Game-Based Learning in e-Learning Environments

Pablo Moreno-Ger, José-Luis Sierra-Rodríguez, and Baltasar Fernández-Manjón

The use of videogames as a part of educational processes is becoming one of the most progressive trends in the field of educational technologies. In our opinion, the integration of videogames and e-Learning environments is a critical aspect in the promotion of this trend, due to the importance of e-Learning in 21st century educational processes. In this article we identify two aspects that are critical in bringing about that integration: (i) the introduction of authoring methods that will cut development costs and help instructors take an active part in that process, and (ii) the development of models to integrate videogames into e-Learning platforms that will facilitate a two-way exchange of information and dispel the perception of games as mere black boxes. This article provides an example of these aspects with <e-Adventure>, an environment for the authoring of educational graphic adventures and the integration of the resulting games into on-line learning environments.

Keywords: <e-Adventure>, e-Learning, Educational Games, Educational Content Authoring, Learning Management System.

1 Introduction

Society today is changing at a great pace, driven by the growth rate of Information and Communication Technologies (ICT). Present day educational structures, put in place in the late 19th century and the first half of the 20th century, are based on the classical idea of encyclopaedic knowledge and a simplistic view of education as the mere direct transmission of that knowledge [1]. But now the industrial age has been overtaken by the information age, in which a new model of society (the Information Society) requires new skills and competencies. Learners today need training that covers topics such as the development of cognitive skills, problem solving skills, information retrieval and filtering, and the acquisition of knowledge in new domains. And this not only requires the development of new skills, but also calls for new ways of interacting with information. Learners today are used to receiving information from various sources in parallel, in rich and attractive multimedia formats, in a participative and interactive manner and always at great speed. The TV generation has given way to the generation of the Internet, videogames, and mobile communications. In many cases the slower, more structured, unidirectional approach of a class (or even of a digital document) is totally at variance with modern learners' normal way of doing things and arouses a sense of antagonism and demotivation.

Meanwhile, videogames have been developing in recent years until they are now one of the most important branches of the entertainment industry, and the idea of using them for educational purposes has been gaining more and more ground [2]. The very elements that we blame for distracting our learners may be the ideal vehicle to reach them. How-

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ever, the arguments put forward by many academics in the field for bringing games into education go beyond the simple idea that "*if they like games and hate classes, let's use games to teach with*". If we take such a simplistic view we run the risk of merely reproducing traditional content under a multimedia wrapper instead of studying and taking advantage of the new and exciting features of the medium. This trend, commonly referred to as *Edutainment*, came to prominence in the nineties, when multimedia computers became widely available to households. Towards the end of the same decade the term *Edutainment* began to lose much of its credibility as the market became saturated with poorly designed games (both in educational and entertainment terms) [3]. Studies researching into which elements make videogames appealing highlight factors such as mechanisms for controlled and perceptible progress, immersion in an abstractly represented world, multimodality and, especially, a very short feedback cycle that allows players to develop theories and put them to the test in such a way that they receive an immediate answer from the game that allows them to find out whether or not their theory was correct [4] [5]. All these elements are, at the same time, desirable characteristics of an effective learning process [6][7].

From our point of view games can be a powerful resource in education, but not if used indiscriminately. Therefore one of the first things to do is to determine what kind of games have an educational value, in which cases the development costs are worth funding, who the target audience groups are, and what subjects they are to help teach. In this respect, we believe that the field of e-Learning may be an ideal proving ground due to its dynamism and technological infrastructure. At the same time, technology needs to address other issues such as facilitating the development, deployment, and maintenance of e-Learning. In this article we aim to analyse the problems arising from addressing the integration of educational videogames into e-Learning environments while keeping costs down and ensuring the active involvement of instructors and content developers. Thus, in Section 2 we take a closer look at why we consider e-Learning to be the ideal proving ground in which to explore the integration of videogames into the learning process, before going on to identify the obstacles that need to be overcome from a technological viewpoint. Later, in Section 3, we describe the <e-Adventure> platform, which was specifically developed to address these technological challenges. Finally, in Section 4, we discuss the impact that this technology may have as a support for developing educational models combining videogames with e-Learning.

2 Educational Videogames in e-Learning Environments

One of the most salient issues to emerge in this field so far is to find an answer to the question of how to incorporate educational videogames and simulations with game elements into the current educational system. In spite of the fact that the inertia of the traditional educational system makes it reluctant to adopt new educational methodologies, if we look a little beyond the concept of the traditional school, we can find fields that are already prepared for the use of these innovative approaches. Perhaps the best example is e-Learning.

E-Learning environments went through a major crisis in the late nineties when they became gigantic "graveyards" of static content of very little educational value [8]. The current trend, however, is towards the creation of complex systems that include the tailoring of content to different user profiles, detailed monitoring of the learning process, and support for varied learning paths that go beyond linear learning models. In some cases, all this process is carried out under standards and specifications intended to ensure the interoperability of content or information about the learners, and even entire instructional designs [9]. Thus, the incorporation of educational games in modern Learning Management Systems (LMS) will allow us to make use of the available technological infrastructure and to facilitate the task of integrating games with the rest of the instructional design and the assessment mechanisms available in these learning environments.

However, videogames should be used in virtual learning environments with caution. The creation of educational videogames is a much more complex and costly task than the creation of other types of educational content. Also, the integration of these games in such environments poses a number of technological challenges in terms of reaping all the potential benefits of videogames. For this reason we view the authoring of content and its integration with existing e-Learning infrastructures as especially important problems.

2.1 The Authoring Factor

The first obstacle encountered when we begin to incorporate educational games in e-Learning environments is their "economic viability". While it may be true that they provide a quality educational experience, just how much better is this experience compared with other content such as HTML documents with explanatory graphics? Enough to justify the enormous difference in cost?

The results of a survey conducted in a session on educational games during the *Game Developers Conference 2005*[1], which included questions on the development costs of projects running at that time, show that 26.23% of the answers were in the $100,000 to $500,000 bracket, while 52.46% of the projects fell within the $100,000 to $10,000,000 bracket [10]. Another study estimates the development costs of a "latest generation educational simulation" at between 15 and 30 person-years [11]. The development of quality educational videogames also requires experts in education and/or the target domain (for example, History or Medicine) to be included in the design teams

[1] <http://www.gdconf.com/>. The conference brings together a number of professionals from the videogame industry and is one of the most important events in this field.

along with the usual designers and programmers. This cost is too high for the budgets of most online educational initiatives, and so we need to create development methodologies capable of optimizing the process to adapt projects to smaller budgets while taking into consideration the particular characteristics of game development (e.g. the coordination of heterogeneous working groups).

Also, as a rule a commercial videogame is fully designed, distributed, and sold as a closed and finished product. Educational content requires greater flexibility to enable it to be easily modified to tailor it to a number of different contexts. In the case of the traditional content of e-Learning environments (based on static or low-interactivity content), it is easy to adapt to these changes by updating the documents.

However, if the content consists of an educational game which is a compiled unit, to modify that content requires the involvement of the developers who created it, who may not even still be available. To overcome this limitation, educational games must be easy to maintain and, in particular, must be easily modifiable and adaptable, ideally without the need for the original developers to be involved. This will allow the educators to play an active role in the upgrading and adaptation of game content.

2.2 The Content Integration Factor

The easiest way to integrate educational videogames into LMS systems is to develop games that can be distributed in a Web environment. Games run on learners' browsers so that they can interact with the game. From the point of view of the LMS, the game is just another document. If we draw a parallel with traditional learning, this is like giving the game to the learners for them to play at home without supervision from an instructor. In engineering terms, this is known as black box behaviour as the game is a self-contained entity that behaves in a certain way, but we do not have any details of its internal workings, neither is there any way we can alter them. When the game finishes, the only information the LMS has for the next sequencing decision is the time elapsed from when the game started running and, in certain cases, the final state of the game (see Figure 1). The main advantage of this approach is that it functions independently of the implementation of the game, provided that the game meets the minimum requirement of being able to be run from a browser. Any LMS, however simple it may be, will be capable of displaying this type of content.

However, with the black box model it is impossible to carry out a detailed monitoring of the interaction between learner and game, which is necessary if we wish the instructor to see whether the student is learning the right lessons by interacting with the game [12]. Rather than simply observing the time elapsed in each game session and the final state of the game, with videogames that do not behave as black boxes it is possible to get the answers to such questions as: "What decisions did the learner make?", "In what order?", and "What was the outcome of the action?". Allowing teachers to have access to such information may help games be accepted in educational processes more readily, especially by the teachers themselves. Therefore the aim is to provide LMSs with a greater control over the internal workings of the game and to achieve a more transparent and flexible integration than with the black box approach.

3 An Example of the Creation and Integration of Educational Games for e-Learning Environments: <e-Adventure>

<e-Adventure> is a platform for the creation of digital educational games intended for integration with e-Learning environments [13]. The platform focuses on the type of games known as Graphic Adventures and was designed as an authoring tool for this type of games. While there are a great many tools and languages for the development of Graphic Adventures, the <e-Adventure> platform was de-

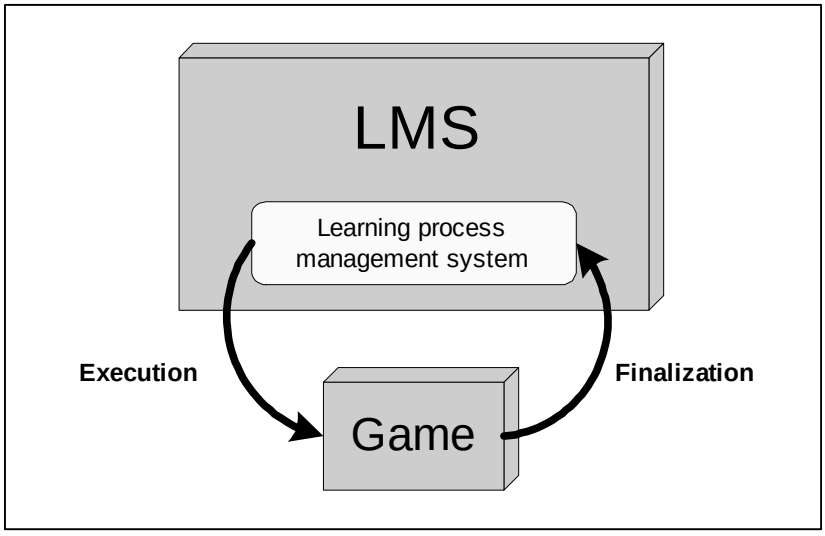

Figure 1: Running an Educational Game under the Black Box Model.

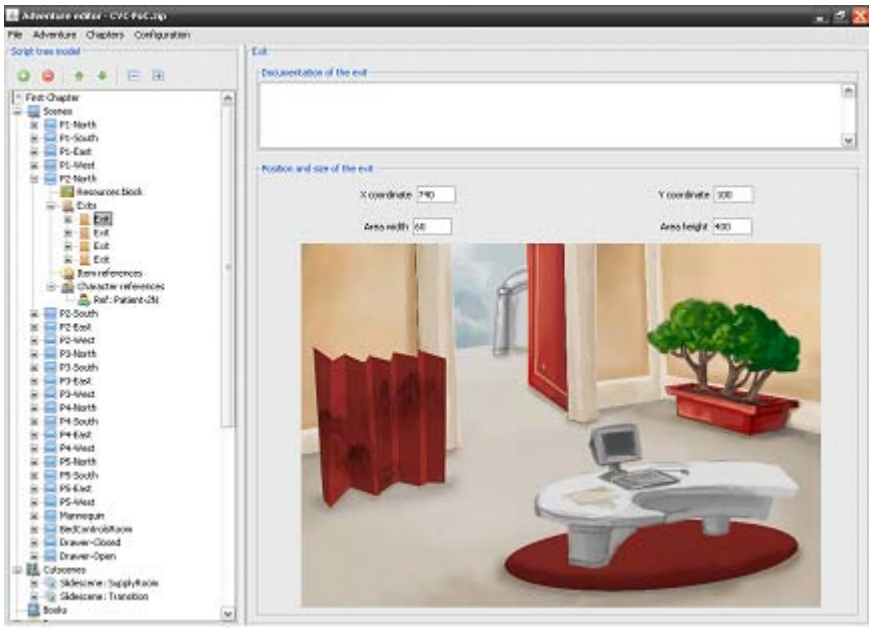

Figure 2: The Educational Graphic Adventures Editor Included in the <e-Adventure> Platform.

veloped specifically for use in educational environments.

With regard to what was discussed in the previous section, <e-Adventure> provides mechanisms and functionalities to facilitate the development process of educational games (by reducing the cost and making it easier for instructors to take part in the process), and to achieve the real (not black box) integration of the resulting games into e-Learning environments.

3.1 Authoring of Educational Graphic Adventures

In <e-Adventure> the authoring process employs a language-based approach [14], making use of techniques regularly used in the development of content-rich applications [15]. The game's storyboard is considered to be the most important element of the game and a specific language has been designed to allow for the markup of the storyboard so as to be able to generate the game by means of automatic processing. The idea is to design an XML markup language which will allow all the elements of the game (e.g. characters, scenes, objects, conversations) to be defined and referenced to the required graphic elements. This approach makes it possible to organize and simplify the participation of several experts (including the educators). To simplify the authoring process and to obviate the need to know XML, an editor for educational graphic adventures is provided (see Figure 2), which enables this type of games to be created at a low cost using a simple user interface.

3.2 Integration with e-Learning Environments

While games developed using <e-Adventure> can also be run as stand-alone applications, they are designed to be integrated into an e-Learning environment. When a common player developed with Java technologies is used, deployment in a browser is direct, and so games can be embedded in the same way as any other educational material (e.g. a PDF document, a Flash animation, etc.) accessible from an LMS. In the simplest case, games developed using <e-Adventure> will follow the black box model described previously. However, <e-Adventure> offers more sophisticated integration options. Throughout the running of the game <e-Adventure>, the LMS has access to its internal state (see Figure 3). This allows the LMS (and, therefore, the instructor) to monitor the learner's progress during the game. Given that, in principle, all games may be conceived as state machines, the task of the instructor consists of identifying the states of the game that are relevant from an educational point of view. Once these states are identified, the LMS monitors state transitions as they occur during the game. Activation of the relevant states is logged and presented to the instructor.

The description of games as state machines also allows the instructor to influence the behaviour of the game from the LMS. All that is required to be able to modify the behaviour of the game is to force the establishment of an appropriate initial state from the LMS.

Of course, this type of integration requires the LMS to be capable of communicating with the content and providing the instructor with the mechanisms needed to interpret and process this information. In the case of <e-Adventure>, this communication process is integrated with environments that are compatible with the IMS Learning Design[3] specification [16], which allows the modelling of complex learn-

[3] <http://www.imsglobal.org/learningdesign/>.

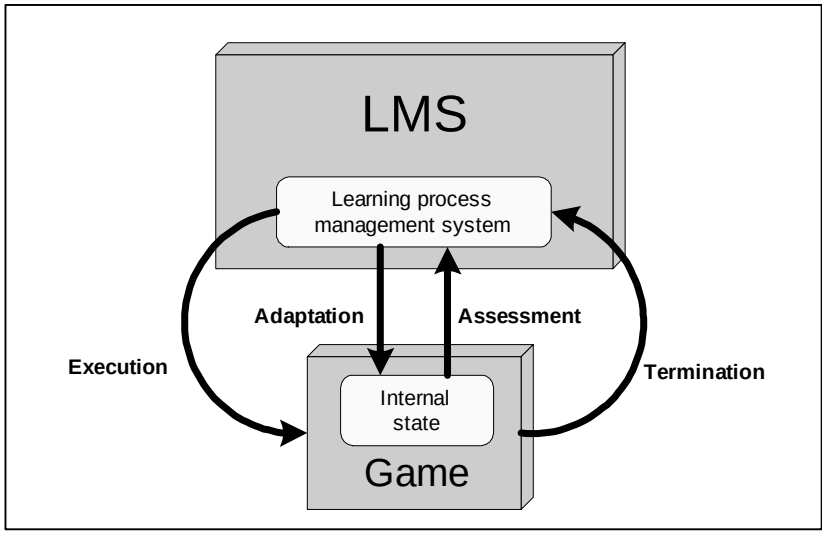

Figure 3: Integration of Educational Games in LMS Environments[2].

ing experiences with multiple educational paths that can be tailored to the needs of each particular learner [17]. The games are run on the learner's computer but there is always a communication channel open with the LMS. This makes it possible to connect <e-Adventure>'s internal monitoring and adaptation mechanisms with IMS Learning Design's execution environment.

4 Conclusions

After several years of academic discussion and various successful pilot initiatives, videogame-based learning is becoming one of the most fashionable of educational trends. The potential shown by existing initiatives points towards some very interesting instructional models combining videogames with other materials. But, as we have discussed in this article, the potential shown up to now should be viewed with a degree of caution. Videogames may be a very powerful educational tool if used properly, but this does not mean that anything remotely resembling a videogame is going to have educational value, nor does it mean that we should convert all our educational content into videogames.

The reduction of development costs is a key issue in any debate regarding videogames and education. The use of authoring tools is an interesting way of addressing this problem, given the low development costs that tend to be associated with such tools. But these tools will need to provide direct support to the special needs of the field of education. Among these needs we would highlight the need to make it easy for instructors and game designers to cooperate in the development process in order to strike the correct balance between educational value and entertainment. It should also be noted that the use of authoring tools such as those provided by the <e-Adventure> platform has a naturally positive impact on content maintainability, thereby meeting another of the basic needs of the field of educational.

It should be mentioned that this reduction in costs is offset by having to limit ourselves to a single type of game, since simplicity is achieved at the expense of flexibility. To strike a reasonable compromise between educational potential and cost, the designers of <e-Adventure> chose to focus on a single type of game: Graphic Adventures. This type of game is often referred to in literature on the subject as having the greatest educational potential, especially in terms of the development of problem solving and planning skills, as well as for learning and understanding processes (as opposed to the learning of information "by heart") [18][19].

With regard to the deployment of content, LMS environments provide an ideal platform. Given its technological nature, it is a field in which it is much easier to deploy interactive digital content (in comparison with a school environment) and where designers are under pressure to find mechanisms with which to overcome the classical concept of e-Learning. But merely to place interactive content in e-Learning environments does not make full use of the educational potential of games, particularly in terms of their capacity for learning experience assessment. This, combined with the possible reluctance of educators to use this type of content, makes it essential to put in place learning process assessment and monitoring systems to work in conjunction with the assessment mechanisms of the various LMSs. The <e-Adventure> platform described in this article is an example of this type of implementation. The combination of IMS Learning Design with educational games developed using <e-Adventure> delivers some very interesting learning patterns, as described in [20], although their application is limited to LMSs able to support the specification.

[2] The management subsystem of the learning process is able to monitor the interaction between learner and game. Also, by forcing changes in the internal state, it is possible to adapt the games to different learning scenarios.

The mechanisms provided by the <e-Adventure> platform for the creation and deployment of educational graphic adventures are a step towards achieving a more or less generalized integration while allowing interesting learning patterns to be implemented by combining videogames with other types of Web content. Developments carried out to date using <e-Adventure> in fields such as medical training [21] have had affordable development costs and have given rise to interesting initiatives in which games are deployed as part of complex learning experiences. It is our belief that this integration model has all the necessary features to ensure the gradual integration of games into educational processes, at least in e-Learning environments. Given the importance currently being placed on approaches combining traditional education with e-Learning environments, commonly referred to as b-Learning (blended-learning) [22], from here the next development could be the popularization of b-Learning as an entry vehicle for the deployment of educational games in traditional learning environments as well.

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References

[1] J. P. Gee. "Good videogames and good learning: collected essays on video games". New York: Peter Lang Publishing, 2007.

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

[3] S. Papert. "Does Easy Do It? Children, Games, Learning". Game Developer Magazine, June 1998: pp 87-88.

[4] R. Koster. "Theory of Fun for Game Design". Paraglyph, 2004. ISBN: 1932111972.

[5] T. Malone. "What makes computer games fun?" Byte, 1981. 6(12): pp 258-276.

[6] D. I. Cordova, M. R. Lepper. "Intrinsic Motivation and the Learning process: Beneficial Effects of Contextualization, Personalization, and Choice". Journal of Educational Psychology, 1996. 88(4): pp 715-730.

[7] L. S. Vygotsky. "Mind in Society: The development of higher psychological processes". Cambridge, MA: Harvard University Press, 1978. ISBN: 0674576292.

[8] R. Zemsky, W. Massy. "Thwarted Innovation: what happened to e-Learning and why". A final report for The Weatherstation Project of The Learning Alliance at the University of Pennsylvania, 2004.

[9] B. Fernández-Manjón, J. L. Sierra, P. Moreno-Ger, I. Martínez-Ortiz. "*Uso de estándares aplicados a TIC en Educación*". 2007, CNICE (National Center for Educational Information and Communication).

[10] D. Michael, S. Chen. "Serious Games: Games that Educate, Train, and Inform". Boston, MA: Thomson, 2006.

[11] C. Aldrich. "Learning by Doing: A Comprehensive Guide to Simulations, Computer Games, and Pedagogy in e-Learning and Other Educational Experiences". San Francisco, CA: Pfeiffer, 2005. ISBN: 978-0-7879-7735-1.

[12] S. de Freitas, M. Oliver. "How can exploratory learning with games and simulations within the curriculum be most effectively evaluated?" Comput. Educ., 2006. 46(3): pp 249-264.

[13] P. Moreno-Ger. "*Una aproximación documental para la creación e integración de juegos digitales en entornos virtuales de enseñanza*". Thesis presented to the Department of Software Engineering and Artificial Intelligence of the Universidad Complutense de Madrid, 2007.

[14] P. Moreno-Ger, J. L. Sierra, I. Martínez-Ortiz, B. Fernández-Manjón. "A Documental Approach to Adventure Game Development". Science of Computer Programming, 2007. 67: pp 3–31.

[15] J. L. Sierra, A. Fernández-Valmayor, B. Fernández-Manjón. "A document-oriented paradigm for the construction of content-intensive applications". The Computer Journal, 2006. 49(5): pp 562-584.

[16] P. Moreno-Ger, P. Burgos, J. L. Sierra, B. Fernández-Manjón. "A Game-based Adaptive Unit of Learning with IMS Learning Design and <e-Adventure>". Lecture Notes in Computer Science, 2007. 4753: pp 247 - 261.

[17] R. Koper, C. Tattersall, eds. "Learning Design - A Handbook on Modelling and Delivering Networked Education and Training". Springer Verlag: Heidelberg, 2005. ISBN: 3540228144.

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

[19] R. Van Eck. "Building Artificially Intelligent Learning Games, in Games and Simulations in Online Learning: Research and Development Frameworks", D. Gibson, C. Aldrich, and M. Prensky, Editors. 2007, Information Science Publishing: Hershey, PA.

[20] P. Moreno-Ger, P. Sancho-Thomas, I. Martínez-Ortiz, J. L. Sierra, B. Fernández-Manjón. "Adaptive Units of Learning and Educational Videogames". Journal of Interactive Media in Education, 2007(05).

[21] P. Moreno-Ger, C. R. Blesius, P. Currier, J. L. Sierra, B. Fernández-Manjón. "Rapid Development of Game-like Interactive Simulations for Learning Clinical Procedures". En Proceedings of Game Design and Technology Workshop and Conference. 2007. Liverpool, UK.

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

