Learning Models for the Integration of Adaptive Educational Games in Virtual Learning Environments

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Abstract. There is a trend in Virtual Learning Environments (VLE) towards flexible and adapted learning experiences that modify their contents and behavior to suit the needs of different learners. On the other hand, the use of educational videogames is also an emerging trend to address diverse aspects, such as student engagement and exploratory learning. Additionally, videogames support adaptation in a natural way. This suggests that they may be a good vehicle to enhance the adaptive features of VLE. However, all those ideas are partially disconnected and, in spite of all the work done, there is still a need for effective learning models that leverage the potential of games, integrating them with the available learning materials and VLE. In this work, we discuss such models and describe how the <e-Adventure> educational game platform supports them.

Keywords: educational games, learning models, user adaptation.

1 Introduction

Nowadays, adaptation to the needs of different learners and contexts is becoming an increasingly important aspect of Virtual Learning Environments (VLE) [1, 2]. This is a result of the need to reach users anywhere and anytime combined with the flexibility of web technologies. Typical adaptation mechanisms build student profiles based on learner preferences, portfolio, previous knowledge, educational objectives, and, in some cases, even different learning styles [3, 4].

Another increasingly important aspect in the field of educational technologies is the inclusion of digital games in educational environments. Works such as [5, 6] identify the importance of motivation in the learning process and, from that base, other authors discuss the benefits of using videogames to enhance the quality of the learning experiences [7, 8]. Moreover, other authors defend that the characteristics that make videogames attractive (immersion, short feedback cycles, scaffolded learning, perception of progress, etc.) are also key elements in any effective learning process [9, 10].

Additionally, the characteristics of game-based learning suggest its potential benefits when applied to adaptive online learning. Adaptation is a pervasive feature of commercial videogames, since they are practically required to support different difficulty levels in order to cater to the broadest possible audience. Moreover, unlike with

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an HTML or PDF document, in a game we can monitor very closely the interaction between the student and the game and use this information as part of our adaptation cycles [11].

However, in spite of all the work created so far, there still is a need for effective learning models that leverage the potential of games integrating them with the available learning materials and VLE. The use of educational videogames as content in adaptive Virtual Learning Environments in a sensible way is not a trivial problem. To begin with, we cannot force all the broad variety of students to learn from game-based solutions. Some students may lack the proper equipment, some public computers may restrict the types of content that can be accessed, and some students may simply refuse to play the games seeing them as a waste of their time [12]. Even from an adaptation perspective, some student profiles may require a very closely guided learning experience as opposed to the exploratory freedom offered by most games. In such cases, a conventional approach based on HTML, PDF and multimedia content could be more appropriate. Finally, traditional web content is more accessible for people with special accessibility needs, for example using text-to-speech tools for blind people.

For these reasons, in the context of adaptive online learning, the employment of educational games should not replace other approaches, but try to complement the learning experience by integrating both alternatives in richer learning environments. We propose a new model of integration, in which game-based content is blended and complemented with traditional web contents as opposed to substituting them.

However, in order to apply such a model, it is necessary to address a number of technical issues. In this work we describe how the <e-Adventure> educational game platform [13]can be used to support this approach, facilitating the development of educational adventure games and their integration with Virtual Learning Environments.

This work is structured as follows: section 2 describes some of the issues regarding adaptation and game-based learning that supply the base for this work. Then, on section 3, we discuss the issues that emerge when substituting traditional content with game-based content and propose a learning model that mixes both. On section 4, we describe our <e-Adventure> platform, which can be used to implement that learning model. Finally, some conclusions and future work are discussed in section 5.

2 Game-Based Learning and Adaptive Learning

2.1 Adaptive Online Learning

When we speak about adaptation in a Virtual Learning Environment, we are usually speaking about a system that gathers information about its students and then uses the information stored in the students' profiles to customize the content delivered to learners and/or the activities they must perform [3]. Therefore, adaptation usually deals with two different problems: Gathering information about the student and then modifying the learning experience. The adaptation may be addressing a wide variety of aspects, such as customizing the Graphical User Interface (GUI), supporting different learning objectives or initial levels of knowledge, adaptation to different use contexts (e.g. a public computer vs. a desktop computer at home), and even supporting

different learning styles. For the scope of this work, we will only focus on the technical needs when it comes to adaptation in terms of a) different levels of initial knowledge; and b) different learning styles.

Adaptation to different levels of initial knowledge requires finding out the current level of each student in order to adapt the content accordingly. For instance, it could be addressed by filtering basic content for those students with a certain level of knowledge, so they could effectively focus their effort

Regarding the adaptation to different learning styles, we are aware that this is still a controversial field. In spite of long empirical efforts to pin them down, the identification of learning styles remains elusive [14]. However, most people with teaching experience acknowledge intuitively that there are differences in how their students learn [15]. For this work we will assume a very rough classification of student profiles, cataloguing them according to whether they are able to self-regulate their own learning processes (preferring a free and exploratory approach), and those who prefer close teacher control and guidance.

2.2 Adaptive Game-Based Learning

The advantages of integrating games in educational environments have been widely discussed in the literature [16-18], However, we would like to point out the properties that make them a particularly adequate medium for adaptive learning.

The entertainment videogame industry has grown and now it is a mature industry that caters for all ages and genders. Driven by a commercial pressure to entertain different player profiles, successful games have developed sophisticated adaptation mechanisms. Most games adapt their behavior to suit different levels of proficiency, adjusting the difficulty of the game (sometimes even automatically [19]). Some games even adapt to suit different playing styles so that each player enjoys the game experience as much as possible. It can be concluded that current game technology inherently supports the features that an adaptive learning experience demands. Additionally, their high interactivity and complexity mean that the content can be adapted both in general behavior and in fine-grained details. Moreover, games can be designed and implemented with the means to track the progress and actions of learners while they are playing, gathering valuable information for both adaptation and assessment purposes.

Therefore, a game can implement a complete adaptive learning cycle, both by gathering information about the player during the game and by modifying its behavior as needed. The game pattern shown in Figure 1 is an example of an adaptive game-based learning architecture. It contemplates different game itineraries for different students. On each itinerary the game behaves differently. The game can exhibit different behaviors in order to support different learning styles (for example, giving the player more or less freedom to explore) or different learning objectives (for example, omitting some advanced details from the game). Additionally, the games can skip those levels that are too basic for the student's initial level of knowledge.

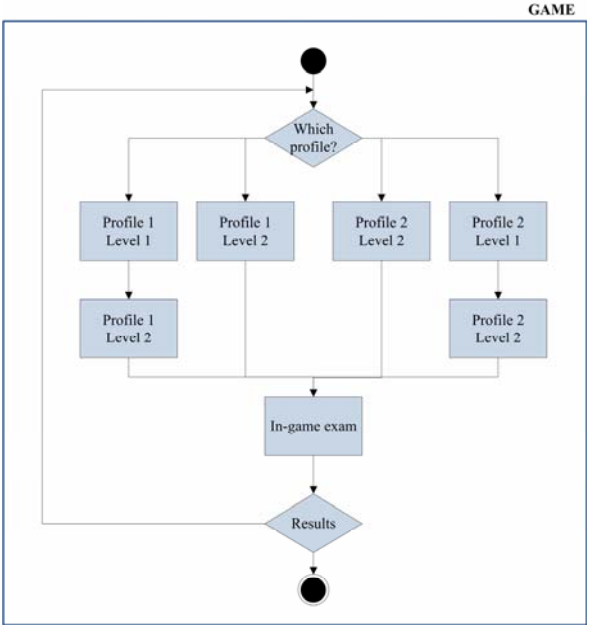


Fig. 1. A game pattern for adaptive game-based learning. The game can exhibit different behaviors to support different learning styles (Profile 1, 2…) and can omit certain levels that are too basic for the level of initial knowledge. The game also gathers information from the interaction during the in-game exam and uses it to modify its own behavior.

This pattern also contemplates using the game mechanics for assessment purposes, monitoring the activity of the student during an in-game exam. Whilst the game is played, a lot of interaction between the learner and the game is produced. From the monitorization of all these interactions it is possible to infer data about the learners that could be used to categorize them into one of the learning styles previously defined. In some cases, if the results achieved by the student are insufficient, it is also possible to reassess the profile of the student and run the game again with a different profile.

3 Combining Educational Videogames and Traditional Content in Adaptive Learning Patterns

Most game technologies and genres can easily support the game pattern outlined in the previous section. However, it must be done cautiously. Game-based learning may not be appropriate for all the students all the time or even for all the possible subjects. Thus, the integration of these games into the Virtual Learning Environments should go beyond simply deploying educational videogames instead of web content.

In this section we describe the issues identified when it comes to integrating adaptive games in Virtual Learning Environments, and then we propose a model supporting such integration.

3.1 Educational Games: User Interaction and Access-Related Issues

As it has been stated in the previous section, educational videogames can be a vehicle for the introduction of complex adaptation procedures in the learning experience, enhancing motivation and providing an immersive domain to interact with. However, game-based approaches would neither suit every student's tastes nor be adequate in all contexts and situations.

First, the technological complexity of videogames is an issue. Most games demand high system requirements and some students may find their computers unable to execute them. Similarly, as videogames are complex pieces of software, its use is restricted in most public and private systems beyond the personal field. Additionally, there is an emerging trend towards the use of mobile devices (e.g. PDAs, mobile phones, etc.), in what has been named m-Learning (mobile learning) [20] and mobile learners usually will favour traditional web-based content.

Apart from the technological issues, sometimes the students themselves would decide not to use these games. Games are usually time-consuming, as they require getting familiarized with the environment (i.e. the domain of study) and sometimes even learning how to use and interact with the universe devised in the game. Moreover, some students are averse to videogames. A person with no experience playing commercial videogames would find in educational videogames an extra and superfluous challenge to waste their efforts on instead of an additional motivation, as witnessed and reported in [12]. If addressing adaptation in terms of students' preferences and learning styles is desirable, we should avoid forcing those students who distrust videogames to learn from game-based contents.

Another issue would be students that cannot interact with game-based contents. For instance, blind people would find it impossible to learn through videogames, as visual interaction cannot be replaced in games with a further use of the other senses. In these cases, alternative learning itineraries, like HTML web pages that can be interpreted by a text-to-speech tool, should be provided, following the current research aiming to provide access for all to Information Systems [21].

Finally, game-based solutions are not recommended for those students that feel overwhelmed by the freedom of exploration provided in games (even when such freedom can be gauged and adapted transparently in the games). In those cases traditional content, in which the interaction during the learning experience is more rigid seems to be more suitable.

3.2 Integration of Games with Traditional Content

Let's consider a typical scenario: a learning module composed by a number of Learning Objects (e.g. HTML documents), which is already deployed in a VLE and being accessed by students via a web browser. However, the instructors decide to seek alternative didactic methodologies including adaptation and educational games. An adaptive game-based version of the content is designed to suit a profile of students who probably have no study habit but have game habit. While carrying out the integration of the new game-based content into the learning module, the instructors find two main issues that need to be tackled:

On the one hand, the educational game is more costly to develop and it may be complicated to ensure that guarantees the accomplishment of the same learning objectives. This adds a new burden for the instructor or the person entrusted to produce and maintain the learning content. On the other hand, the inclusion of the game in the learning module would require reshaping the content and the pedagogical approach in order to fit in a game-based delivery.

These issues could be addressed by supplying instructors (or content designers) with mechanisms for the automatic integration of the existing content into the new game-based content so that it can be easily accessed from the game, with no extra effort for the instructors. In this way, both learning itineraries (traditional and game-based) would incorporate the same information.

3.3 Description of the Resulting Adaptive Learning Pattern

Taking into account the aforementioned aspects, we propose an adaptive model (Figure 2) with two adaptation layers. Firstly, the VLE decides whether a game-based or a traditional HTML approach is more appropriate for the learner according to the profile. This decision may depend on the requirements of the student (learning styles, disabilities, etc.), the current context (a mobile device or a short consultation session) or the student's preferences. Secondly, when game-based content is chosen, a more fine-grained adaptive mechanism is applied to adjust the game's behaviour in the terms discussed thus far.

These adaptive mechanisms are supported mainly by a test performed at the beginning of the learning experience. This pre-test, checks whether the game-content is suitable for the students and their initial level of knowledge. In some cases, the student profile kept by the VLE will be sufficient to decide the shape of the content to be delivered, making this test unnecessary. In other circumstances (e.g. when the student is a novice using the system) a questionnaire could be given to the student in order to find out their knowledge, preferences and perhaps some information about their "learning taste", so that their learning style can be inferred. The complexity of these tests is in accordance with the adaptation mechanisms that we wish to apply. Most models that attempt to capture learning styles include methodologies to infer the learning styles of each student (like Vermunt's Inventory of Learning Styles questionnaire [22]).

The adaptation within the game can fit different learning styles by displaying different game behaviours (such as biasing the behaviour towards guided or exploratory styles) and also support different levels of initial knowledge by skipping those sections which appear too simple for a particular student.

After the learning experience has been completed, a second test (post-test) is performed. The results of this test (that can be obtained within or outside the game) can be used to refine the student's profile in order to improve future adaptation decisions. If a game-based content was the choice, an in-game exam could be the source of the assessment, along with other data gathered through the monitorization of the interaction of the student with the game. On the other hand, if conventional content was chosen, a traditional online exam would provide the information.

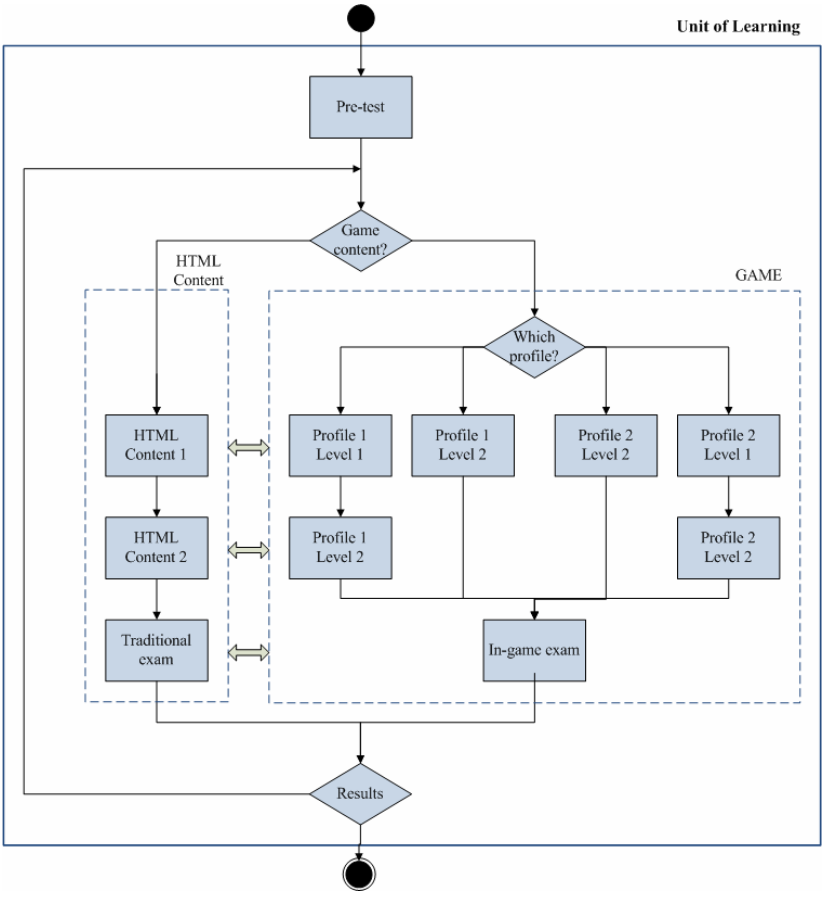


Fig. 2. Adaptation model considering two different learning itineraries: HTML-based and GAME-based. The adaptation is focused on two conditions: learning styles (different content paths, different profiles in the game) and prior-knowledge (initial levels of the game can be skipped).

Regarding the issues when integrating game-based content in the learning experiences, we consider that both learning itineraries should not be disconnected. As shown in figure 2, the itineraries are linked allowing the games to access the HTML content as suggested in section 3.2.

4 Implementation of the Adaptive Pattern Using <e-Adventure>

<e-Adventure> is an educational game engine designed to facilitate the creation of interactive educational content, focusing on pedagogical aspects such as adaptation and assessment [11]. It is a complete authoring environment for graphical *point and click* adventure games, built around an XML-storyboard, which supports the adaptive model proposed in this article.

The platform can be integrated with Virtual Learning Environments. When deployed from a standards-compliant VLE, the implementation of the engine can query the LMS for a set of properties that are used to adapt the game. The games are defined so that the different values of those properties will change the initial state of the game and consequently the game will be adapted, thus supporting the second adaptation level of the general pattern described in section 3. The adaptive cycle is closed by in-game tests, which are automatically assessed by the engine providing the necessary feedback to readjust the student's profile if necessary.

Another issue to address is how to effectively provide domain information to learners while playing because this aspect is not usually present in commercial games. Following the traits of the adventure game-genre [23], the interactive conversations with the characters that the players encounter inside the game represent a good source of information. However, interactive conversations with other characters are not always ideal. Some contents may require being delivered through alternative metaphors. When a large amount of data has to be delivered, conversations are not the most "natural" channel. Long conversations will prompt the students to loose their attention and focus. Moreover, embedding large amounts of information in conversations reduces its availability.

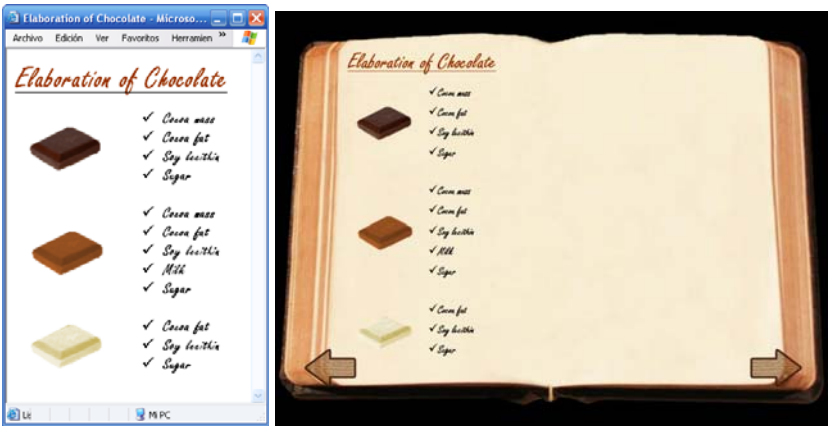
It is often desirable to make sure that some reference information is at the reach of the student at every moment. A first solution would be to allow the students to consult separate online materials containing the information, although this can be cumbersome for the student who is forced to switch back and forth between the game and the contents. For these reasons, <e-Adventure> includes the notion of *in-game books*. Those books are available to the learner at any moment to be looked up, supporting both text and images.

The books can be specified in <e-Adventure> by two different approaches: On the one hand, the content of the books can be marked up along with the XML-storyboard, as depicted in Figure 3. On the other hand, the definition of the contents of the books can be detached from the game content by referring to a web page. In this manner, the

```
<book id="BookElaborationChocolate">
  <resources>
    <asset type="background" uri="assets/background/book.jpg"/>
  </resources>
  <text>Elaboration of chocolate
    <img src="assets/image/DarkChocolate.png"/>
          Cocoa mass
          Cocoa fat
          Soy lecithin
          Sugar
          --
    <img src="assets/image/MilkChocolate.png"/>
          Cocoa mass
          Cocoa fat
          Soy lecithin
          Milk
          Sugar
          --
    <img src="assets/image/WhiteChocolate.png"/>
          Cocoa fat
          Soy lecithin
          Sugar
          --
  </text>
</book>
```

Fig. 3. A fragment of a marked-up in-game book in <e-Adventure>. The figure depicts how a book is represented in the storyboard (left) and how it is visualized in the game (right), as an actual book.

content of the book is retrieved from a URL where an XHTML document is located and subsequently displayed in the game, as depicted in figure 4. A first advantage of detaching the content of the books from the storyboard (where books are marked up) is that the production and maintenance of book content is eased as the instructor can edit and organize the information using HTML authoring tools. However, the main advantage of this approach is how it supports the integration of existing web content in <e-Adventure>. This can be leveraged to support the key issues from the adaptive learning model described in section 3, allowing direct access to the web-based content deployed on the VLE from inside the game.




```
<book id="BookElaborationChocolate">
   <resources>
         <asset type="content" uri="assets/books/elaboration/content.htm"/>
         <asset type="background" uri="assets/background/book.jpg"/>
   </resources>
</book>
```

Fig. 4. Reference information can be designed using web authoring tools as an XHTML document (left). Then, <e-Adventure> renders this document into a better designed book (right). The piece of XML (below) shows how the book is defined by just referring to its assets (background image and content web page).

5 Conclusions

In this work, we have argued the necessity of bringing together two increasing trends in online education: adaptation (in order to suit the broader range of people, reaching users anywhere and anytime) and the application of videogames to educational purposes. Nonetheless, it has been remarked that traditional content should not be totally replaced, as game-based solutions are not always the best choice for everyone at anytime. Instead of that, both approaches should coexist in the Virtual Learning Environments, combining the advantages of both approaches. In our opinion, the achievement of the aforementioned goals will need the research to move towards the development of learning models that integrate in a sensible way both key concepts (adaptation and use of educational videogames).

Considering all these reasons, we have outlined an adaptive learning model supporting a full adaptation cycle and the integration of game-based content with traditional alternatives. This model addresses adaptation in two layers: First, we introduce the capacity to diversify the learning experience, supporting different itineraries (including game-based and traditional content) in order to suit the broadest range of learners and situations. The second adaptation stage takes place when game-content is chosen, leveraging the characteristics of videogames to provide a much more fine-grained adaptation mechanism. The first adaptation step is thus to decide what sort of content is to be delivered according to the learner's profile. Therefore, this layer not only represents a first adaptation step, but also a general guideline for the integration of educational videogames in existing VLEs: Traditional content should be kept and offered as an alternative instead of replaced.

Another relevant concept discussed is the relevance of integrating the existing web content inside the games. Some types of information do not translate easily into game features, and simply work better in their textual form.. A first idea would be to allow the students to consult the online materials while playing, although this can be cumbersome for the student who is forced to switch back and forth between the game and the contents. Another approach would be to embed all the HTML content into the game. This allows the student to use the reference materials from within the game. However, duplicating the content is not a sustainable approach from a content adaptation and maintenance perspective. The solution presented here is to link these contents from the games, having the game engine render web content retrieved directly from the VLE.

It is important to remark that the proposed model is a simplification devised to display the features that should be supported by the technology employed to perform the integration of adaptive games in online education. For the sake of simplicity, the model only displays adaptation driven in terms of learning styles and prior-knowledge, although it is broad enough to support other adaptation approaches.

As described in section 4, this model can be implemented using the <e-Adventure> educational game platform. The assessment and adaptation mechanisms offered by the platform support the adaptive features described in the adaptive game model outlined in section 2.2. Additionally, since <e-Adventure> can be deployed in standards-compliant Virtual Learning Environments, it can support the general adaptive cycle described in section 3.3, facilitating the proposal of alternative game-based itineraries without detaching the game experience from the rest of the learning process. Finally, the capacity of the platform to render HTML-based Learning Objects inside the game using a book metaphor solves the issues related to the integration of existing web content inside the games in a sensible way.

As a final remark, it must be mentioned that the use of in-game books to provide the learner with reference information, may be a double-edged weapon: an abuse of in-game books is prompt to make the learning experience boring and give the narration a slow pace, instead of making it more motivating and attractive. When talking about educational videogames we should always bear in mind that both *fun* and *educational content* should be present and balanced; otherwise we will have the "benefits" of a bad learning experience (sometimes referred as "eduboring") but at a higher cost. We are trying to achieve such balances developing learning modules that

implement this model in the field of Computer Science teaching. The results obtained will be useful to gauge a further detailed model and propose future lines of work.

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