentes, Gómez-Martín, & Fernández-Manjón, 2009) use *Moodle™* as a backend for a 3D Virtual Environment which is used as a central server. Other example is Delta3D™ (McDowell, Darken, Sullivan, & Johnson, 2005), a 3D game engine that implements SCORM to enable the communication between the games and a SCORM-compliant VLE. However, all these approaches use ad-hoc implementations of the **communication** between content and VLE, which limits the impact to a concrete platform and hinders the general adoption in educational settings. Additionally, while the problem of connecting interactive content (such as games and interactive simulations) with a VLE in standard-compliant ways has been partially addressed (De Antonio-Jiménez, Ramírez-Rodríguez, & Madrigal-Alfaro, 2008; Del Blanco *et al.*, 2010), there is still a need of research about how to use this connection automatically for **adaptation** and **assessment** purposes, and how to assure that the developed games will be resilient to future changes in the current standards.

In order to facilitate the inclusion of educational games into the **student-centered** VLEs, we need to achieve a greater independence between the implementation of the games and the standards used to connect them with the VLEs for adaptation and assessment.

AN ARCHITECTURE TO INTEGRATE GAMES IN STUDENT-CENTERED VLEs

In this section, we describe a general architecture that facilitates the integration of **educational games** in **student-centered** VLEs. The architecture uses a general model for assessment and adaptation concepts that hides the technical difficulties derived from this process from the instructors and content developers, and tries to alleviate the potential issues described in the previous section in terms of standards compatibility, **adaptation** and **assessment**.

First, it is necessary to solve the problem of the **communication** between game and VLE. The development of games must be as independent as possible from the standards being used for enabling the communication or the specific VLE that will receive the communication. In addition, it is important to be able to define adaptation and assessment patterns that are independent of the specific game or technology. Finally, it would also be desirable to abstract the content creators from the knowledge of the standards in terms of **adaptation** and **assessment** thus facilitating this process.

Overview of the Architecture

The architecture is divided in two modules, one focused on abstracting the communication and the other focused on abstracting the **adaptation** and **evaluation** patterns.

The first module, called *Communication Module* (CM), is responsible for establishing and managing the communication channel between the VLE and the game in a standardized way. This module will typically execute actions such as "start / end" communication and "send / receive" data. The results of these actions depend on the current standard being used. The CM isolates the content from the specific characteristics of the potentially different communication methods and standards. The module thus identifies the VLE and manages the agreement of the communication protocol to be used between game and VLE. The module has a set of communication plug-ins (one for each standard that it implements) that support the actual communication with the VLE. All these plug-ins implement a common API facilitating a plug-and-play architecture where different communication modules can be added or removed.

The second module is the *Adaptation and Evaluation module* (AEM). It has two missions. On the one hand, it decides the changes that should be done in the game in terms of adaptation and eventually execute those changes (*Adaptation*). On the other hand, this module tracks the student interaction in the game in order to extract information about the progress of the student. This information is processed and submitted to the VLE for assessment purposes through the *CM (Evaluation)*.

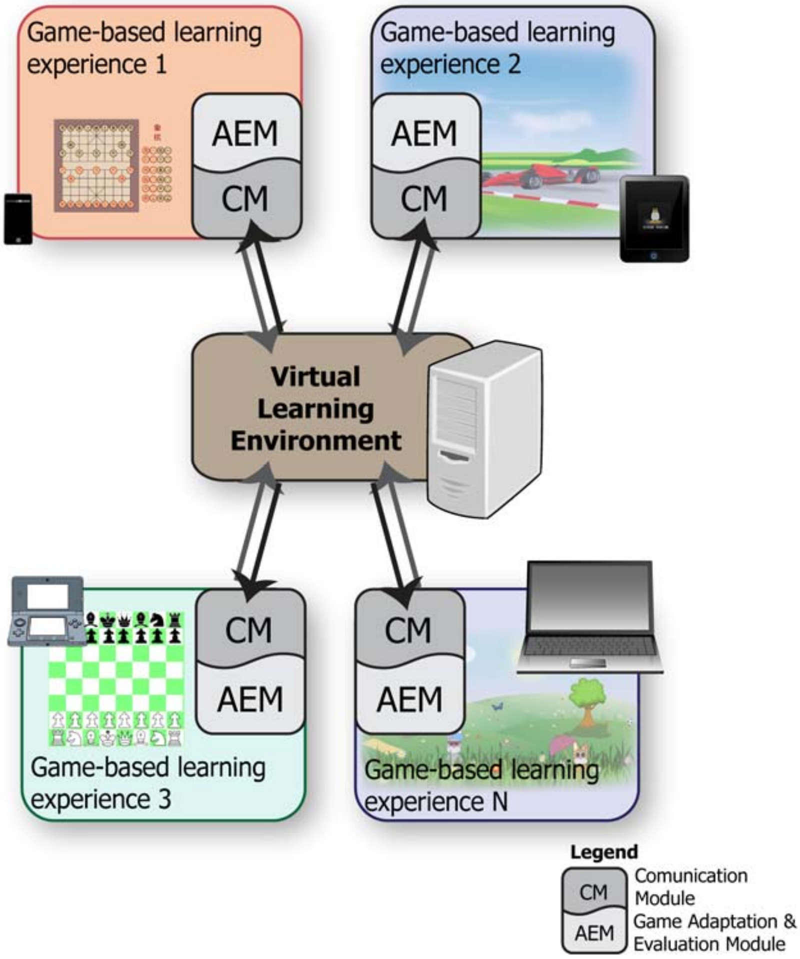

Figure 1: Top-view of the architecture. Games and VLEs can be connected using different communication protocols.

These abstractions allow a game to **communicate** with different VLEs regardless of the specific standards and communication protocols supported by each specific VLE. They also allow a VLE to support different adaptation and evaluation approaches, although this requires both sides to support a specific model to define adaptation and evaluation concepts.

For this reason, the middle-ware is built according to a *General Data Model for Adaptation and Evaluation* (GDMAE). The fact that the middle-ware uses abstract adaptation and assessment constructs means that both the game and the VLE can be developed independently. Also these general terms allow people without specific knowledge about the design and implementation of the game and/or the standards that will be used to define assessment and adaptation for game-based learning scenarios.

The next subsections provide additional details about the data model (GDMAE) and the two modules: CM and AEM.

The General Data Model for Adaptation and Evaluation (GDMAE)

The API **communication** functions provided by the CM are expressed in terms of a generic data model. For example “receive the name of the student” or “store the activity assessment". The model defines situations involving **adaptation** and/or **assessment** tasks. The AEM will use these data along with the information gathered from the game and the VLE to decide whether to perform adaptation or not and what will be the concrete in-game adjustment to be performed. The role of the games in terms of assessment is to provide valuable information about the performance of the student. This information is used by the middle-ware to drive a fine-grained online adaptation of the learning experience and to produce assessment data as attribute-value pairs or in the form of a report that can be attached to the VLE's student profile.

This model defines two set of terms: 1) a set of general terms to express the situations that will imply adaptation or evaluation and 2) the terms to configure the CM. "Adaptation" is defined as the action of adjusting the game experience according to the profile of the student or the current in-game situation. "Evaluation" (which is also a synonymous for "assessment") is defined as the identification of an in-game situation that is relevant for evaluating the performance of the student and committing to the VLE the assessment actions that must be performed (e.g. set a student grade).

To express which **adaptation** actions should be performed when certain situations are detected in the VLE we use the concept of *adaptation rule*. The structure of adaptation rules uses the well-know concept of rule, which includes a set of actions to execute when a set of conditions are achieved, and could be summarized as follows:

If (VLEstate) then (changeGame)

Where "*VLEstate*" is a general adaptation term (as defined in the model) that declares a finite set of conditions that must be met in the VLE side and where "*changeGame*" is a general term that identifies the set of actions that must be performed in the game.

Similarly, we define the concept of **assessment** rule to reflect the actions that must be carried out in the data model at VLE-side when certain circumstances in the game resulting from the interaction of the learner are detected. Assessment rules are defined as follows:

If (gameState) then (changeVLE)

Where "*gameState*" is a general assessment term that identifies a particular state in the game that, when reached, will involve the triggering of the "*changeVLE*" action block. "*changeVLE*" is a general term characterized according to the assessment data that should be generated and sent to the VLE for processing.

This model includes the definition of a language for specifying the general terms, which are closed to natural language and define how to adapt and assess the game-based learning experience, distancing in this manner the author of adaptation and assessment from the technical details.

The Communication Module (CM)

The Communication Module is responsible for requesting and transmitting information in both directions to the VLE and to the AEM module. The CM abstracts the **communication** between the game and the server, but internally depends on the standard used. It requests the data of the student profile, receiving such information in the specific format that the standard or the specification declares. Then, it converts the standard-specific data to the general language that the corresponding module understands. In turn, it receives information from the AEM using evaluation general terms that need to be transformed and sent to the VLE, which will store them following the specification in use (if this specifies how to do so). By using the CM it is possible to receive and store adaptation and assessment information in the VLE regardless of the actual standard that the server uses.

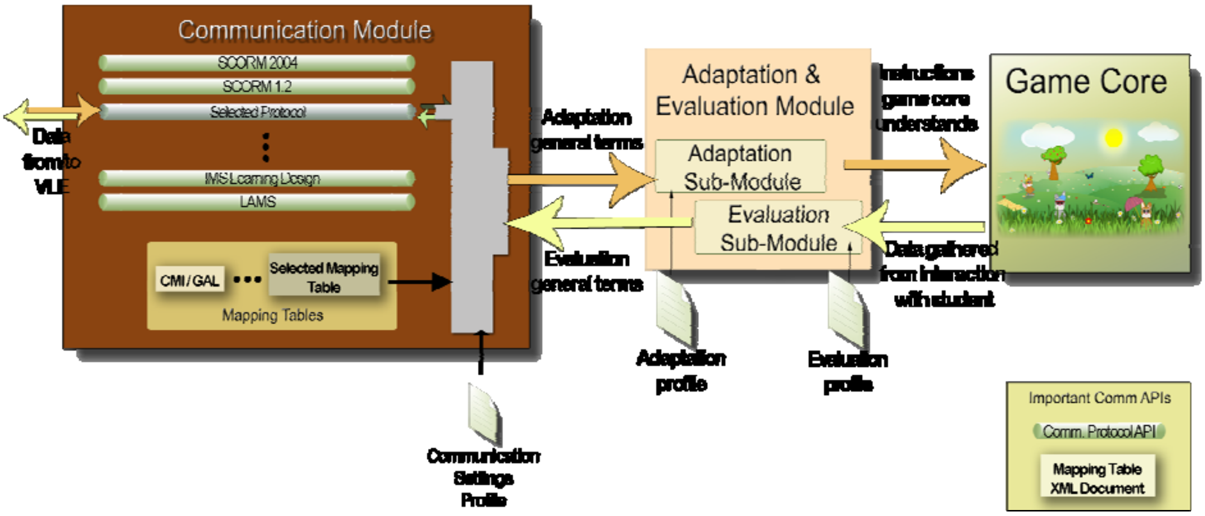

Figure 2: Communication sequence between the two middle-ware modules and the game core.

The CM module includes out-of-the-box implementations for some common standards in **student-centered** environments (based on specifications such as SCORM1.2 or SCORM2004). The CM also gives support to specific VLEs which do not contemplate a standardized communication protocol. This is the case of the LAMS Learning Authoring and Management Tool (Dalziel, 2003). When the game is run, the CM consults a configuration file (communication settings profile) to select the standard used to establish the communication with the VLE.

For each standard or specific VLE, the CM includes two relevant elements: an implementation of the **communication** protocol defined or supported by the VLE, and a profile (mapping table) specifying how to map the information in the cases where the standard already provides a pre-set data model (e.g. CMI data model for SCORM). The abstract **adaptation** and **evaluation** data model must be connected to the language defined by the communication protocol. When the selected standard does not define the communication data model (e.g. IMS Learning Design), the communication settings profile can include a mapping table defining an application-specific data model. The CM must use this table in the communication process to store and retrieve the required information. In these cases, the information contained in the profile will depend on the specific course (although it will be independent from the specific game).

The components of the CM have clear and formally defined interfaces to allow flexible and systematic extensions and modifications, which guarantees interoperability and a longer life cycle for the middle-ware. New standards can be easily plugged in into the CM by carrying out two tasks: First, the communication protocol must be implemented following a specific API. In some cases this API will be provided by the standard (e.g. SCORM). In some other cases, it will be dependant on the VLE. Then, the mapping table must be written, defining the translations between the abstract constructs and the VLE-dependant constructs.

With this structure the underlying **communication** standards are completely transparent. Authors only need to modify the middle-ware configuration file to change the standards and specifications used in the communication.

The Adaptation and Evaluation Module (AEM)

The AEM is responsible for carrying out the **adaptation** tasks in the game according to the adaptation rules and using data provided by the VLE. It is also responsible for monitoring the activity in the game to detect situations that require evaluation. As both **adaptation** and **assessment** are well-defined tasks with both common and specific features, this module delegates both responsibilities in two sub-modules respectively (thus both are addressed individually): the *Adaptation Sub-Module* (ASM) and the *Evaluation Sub-Module* (ESM).

The ASM receives input data about student's information stored in VLE (e.g. progress in the educational process, social and cultural factors, etc.) for adaptation decision-making process (figure 2). These are "get actions" expressed in "*VLEstate"* terms. The ESM also uses the CM to submit information about the achievements of the student in the game (e.g. the level of completion of the activity is 60% or the completion of learning goals is 75%) and sends it through a standard-compliant channel to the VLE. These are "set actions" expressed in "*changeVLE*" *terms*. As aforementioned, the CM is the responsible of managing these general terms, translating them to the specific low-level communication protocol if necessary. This is how the CM adds independency from the specific standard supported by the VLE both for **adaptation** and **assessment communication**. In addition, the AEM communicates with the game core in order to receive information about user's in-game interaction (using "*gameState" terms*) and to make changes as a result of adaptation decisions (using "*changeGame"* terms).

The in-game situations that should produce either some kind of **adaptation** and/or **evaluation** are defined by the author in the adaptation and evaluation profiles. These profiles contain a set of rules defined as it was explained in General Data Model for Adaptation and Evaluation. Both sub-modules must "understand" the meaning of each term to concrete them in actions in the game or VLE.

CASE STUDY: INTEGRATION IN <E-ADVENTURE>

To test this approach we have implemented the architecture in the <e-Adventure> platform (Del Blanco, Torrente, Moreno-Ger, & Fernández-Manjón, 2009). <e-Adventure> (Moreno-Ger, Burgos, Sierra, Fernández-Manjón, 2008) is a platform created in order to facilitate the introduction of **video games** and game-like

simulations in the **educational process**, trying to overcome some barriers that hinder the generalization of educational games. <e-Adventure> provides a game editor to create the games and a game engine to execute them. Both components play different roles in respect to our architecture. On the one hand, the architecture is integrated in the game engine to enable the **communication** with VLEs. On the other hand the game editor allows the configuration of both modules, generating the settings, **adaptation** and **evaluation** profiles (which are called assessment profiles in <e-Adventure>) that the architecture needs. This process is performed transparently to the author. When the final version (runnable version) of the game is produced using the editor, those profiles are packaged within the game, following the specifications in terms of content packaging that the standard being used defines (if any).

Implementation of the Communication Module

To include the CM in the platform we complete the following tasks: to implement a module for every standard, to give support to the metadata for the new included standards and to add new types of exportation profiles for the <e-Adventure> games. At the moment, the official <e-Adventure> release provides support for SCORM v1.2, 2004, LAMS (Del Blanco *et al.*, 2010). Unofficial releases have been produced to support other VLEs and specifications, like an *ad hoc* protocol defined to communicate with servers running IMS Learning Design (the server side of this protocol was implemented as a plug-in for *CopperCore* and .LRN (Burgos *et al.* 2008)) or the GameTel VLE (Anido *et al.* 2011).

The CM is made up of a set of modules with the particularities of each standard or specific VLE. Every module implements the **communication** protocols that the standard uses. In case the standard has a specific data model, it must be also included in the specification of the module. When there is not a data model defined, it has to be set in the **adaptation** and **assessment** profile via the corresponding mapping table.

There are different types of game exports as Learning Objects in reference to the different types of standards and VLE that the current architecture implementation supports. Choosing one of the exportations, the communication sub-module that will be in use is selected.

In addition an editor of metadata has been added to include this type of information in every exportation type that should need it.

Implementation of the Adaptation and Evaluation Module

The <e-Adventure> platform includes features to support both **adaptation** and **assessment**. The platform already includes implementation for parts of the AEM that are responsible for these actions which are specific for each game engine. It also allows adding assessment and adaptation profiles where the sets of rules of adaptation and assessment are defined.

The profiles take into account the peculiarities of the architecture. In these profiles the user can choose a standard in order to establish both **communications** with the

VLE and the data model. The user can either define the data model in the profile or use a default model provided by the selected standard. The user can determine conditions and execute actions which modify the state of the VLE data model. The mechanism of variables and flags that <e-Adventure> provides is used to introduce changes and to define conditions on the game state (Moreno-Ger, Sierra, Martínez-Ortiz, & Fernández-Manjón, 2007). The AEM will be configured by filling in these profiles with adaptation and assessment rules and selecting a standard. The assessment rules can also produce annotations in a human-readable report to be shown at the end of the game as auto evaluation for the student or to be sent to the VLE for teachers' review.

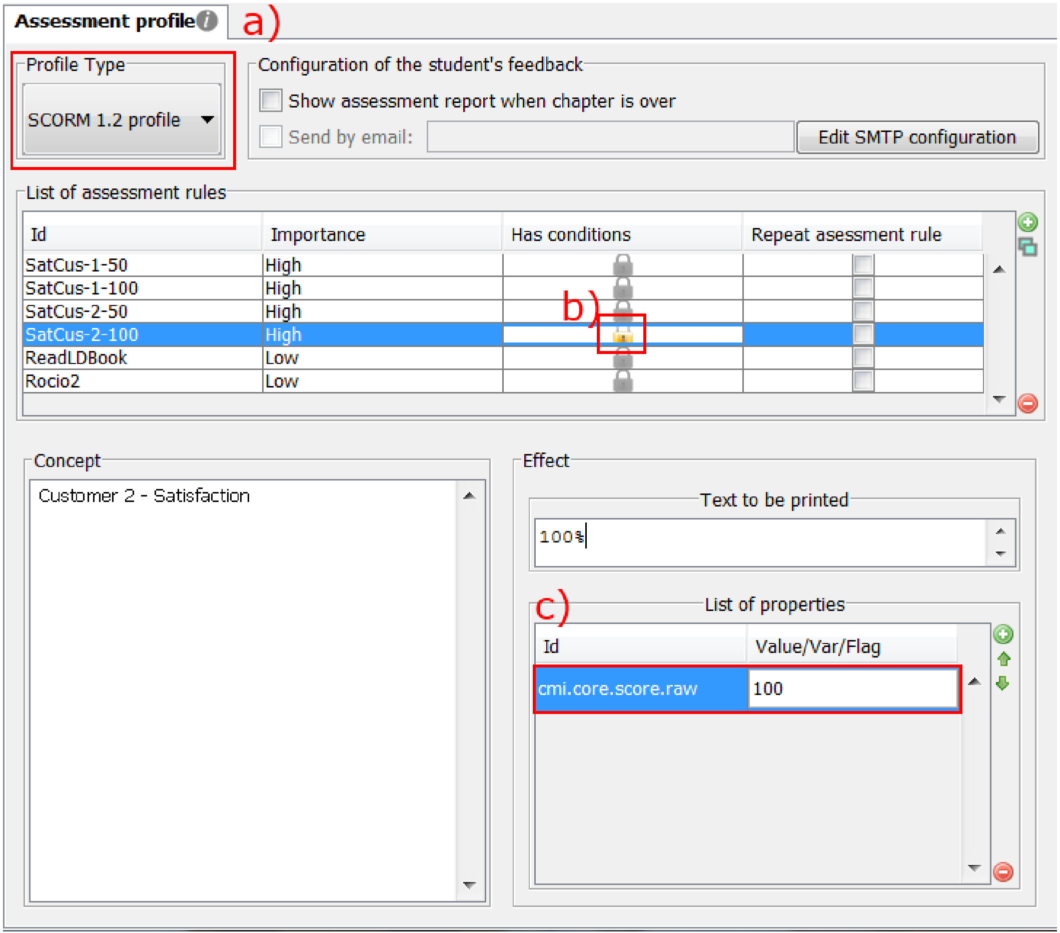

Figure 3: The <e-Adventure> editor. The screenshot shows an assessment profile with some assessment rules. a) The area that allows selecting a standard or VLE. b) The area for defining conditions (“gameStates”). c) Area for defining what will be set in VLE (“changeVLE”).

Experience 1: Example of Communication Between VLE and Game

The architecture was preliminary tested and exemplified with the “Paniel and the Chocolate-based Sauce Adventure” game, which can be integrated into different **student-centered** VLEs. The game was originally developed to be integrated only with the *CopperCore* IMS Learning Design module (Burgos, Moreno-Ger, Sierra, Fernández-Manjón, Specht, & Koper., 2008). The goal of the game is to introduce chocolate-based cooking techniques from a practical perspective, and it is divided in three stages of different levels of difficulty. The initial level teaches how to make chocolate, the second level teaches how to make chocolate-based sauces, and the third level teaches how to marry them with dishes (the most challenging level). First, we analyze the theoretical behaviour, and afterwards we describe the real behaviour in our case study.

The AEM is set up with an adaptation profile that modifies the game depending on the prior knowledge of the student (figure 4a). When the game is executed, the AEM requests information from the VLE asking the overall grade of the student (figure 4c-step1). Then the CM, which has previously set up the communication channel with the VLE accordingly to the communication settings profile, codifies the request using the general model, and sends it to the VLE. After the CM receives the VLE response, it translates that response into adaptation terms and sends them to AEM. The AEM then interprets the abstract response and uses the adaptation profile to decide to which level the student should go, skipping the first levels if appropriate. In this example, the adaptation profile determines that if the student overall grade is greater than 50% and less than 75% the first level is skipped. If the overall grade is greater than 75% the second level is skipped. Finally, if the overall grade could not be retrieved for any reason, or if the overall grade is less than 50%, no levels are skipped (fig 4c-step 5).

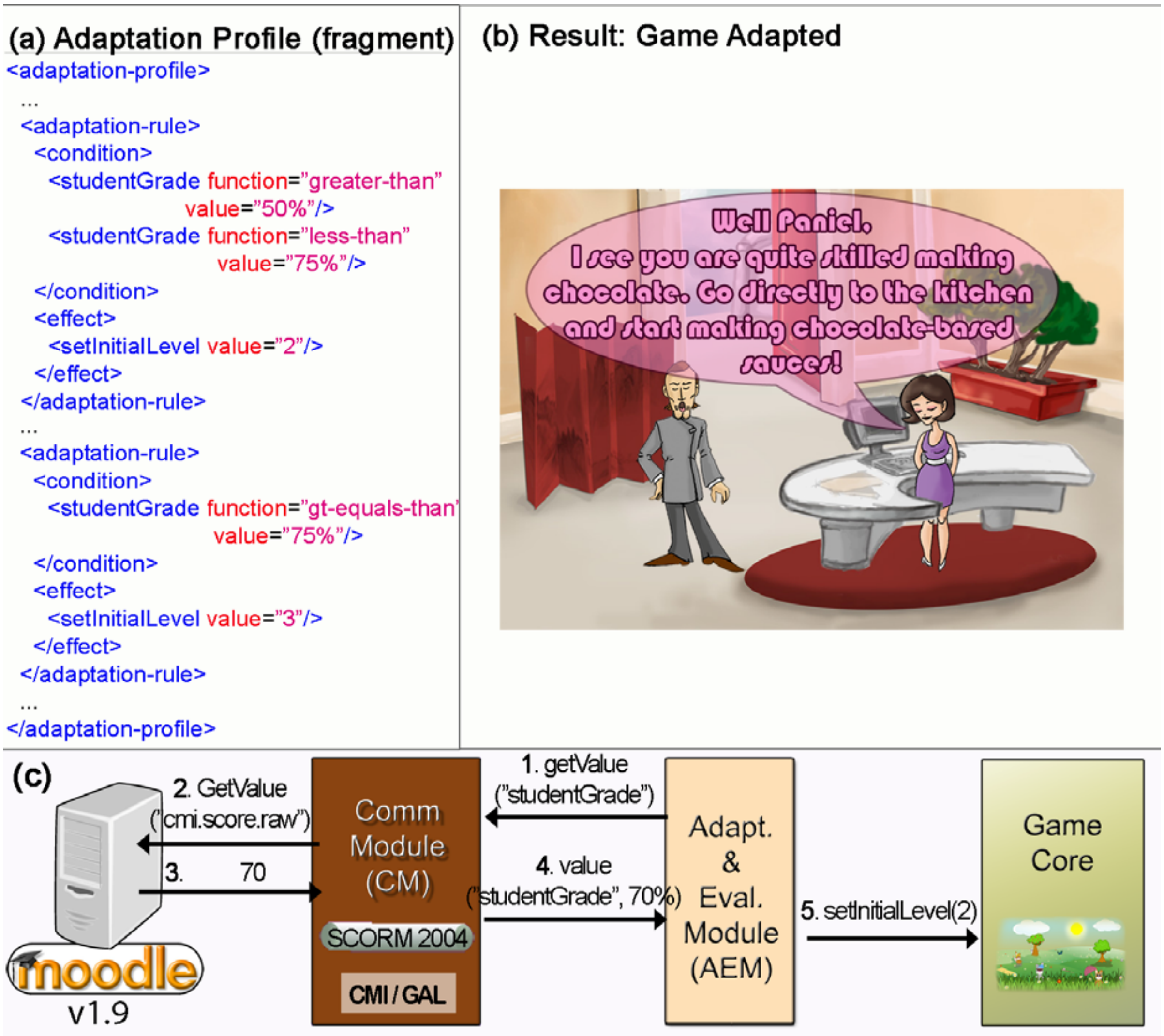

Figure 4: (a): Fragment of the adaptation profile used in the example. (b): Screenshot of the game adapted. (c): Communication sequence between the two modules (CM and AEM), the VLE and the game core. While (a) and (b) are independent of the actual platforms being used, (c) depicts the communication through the platforms and standards that were actually used.

Besides, the game includes an in-game test that produces a final grade. This abstract grade is submitted to the VLE through the middle-ware, following the same steps (translation of the game concepts into general terms and then translation into VLE-specific constructs). This grade can then be used in future executions of the game to make the initial adaptation decision.

While testing this example in an <e-Adventure> case study, we use the same profiles but in this case we set the architecture to work with SCORM v1.2. to the game was integrated in *Moodle*™ v1.9 (the VLE) as a SCORM/AICC activity. As we have not implemented the GDMA yet in the case study, the terms related to the game state in the rules are expressed in terms of <e-Adventure> variables and flags. The terms related to the VLE state are expressed as SCORM v1.2 data model elements. The <e-Adventure> editor assists the process to fill this information in the profile.

For this example, the <e-Adventure> game developer must only know the game flow (a task that is well identified in the editor) and the SCORM 1.2 data model. Should the developer want to distribute the game through a different platform, for example, SCORM 2004, the only required task is to modify the communication profile, using elements from the SCORM 2004 data model. The game itself does not need to be changed.

Experience 2: Using <e-Adventure> and Moodle 2.0 in the Spanish R&D eduWAI Project - "The Big Party"

The game "The big party" aims to foster the develop social skills and personal autonomy for people with intellectual disabilities (e.g. Down Syndrome). The game has been developed in collaboration with the educators of Prodis[1] foundation for the eduWAI Spanish R&D project, which seeks the inclusion of this collective in the workplace. The game trains students for a social event organized by the company where they work. To complete the game, the student must achieve five objectives related to personal hygiene, clothing, principles of etiquette, principles of good behavior and use of common resources. At the beginning of the game, the user selects him/her gender. This choice will be used to adapt the game to fit the clothes and hygiene items to be shown. Some student's interactions can modify the flow of the game, but no game adaptation is defined taking into account the student profile. The game includes a detailed assessment definition to track those players' interactions related to the achievement of the objectives.

The eduWAI platform includes Moodle 2.0 for managing the educational courses. "The big party" game has been integrated in Moodle 2.0 as a SCORM 2004 activity in the aim of communicating the assessment information generated by the game. We followed the same steps as in the previous experience in terms of setting up the

[1] http://www.fundacionprodis.org/

architecture, but for SCORM 2004. Each broad objective was divided in 42 different sub-objectives and each of them was mapped to an assessment rule. Each sub-objective reflects a set of user interactions that are educationally relevant, filtering the assessment data. Besides, the rules append annotations about the achievement of the objectives and sub-objectives onto the assessment report. The evaluation profile has been set to send the assessment report to the CMI data model. As a consequence, educators are provided with different levels of information. They can use the assessment report for a gathering a glance of the experiences, and if they want more detailed information, they can consult the data sent by each single assessment rule.

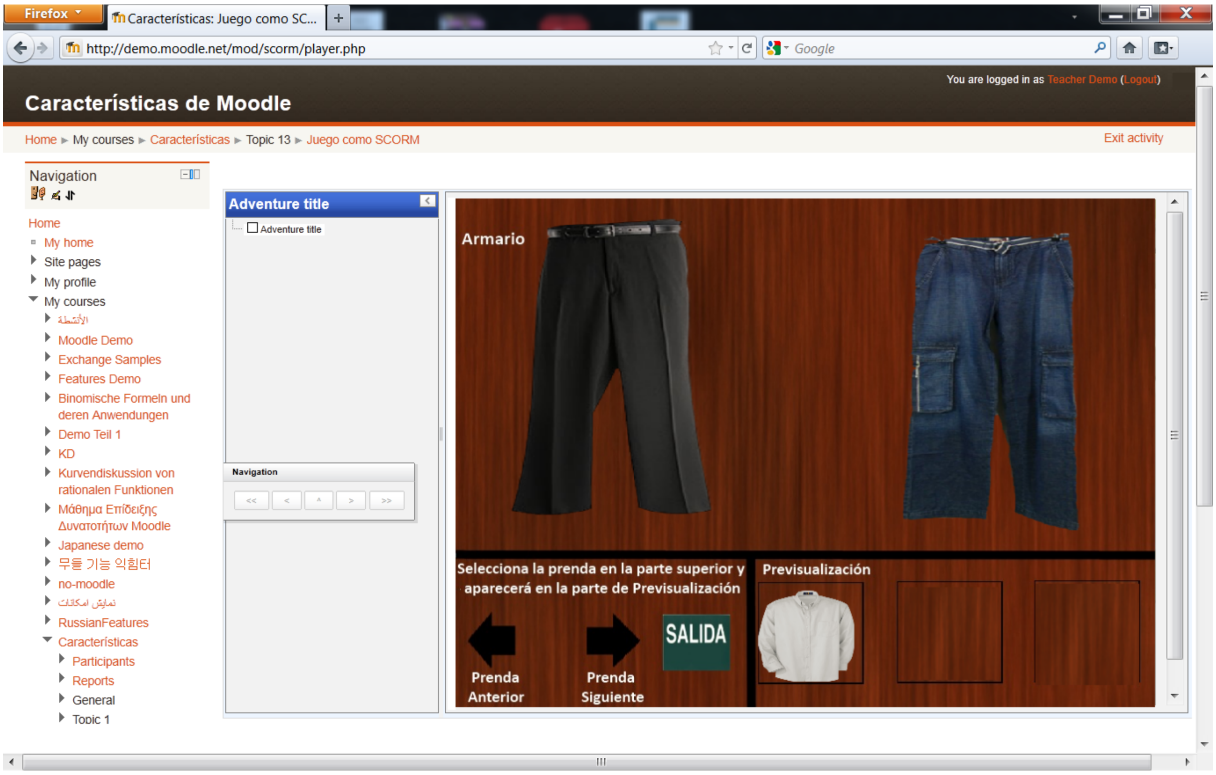

Figure 5: Example of "The big party" game integrated in eduWAI platform using SCORM 2004 module in Moodle 2.0. The figure depicts the wardrobe where the student has to choose the appropriate cloths for the party.

Experience 3: Using <e-Adventure> and LAMS in K-12 schools - "The Parity" game

In collaboration with teachers of the first courses of a primary school in Madrid (Ramiro de Maeztu) we created a sequence of activities to teach basic mathematics (Del Blanco, Torrente, Marchiori, Martínez-Ortiz, Moreno-Ger, Fernández-Manjón, 2011). In this process, a game to teach parity was developed using <e-Adventure>. The game uses the story about a couple of turtles, called Odd and Even. In the beginning of the story Odd is identified with odd groups and Even with even groups. Later on the pupils must match Even to even groups and Odd to odd groups using a drag&drop mechanism. The difficulty increases through five levels including numbers from one to ninety nine where the students have to identify the parity in groups, single numbers, additions and subtractions (in these two cases they'll also need to make the calculation first). The game includes assesment and a simple adaptation profile. The students begin with one hundred points score. Matching one of the turtles to a wrong element results in a score drop of ten or five points, depending on the current level. This information is sent to a LAMS system, which was used as VLE, and appended as an annotation in the assessment report with a timestamp, the level and wether it was with odd or even groups.

We implemented the lesson as an activity sequence in LAMS, where each step in the educational lesson is represented by an activity. The following activities are identified in the educational lesson and mapped in LAMS as follows. First an explanation about parity is presented to introduce the main concepts. It is done using a power point presentation in an LAMS “Image Gallery” activity. Then, we use an “<e-Adventure>” Activity (Del Blanco *et al.* 2010) where through a small story the acquisition of the concepts are reinforced and where the pupils must identify a set of odd an even groups. If the student passes the test presented in the game, the sequence is over. If the student does not complete the game, another presentation is showed for odd an even concepts review and he or she will have to play the game again.

A LAMS Branching Activity was used to define the flow control of the sequence. The Braching Activity can communicate data with the game, and allows using this data to define the path to be followed. The input and outputs the game accepts are produced by the game editor and enclosed in the game package when the game is exported. LAMS does not provide a specific data model, so game developers are free to define the name of parameters to be sent (using the game editor) and give them the use they consider appropriate. In order to ease this process for developers who are not familiarized with the assessment of educational video games, we proposed a small predefined data set as a start point. This data set includes the game score, timestamp and if the game was completed, but can be extended when needed without modifying de CM profile for LAMS. We use this data set in this experience so each Branching activity uses the score and the completed values for bifurcating students to the two possible paths.

In this experience, educators can define automatic flow modifications over the sequence in LAMS that depends on game assessment. Furthermore, they can review the assessment report and the variables sent to LAMS to get further information about what happened during the game execution. The game does not extract information from LAMS to adapt the content but the assessment data is used to adapt the sequence automatically.

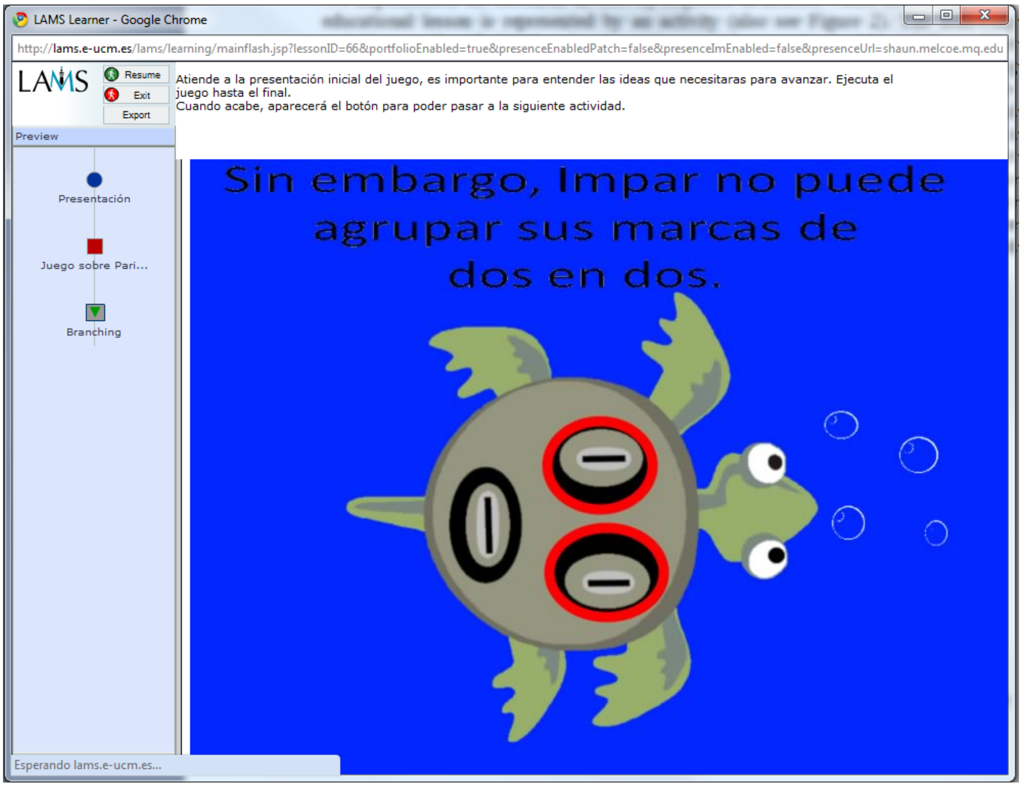

Figure 6: Example of "The parity" game integrated in LAMS platform and used in Ramiro de Maeztu School. The figure depicts the initial instructions gave to students.

CONCLUSIONS AND FUTURE WORK

In this paper we have discussed the benefits that game-based learning can bring to e-Learning in terms of **adaptation** and **assessment**. However, bringing both worlds together is a technically challenging task ought to the complexity of both fields. Especially relevant in this concern is the diversity of VLE **communication** and standards (SCORM, IMS LD, etc.) in e-Learning.

Our contribution is a general architecture for the integration of adaptive games in **student-centered** VLEs, consisting of a two-module middle-ware which abstracts the existing standards or specific VLE implementations. Using this architecture, the communication between a standards-compliant VLE and an adaptive educational video game is independent of the specific game or standard. This allows game developers to create games without needing to be concerned with the internal details of each possible implementation of the student-centered VLE, focusing in this manner on the design of pedagogically relevant aspects.

For example, if a teacher were interested in using "The big party" game in a LAMS VLE, only the communication settings profile would need to be changed. In this way teachers can exploit these educational features. However, if the game had been designed directly as a SCORM package, it could only be used in a SCORM-compliant VLE for the specified purposes of **adaptation** and **assessment** unless those features were implemented again. This widens the range of teachers that can reuse the educational games as this approach is scalable to other platforms, games and educational settings. The interoperability, maintainability and reuse of the contents are addressed as the architecture is flexible enough to support new standards and revisions thanks to the notion of pluggable adapters.

We have tested this middle-ware in the <e-Adventure> educational game platform, which provides an authoring environment for **educational games** with special emphasis on the integration with VLEs, adding support for the APIs provided by the architecture. We use the rules model implemented in <e-Adventure> to implement the concepts exposed in the General Data Model. In the last years we have conducted real experiences in different educational settings in order to test the **assessment** and **adaptation** features following instructions and advice by the teachers and educators we collaborated with. In "The big party" game, educators decided to extract accurate information about the students' performance in different levels of granularity in a standard way. In "The parity game" educators sought a first contact with game usage in education taking advantage of assessment and evaluation features.

The instructors from the Ramiro the Maeztu public school were pleased with the easiness of creating sequences in LAMS and connecting <e-Adventure> games in the sequences. Educators working in the eduWAI project have also left very positive feedback about the possibilities presented by the use of the SCORM specification to gather information from the game and access it through their own Moodle. They also highlighted the usefulness of this Game-Base Learning approach (Del Blanco *et al.* 2011). Both examples depict how the architecture can be used to implement similar adaptation and assessment models in two different games, and communicate the results to/from two very different VLEs but hiding the technical details of the communication to educators.

The preliminary results are promising, but also indicate some issues that will require further research. On the one hand, adaptation is a very complex issue. To exploit all the potential of adaptive game-based learning the general adaptation model must be extended and refined far beyond its current state. The discussion of how to adapt the content and in what circumstance it should be adapted is still an open research question. Moreover, the automatic detection of in-game situations which require adaptation deserves its own line of research.

On the other hand, the middle-ware must be expanded to include more modules for additional communication standards, including VLE-specific plugins for those environments that do not provide a standardized method for content-to-VLE communication. On the game side, we are also working on the implementation of the architecture for different game engines in different platforms.

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