Bridging the Gap: Adaptive Games and Student-Centered VLEs

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Abstract. The widely used e-learning technology is facing new challenges such as how to produce student-centered systems that can be adapted to the needs of each student. Those objectives should be met in a standard compliant way to simplify general adoption. In this context, educational videogames are proposed as an ideal medium to facilitate adaptation and tracking of the students' performance for assessment purposes. However, there are still barriers between the gaming and e-learning worlds preventing their mutual interaction. In this paper we propose a middleware to bridge this gap, integrating adaptive educational videogames in e-learning environments with a special focus on the ongoing standardization efforts.

Keywords: Educational videogames; Virtual Learning Environments; Adaptive Learning; Assessment; SCORM.

1 Introduction

Nowadays, the use of e-learning is increasing in industry and educational institutions. At the same time, e-learning systems have evolved from the original repositories of static content into richer Virtual Learning Environments (VLE), also known as Learning Management Systems (LMS) that follow different standards and specifications to assure the interoperability of the materials. The new student-centered features being adopted (such as VLE-driven adaptation of the learning experience or user tracking and assessment) demand further standardization efforts and raise new technical challenges.

Besides, there is an emergent trend in Technology-Enhanced Learning advocating for the use of educational videogames and game-like simulations [1, 2]. Educational videogames have key advantages such as their suitability to convey concepts [3] or to increase students' motivation [4]. Another key feature of educational games is that their high level of interactivity can provide fine-grained adaptation and performance-tracking mechanisms. This interactivity can open new possibilities in the e-learning field in terms of adaptive learning experiences, compared to those offered by more "traditional" hypermedia contents.

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However, to bring the benefits of adaptive educational gaming to the e-learning field, we need to deal with the current diversity of VLE and with a lack of proper standardization support for the peculiarities of game-based learning.

This article presents a general architecture to integrate games in VLE with special emphasis on supporting adaptation and assessment. This architecture is designed to provide an abstraction layer (i.e. middleware) that allows game designers to create adaptive educational games without committing to a specific educational standard, thus offering the possibility of reusing the same game in different VLEs and contexts.

This paper is organized as follows. First, in section 2, we analyze the current state of the e-learning field in terms of assessment, adaptation and standards; then, in section 3 we discuss how videogames can contribute to assessment and adaptation in e-learning and current challenges behind this approach. Section 4 describes the architecture we propose and finally, in section 5, we present some conclusions and outline future lines of work.

2 VLEs: Assessment, Adaptation and Standards

VLEs are rapidly evolving, giving the instructor more support and advanced tools to create complex online learning experiences. However, the increasing complexity of the content, including highly interactive pieces of content such as educational videogames, requires further support for the instructors. The new VLEs need to facilitate tasks such as tracking the progress and the skills acquired by the student within the games, 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. At the present time, compliance to e-learning standards is a crucial factor when selecting a new VLE implantation within an organization.

E-learning specification and standardization initiatives are numerous, involving different organizations and consortiums such as the IEEE or IMS, and deal with the different aspects of the e-learning processes. This includes standardizing aspects such as supporting the creation of courses as aggregations of simple units of content (the Learning Objects Model [5]), the annotation of contents or the packaging of the courses. However, the ongoing standardization efforts are also covering more sophisticated aspects such as content sequencing or student profiling.

Even though the use of standards to package and distribute content is well established in current VLEs, these standards do not simplify the widespread adoption of student-centered approaches with adaptation and performance tracking. For that reason, some initiatives such as the IMS Learning Design specification [6] are aiming to provide a standardized representation of the full learning process, taking into account pedagogical values.

With a lower degree of expressivity but a much wider adoption, the SCORM framework (Shareable Content Object Reference Model) has been proposed by ADL (Advanced Distributed Learning). This framework, an initiative of the U.S. administration to improve e-learning [7], is probably the most extended solution

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nowadays. In addition, SCORM defines a communication model that allows the exchange of information between the content and the VLE in a standardized way.

However, currently two versions of SCORM coexist: SCORM1.2 and SCORM 2004 in most VLEs. Even though the newer version is more complete and adaptable, the full adoption of SCORM 2004 by mainstream VLEs (e.g. Moodle, Sakai or BlackBoard) is still an ongoing process. In addition, some environments such as those based on the IMS Learning Design specification [6] or supported by LAMS [8] are also valid alternatives for student-centered processes.

Therefore, the adoption of this type of advanced VLE 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.

3 Game-based Learning and e-learning

As it has been widely discussed in the literature during the last years [9], the use of videogames can enhance the learning processes in many aspects. The most frequently cited benefits of game-based learning are the increase of the motivation of the students, the relation between videogames and constructivists theories [4] or their support for collaborative/competitive learning. However, the full potential of videogames for education is almost undiscovered and requires further research.

3.1 Videogames, adaptation and assessment

Nowadays, personalization is a common feature in videogames. Game developers and publishers include mechanisms in their videogames to adapt the game experience to suit the requirements of the widest possible range of users. The most obvious type of adaptation in videogames is the inclusion of different levels of difficulty, trying to adjust the challenge to different skill levels.

However, the potential is even bigger thanks to the high interactivity of games that can be used to implement much more fine-grained adaptation mechanisms (which can be carried out even transparently to the user). For example, the *MaxPayne*™ videogame incorporates Dynamic Difficulty Adjustment techniques [10] that alter the game execution depending on the actual performance of the user.

In addition, this fine-grained interactivity can also be monitored, allowing the collection of data gathered from user-game interaction that can be used to track the students' performance. This can bring new opportunities to the e-learning field to produce automatic assessment reports of the learning achievements of the player.

3.2 Current challenges integrating game-based learning in VLE

As previously discussed we believe that educational games can be an ideal medium to deliver student-centered content in VLEs. However, new challenges must be faced to exploit the potential synergies between adaptive game based learning and e-learning.

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One issue concerns the flexibility and maintainability of the content, a key issue in e-learning but which is rarely present in videogames. In order to become a more useful tool in student-centered VLEs, the games must behave more openly, allowing the instructor to know what happens during the game sessions and to modify the behavior of the game. This requires the definition of specific models that allow the instructor to interact with the game experience remotely. This can be done using the standards mentioned in the previous section, which presents two open 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 [11]. 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. For a single videogame these issues may be acceptable, but if a large investment is planned, the problem becomes significant. This is especially relevant if we want to move towards educational experiences that contain diverse types of games that communicate with each other [2].

On the other hand, there are no tools that facilitate the addition of adaptive and tracking behavior to educational games. When developing an adaptive and assessable educational videogame, it is necessary to maintain a model of each student persistently, and developers must decide how to adapt the game experience according to that user model. If this behaviors are programmed ad-hoc in the game, the investment could become useless if instructors need to modify the adaptive and assessable behavior of the game (for instance, if the educational videogame is to be used in a new educational context). The problem of the student model persistence could be solved if instructors could directly set up the adaptation and assessment configuration of the game and connect the videogame with a LMS.

While the problem of connecting interactive content (such as games and interactive simulations) with LMS in standard-compliant ways has been partially addressed [12], 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.

Therefore, to facilitate the inclusion of educational games into the current student-centered VLE 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.

4 The architecture

In this section, we describe a general architecture that facilitates the integration of educational games in student-centered VLEs. The architecture was designed to alleviate the potential issues described in the previous section in terms of standards compatibility, adaptation and assessment.

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4.1 Overview of the architecture

The architecture provides a two layer middleware. The first layer, called communication layer (CL), abstracts the communication between the game and the VLE. This layer is dependant on the specific standards supported by the VLE (e.g. SCORM). The VLE-specific data is translated to abstract adaptation and evaluation concepts. The abstract adaptation data is transmitted to the game-adaptation layer (GAL) that is specific for each game or game engine. The GAL translates this abstract adaptation constructs into specific actions or transformations within the game.

In addition, the GAL tracks the activity of the student and uses such information to produce an evaluation of the student in abstract terms. The assessment abstract commands are given to the CL, which sends it through a standard-compliant channel to the VLE. Thus, the CL adds independency from the specific standard supported by the VLE both for adaptation and assessment communication.

The fact that the middle-ware employs abstract adaptation and assessment constructs means that both the game and the VLE can be completely independent and interoperable.

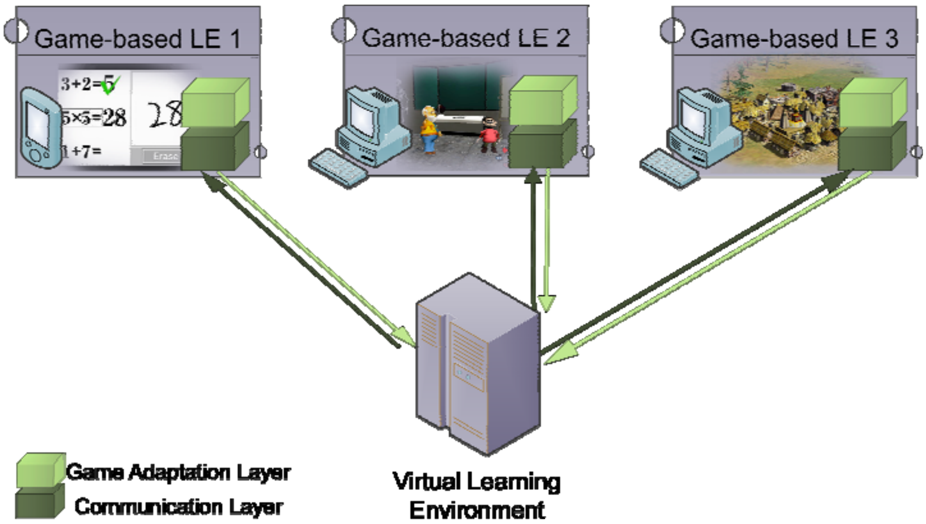

Fig. 1. General view of the architecture

The role of the games in terms of assessment and adaptation is to provide valuable information about the performance of the student. This information is used by the middleware to drive a fine-grained online adaptation of the learning experience and to produce an assessment report that can be included in the VLE student profile. Those reports can be also used to update the student profile, therefore supporting a full adaptation cycle.

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4.2 Using the double layer middleware

The CL layer includes implementations for some common standards in student-centered environments (based on specifications such as IMS-LD, SCORM1.2 or SCORM2004). When the game is run, the CL consults a configuration file (communication settings profile) to select the standard used to establish the communication with the VLE.

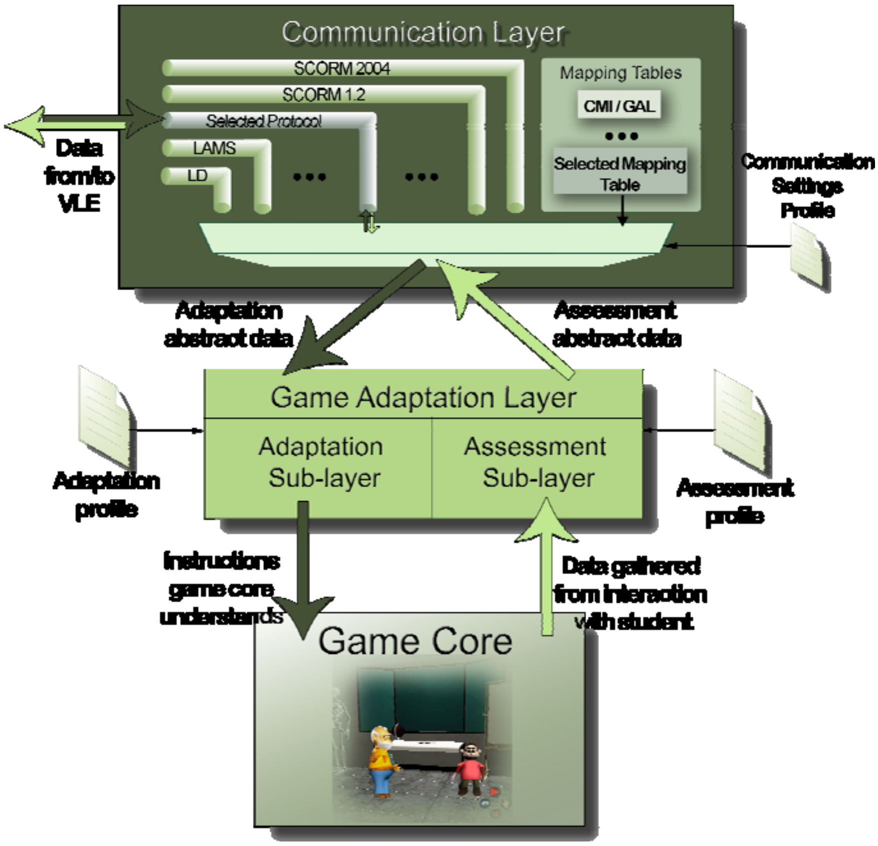

Fig. 2. Communication between the two layers (middleware) and the game core.

For each standard, the CL includes two relevant elements: an implementation of the communication protocol between the VLE and the game-based content that the VLE supports or defines, and a profile specifying how to map the abstract adaptation and assessment data model that the GAL understands to the communication data model defined by the standard. In some cases, the standards already provide a pre-established data model (e.g. CMI data model for SCORM). However, when the selected standard does not define the communication data model (e.g. Learning Design) the Communication Settings Profile would include the mapping table that the CL must use in the communication to store and retrieve the required information. In

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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 CL are clearly isolated to allow flexible and systematic extensions and modifications of the layer, which guarantees interoperability and a longer life cycle for the architecture. New standards can be easily plugged in into the CL 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 other cases, it will be dependant on the VLE. Secondly the mapping profile must be written, defining the translations between the abstract constructs and the VLE-dependant constructs.

In turn, the GAL focuses on translating the abstract constructs into game-specific commands. In a typical case, the GAL, via the adaptation sub layer (figure 2), polls the CL to get abstract adaptation commands (the CL gets the data from the LMS and translates it to the GAL language), and transforms those commands into game specific actions that modify the game experience. Then GAL will also listen to the interaction of the player in the game through an API that game developers must follow and will detect those situations that must trigger adaptation mechanisms. The specific actions that must be executed to adapt the game experience are defined by game authors through an adaptation profile (e.g. adjust the difficulty, give additional guidance, etc.).

The assessment sub-layer listens to the interaction between player and game as well. It uses also a profile (assessment profile), defined by the game author or the instructor, which determines the situations that must be assessed and how to track the activity of the student by defining assessment rules. When the game enters states matching any of the assessment rules (e.g. the student fails in completing a task) the assessment sub layer translates it into an abstract assessment construct.

Then the CL transmits the information to the VLE, encoded according to the data models of the specific target environment, so that the VLE can attach the results to the profile of the student. In this manner the student is re-profiled and in future executions the adaptation can be performed more accurately.

With this structure the underlying communication standards, as well as the specific details of each game are completely transparent. Authors only need to modify the middleware configuration file to change the standards and specifications used in the communication. Besides, the double layer middleware helps instructors and educational game developers to think about adaptation and assessment more naturally, without considering technical communication details.

4.3. Example of the communication between VLE and game

The architecture presented can be 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 with a specific VLE which supports the IMS Learning Design specification [13]. The purpose of the game is to introduce chocolate-based cooking techniques from a practical perspective, and is divided in three stages of different levels of difficulty. The initial level (the simplest) teaches how make chocolate, the second level teach how make chocolate-

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based sauces, and the third level teaches how to combine them with dishes (the most challenging level).

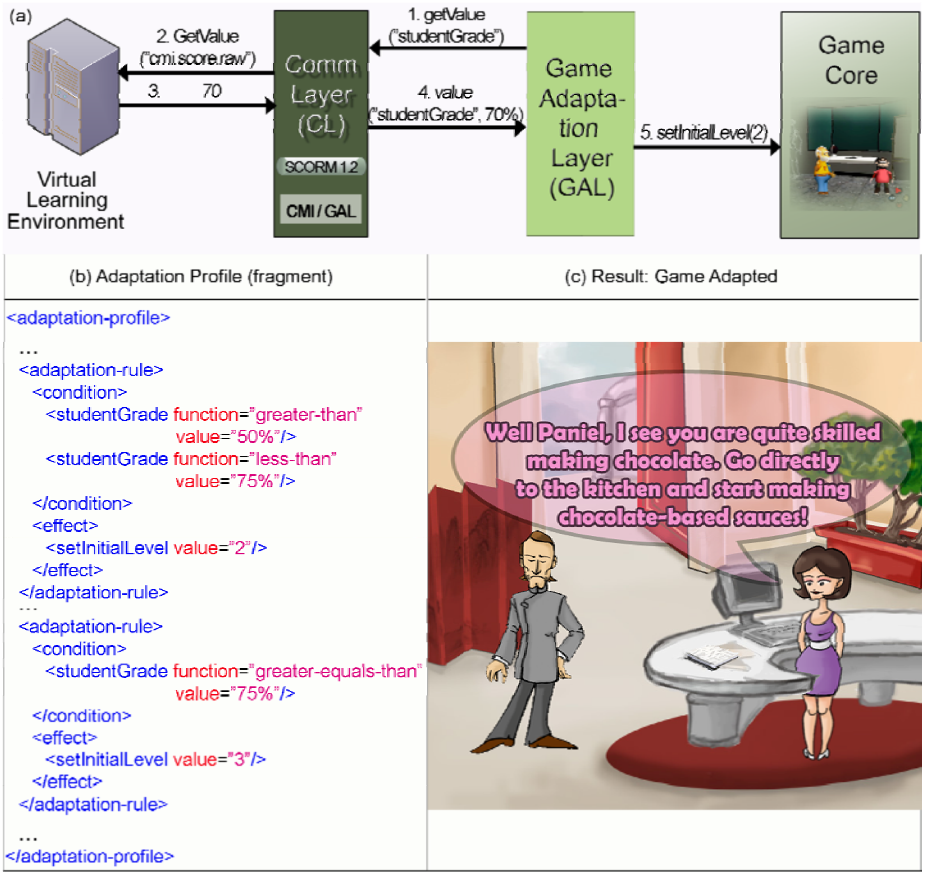

Fig. 3. (a): Communication example diagram between the two layers, the VLE and the game core. (b): Fragment of the adaptation profile used in the example. (c): Screenshot of the game adapted

For this game the GAL is set up with an adaptation profile that modifies the game depending on the prior knowledge of the student (figure 4b). When the game is executed, the GAL requests information from the VLE asking the overall grade of the student (figure 4a-step1). Then the CL, which has previously set up the communication channel with the VLE accordingly to the communication settings profile, codifies the request using the appropriate model, and sends it to the LMS. For instance, when deployed in a SCORM-compliant environment, the CL translates this abstract request into a check of the appropriate fields from SCORM's CMI data model (figure 4a-step2). The layer manages the request through the SCORM RTE and maps it to the GAL abstract data model (figure 4a-step4). The GAL then interprets the abstract response and uses the adaptation profile to decide to what level the student should go, skipping the first levels if appropriate. In this example, the adaptation

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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 due to any cause the overall grade could not be retrieved from the VLE, or if the overall grade is less than 50%, no levels are skipped (figure 4a-step 5).

Besides, the game includes an in-game test that produces a final grade. This abstract grade is translated to the appropriate fields of the SCORM data model and submitted to the VLE through the middle-ware, following the same steps (translation of the game concepts into abstract information 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.

5 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 games in VLE, consisting of a two-layer middleware which abstracts the existing standards. Using this architecture, the communication between a standards-compliant VLE and an adaptive educational videogame 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. 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 middleware in the <e-Adventure> educational game platform [14], which provides an authoring environment for educational games with special emphasis on the integration with VLEs [15], adding support for the APIs provided by the architecture. The preliminary results are promising, but also indicate some issues that will require further research.

On the one hand, adaptation is a complex issue. To exploit all the potential of adaptive game-based learning the abstract 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 middleware must be expanded to include more modules for additional communication standards, including VLE-specific plug-ins 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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References

1. Tang, S., Hanneghan, M. and El Rhalibi, A.: Describing Games for Learning: Terms, Scope and Learning Approaches. The Fifth Annual International Conference in Computer Game Design and Technology, Liverpool, UK (2007) 98-102.
2. Torrente, J., Lavín-Mera, P., Moreno-Ger, P., Fernández-Manjón, B.: Coordinating Heterogeneous Game-based Learning Approaches in Online Learning Environments. the Sixth International Game Design and Technology Workshop and Conference (GDTW2008), Liverpool, UK (2008) 27-36.
3. Hamid, A.A.: e-Learning: Is it the "e" or the learning that matters? The Internet and Higher Education **4** (2001) 311-316.
4. Gee, J.P.: What video games have to teach us about learning and literacy. Palgrave Macmillan, New York ; Basingstoke (2003).
5. Balatsoukas, P., Morris, A., O'Brien, A.: Learning Objects Update: Review and Critical Approach to Content Aggregation. Educational Technology & Society **11** (2008) 119-130
6. IMS Global Consortium: IMS Learning Design Specification, Version 1.0 Final Specification. (2003).
7. ADL: Advanced Distributed Learning Sharable Content Object Reference Model (ADL-SCORM). Vol. 2006 (2006).
8. Dalziel, J.: Implementing Learning Design: The Learning Activity Management System (LAMS). In: Crisp, G., Thiele, D., Scholten, I., Barker, S., Baron, J. (eds.): 20th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education. ASCILITE www.ascilite.org.au, Adelaide (2003).
9. Aldrich, C.: Learning by Doing: A Comprehensive Guide to Simulations, Computer Games, and Pedagogy in e-Learning and Other Educational Experiences. Pfeiffer, San Francisco, CA (2005).
10. Robin, H.: The case for dynamic difficulty adjustment in games. Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. ACM, Valencia, Spain (2005).
11. Kanendran, T.A., Savarimuthu,J. and Durga-Kum, BV.: e-Learning Standards. Proceedings of the 3rd European Conference on E-Learning, Paris, France (2004) 131-143.
12. A. de Antonio Jiménez, R.R., J., & Madrigal Alfaro, Z.: Architecture for Integration of Simulations with SCORM in E-learning Environments. Eighth IEEE International Conference on Advanced Learning Technologies (ICALT 2008), Santander, Spain (2008) 217-221.
13. Burgos, D., P. Moreno-Ger, J.L. Sierra, B. Fernández-Manjón, M. Specht, & R. Koper: Building Adaptive Game-Based Learning Resources: The Marriage of IMS Learning Design and <e-Adventure>. Simulation & Gaming 39 (2008) 414-431.
14. Torrente, J., Moreno-Ger, P., Fernández-Manjón, B., Sierra, J.L.: Instructor-oriented Authoring Tools for Educational Videogames. 8th International Conference on Advanced Learning Technologies (ICALT 2008). IEEE Computer Society, Santander, Spain (2008) 516-518.
15. Moreno-Ger, P., Burgos, D., Sierra, J.L., Fernández-Manjón, B.: Educational Game Design for Online Education. Computers in Human Behavior **24** (2008) 2530-2540.

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