Adaptive Units of Learning and Educational Videogames

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Abstract: In this paper, we propose three different ways of using IMS Learning Design to support online adaptive learning modules that include educational videogames. The first approach relies on IMS LD to support adaptation procedures where the educational games are considered as Learning Objects. These games can be included instead of traditional content to adapt the learning experience to the preferences of the student. In the second approach, the game engine supports the entire adaptation cycle, simply using IMS LD as a delivery mechanism for the packages containing the games. The learner profile is used to adapt the game, and the activity within the game is used to adjust the profile. Finally, the third approach stands between the other two, using IMS LD to model the general adaptation guidelines and then refining the adaptation inside the games. We illustrate these approaches with the <e-Adventure> educational game engine, which includes the mechanisms required to support these adaptation cycles.

Keywords: e-learning, adaptation, IMS Learning Design, <e-Adventure>

1 Introduction

Constructivism and learner-centered instruction are two very popular trends in education (Harasim 1990; Duffy and Jonassen 1991). According to constructivist educational theories the focus on education and training needs to shift from passive reception of data to student knowledge transformation wherein an individual constructs new knowledge through direct interaction with learning activities (Piaget 1970). Constructivist principles include building on students' prior knowledge, making learning relevant and meaningful and giving the students choice and autonomy. In turn, learner-centred pedagogy asks what students need to learn, what is meaningful to them, and what their preferences and their learning styles are.

The main assumptions behind constructivism have a significant impact in the conception of on-line educational environments, as analyzed in (Doolittle 1999). In particular, a constructivist learner-centered educational environment should focus on making learning more relevant, building on students' prior knowledge, and addressing aspects such as learner misconceptions, their learning styles and their preferences. In order to accomplish these objectives, online educational tools should provide adaptation in at least three different aspects: learners' background, their learning objectives and their learning styles (Hannafin and Land 1997).

Nevertheless, adaptive learning in terms of students' learning styles remains an elusive milestone for mainstream online learning applications (Kalaydjiev and Angelova 2002) and has become a very controversial domain. Some authors affirm that there is a lack of experimental measurements of their pedagogical efficacy (Coffield, Moseley et al. 2004), that there is an "utter failure to find that assessing children's learning styles and matching to instructional methods has any effect on their learning" (Stahl 2002), and even that the models rest on dubious theoretical grounds (Curry 1990). In response, some other authors such as (Lovelace 2005) conclude that "matching students' learning-style preferences with complementary instruction improved academic achievement and student attitudes toward learning" in reference to Dunn and Dunn's model. With research considering learning style models as the educational panacea and research hinting that it might not be a relevant approach, some authors are between both extremes demanding a consensus (Reid 2005) (Rayner 2007).

In spite of this controversy, a unifying aspect in this discussion is the IMS Learning Design specification (IMS Global Consortium 2005a). Currently, it is considered the best tool for modelling rich and varied instructional approaches (Burgos, Tattersall et al. 2006a) and, if adaptive learning is to be accepted as a mainstream feature of online education, the IMS LD specification is likely going to play a key role in the process.

On the other hand, we believe that digital game-based learning presents new opportunities for re-considering constructive learner-centred approaches. Videogames are immersive spaces where learning is often experience-based, problem-based or exploratory, allowing students to rehearse skills for the "real world" (Squire 2005). Additionally, videogames are a natural medium for applying adaptation. The use of difficulty settings to fit players of different skill levels is customary in games, but we also believe that a game adapted to the learning style of the student may increase its effectiveness.

From these ideas, if the introduction of educational videogames into adaptive learning experiences is a desirable objective, this should not be done by turning our backs on the IMS Learning Design specification. However, adaptive games and adaptive Units of Learning modelled with IMS Learning Design attack the problem from two different perspectives. In this paper we present three possible approaches to the integration of LD and games to construct adaptive learning experiences. Thus, the paper is structured as follows: section 2 gives some preliminaries, stating the potential for identifying learning styles for adaptation purposes and how both IMS LD and the application of videogames can be used in adaptive learning scenarios. It also highlights the fact that there are different possible approaches to jointly using IMS LD and educational videogames when providing these adaptive experiences. In section 3 we describe three such approaches, comparing them with a general pattern for an adaptive learning experience that includes feedback loops, and we also describe how these approaches can be supported by an environment formed by the SLeD player and the <e-Adventure> educational game engine. Finally, some conclusions are presented in section 4.

2 Preliminaries

In this section we highlight some preliminaries regarding the use of learning styles to make adaptations in online education (section 2.1), the educational potential of videogames (section 2.2), and the use of IMS learning design and such educational videogames in promoting adaptive learning (section 2.3).

2.1 Adaptation and Learning Styles

Achieving adaptive behaviour, which is a central subject in e-learning, can be characterized as the ability of an e-learning system to adapt to different conditions over time in order to optimize pre-defined measures of success (e.g. learning time, economic costs, user satisfaction, etc.) in order to improve the effectiveness of the learning process. Therefore, it involves many different aspects (e.g. user characteristics, learning context, accessing devices, etc.). Among them, the ability of the system to construct and maintain a suitable model of the student, which is closely related to other areas such as user modelling (Benyon and Murray 1993; Vassileva 1996) and adaptive hypermedia (Karampiperis and Sampson 2005; Kinshuk et al. 1999; Brusilovsky 1996), is particularly relevant. The model can include many aspects such as previous domain knowledge (Nykänen 2006), learning styles (Graf, Lin and Kinshuk 2005), preferences (Bontcheva and Wilks 2005), etc.

There is an intuitive notion of the existence of individual learning styles when teachers notice that students vary enormously in the speed and manner with which they pick up new information and ideas, and in how they process and use them in different contexts (Coffield, Moseley et al. 2004). However, it is necessary to be cautious with that argument. In spite of long empirical efforts to pin them down, the identification of learning styles remains elusive (Mayes and De Freitas 2004). In the report (Coffield, Moseley et al. 2004), an in-depth evaluation of many of the existing learning style models is carried out. The authors are rather sceptical about most of the assumptions made about the importance of learning styles in education. Nevertheless, the approaches that describe learning styles as flexible strategies to approaching learning get more positive evaluations than the rest of the models studied.

Although the details are still open to discussion, in this paper we assume as a hypothesis that both learner motivation and performance benefit from adapting education to learning styles in all educational paradigms, including constructivism and, particularly, game based learning.

2.2 Game-based Learning

Many educators agree on the existence of a global trend in which student motivation is decreasing. New generations of students seem to perceive the learning process as a boring duty or even as a waste of time that they would rather employ in more exciting activities. In a traditional learning setting, the contact with the instructor and the group can alleviate this effect, but the phenomenon is particularly acute in online learning settings where these elements are absent.

Several authors (Prensky 2001; Gee 2003) see technology as the main influence of this apparent lack of interest by the students. New generations have grown up using technology in their everyday lives: computers, mobile phones and video consoles are their quotidian entertainment and communication tools. According to this explanation, it may not be a problem with the content itself, but with the format used to deliver this content. For example, Oblinger claims that perhaps students expect their teachers and their learning environments to offer learning opportunities in the exciting and engaging formats they are used to (Oblinger 2003).

In this sense video games can be a very helpful learning tool, as long as motivation is a key aspect of effective learning (Cordova and Lepper 1996; Martens, Gulikers et al. 2004). It is commonly agreed that an intrinsic advantage of game based learning over more traditional approaches to learning is that games are motivating (Malone 1982; Malone and Lepper 1987; Garris, Ahlers et al. 2002).

Additionally, modern videogames are immersive, giving the player the power to drive the game experience, fostering competition and/or collaboration, and providing a safe environment with a very tight feedback loop where trial and error is encouraged. These are all desirable characteristics in constructivist and/or learner-centred learning approaches (Ebner and Holzinger 2006; Ju and Wagner 1997; Clinton 2004; de Freitas and Oliver 2006).

Finally, educational games are a highly interactive medium, consisting of complex pieces of software that are (usually) executed on the student's computer. From a technological perspective, this makes them the ideal medium to support an adaptive learning experience, as the game can both monitor the activity of the student within the game and change its own behaviour accordingly.

2.3 Using IMS Learning Design to Support Adaptive Learning.

IMS learning design (IMS LD) is the *de-facto* standard for educational modelling. According to (Koper and Olivier 2004) a *learning design* specifies the teaching-learning process, that is to say, under which conditions, what activities have to be performed by learners and teachers to attain the desired learning objectives. The packaging unit for a learning design and its associated resources is called a Unit of Learning (UoL). A UoL refers to a complete, self-contained unit of education or training, and it can be identified with a course, a workshop, a lesson, etc. that can be instantiated and reused in an online environment.

In addition, as described in (Burgos, Tattersall et al. 2006a) and (Burgos, Tattersall et al. 2006b), IMS LD is also equipped with very valuable features in order to support adaptation. In the definition of the learning design, designers have to specify all the activities to be performed by the different roles involved in the learning process and, as well, they have to define the sequence of the activity performance (the method). As stated in the specification, the design of personalization in IMS LD is supported by a mechanism of conditions and properties. Personal characteristics and information about the state of the learning experience are stored in "properties". Conditions can be defined to adapt the learning design to learner characteristics during the execution of the learning experience. This approach has been used in a number of UoL developed at the Open University of the Netherlands such as (Tattersall and Burgos 2005). The learning styles of learners were measured and on the basis of the results obtained, students were advised to follow one particular learning style. The choice could be made among two possibilities, a more exploratory and a more structured approach.

3 Integration of Game-based Learning and IMS Learning Design

Both IMS Learning Design specification and educational games can support adaptive learning experiences. However, as stated in the previous section, each approach has its own rationale. Therefore, when both of them are used together, it is necessary to decide which one will mainly be responsible for the management of the adaptation cycle. While in some scenarios the use of LD adaptation mechanisms may be more suitable, there are some other situations where game adaptation features are preferable.

In order to understand the potential advantages and shortcomings of each approach, we will use a general pattern for our adaptive Unit of Learning. In this section, we start by defining such a pattern and then we analyse how to implement it using three different approaches. At one extreme, the UoL is mainly responsible for the adaptation process and games are treated as content black boxes. At the other extreme, the game would be responsible for establishing feedback and adapting its own content, while the UoL would act as a mere container allowing the deployment of the games through LD compliant players. At the middle ground between these two extremes, a blended approach is also proposed.

We have developed a sample course to serve as a basis for evaluating the applicability of the different approaches. It is a short proof-of-concept course in the field of workplace safety regulations in the field of construction. Even though it is just a small sample, the topic is relevant in itself and it is a field that would benefit from adaptation, given the broad demographics of potential learners and the variability of regulations in different regions. The syllabus for the sample course is simple, covering essential regulations regarding prevention of falls and electrical safety.

3.1 The Adaptation Pattern

For our sample courses, we require adaptation covering the following aspects:

- Adaptation to different initial levels of knowledge. If students are already familiar with one of the themes, it should be possible to skip the corresponding lesson.

- Adaptation to the learning style. The contents should offer alternatives in terms of adaptation to learning styles. For the scope of this work, we employ a simplified version of Vermunt's model (Vermunt 1996). Within Vermunt's framework, four learning styles are defined: meaning-directed (MD), application-directed (AD), reproduction-directed (RD) and undirected (U) (See Table 1). For the sake of simplicity, in our sample course we have merged the four profiles into two: learners are considered as capable or not capable of their own learning regulation. According to Vermunt, in order to obtain optimum benefit from the learning process, teacher strategies have to be congruent with students' learning patterns (Vermunt and Verloop 1999). In this sense, those students who are able to self-regulate their own learning processes (which is usually highly correlated with MD and AD patterns) would benefit from a loose teacher strategy, while students that do not present this capability need strong teacher control and guidance (RD and U patterns).

	Meaning-directed	**Application-directed**	**Reproduction-directed**	**Undirected**
Cognitive processing	Look for relationships between key concepts/theories: build an overview	Relate topics to everyday experience: look for concrete examples and uses	Select main points to retain	Find study difficult: read and re-read
Learning orientation	Self-improvement and enrichment	Vocational or "real world" outcomes	Prove competency by getting good marks	Ambivalent; insecure
Mental model of learning	Dialogue with experts stimulates thinking and engagement with subject through exchange of views	Learn in order to use knowledge	Look for structure in teaching and texts to help take in knowledge and pass examinations. Do not value critical processing or peer discussion.	Want teachers to do more. Seek peer support
Regulation of learning	Self-guided by interest and their own questions; diagnose and correct poor understanding	Think of problems and examples to test understanding, especially of abstract concepts	Use objectives to check understanding; self-test; rehearse	Not adaptive

Table 1. Vermunt's learning styles. Source: (Vermunt 1996)

Taking these two aspects to be functional requirements, we propose the adaptive cycle shown in Figure 1, which reflects common practices in adaptive learning. At the first step (labelled as *pre-test)* the system classifies the student into a certain learning profile by gathering the two types of information required (previous knowledge and learning style). The methods for acquiring this knowledge may be varied. Some systems infer the information from observing the student's activity, some others leave the decision up to the student and simply ask which the preferred learning path is, and others use previous tests to classify the student into a certain profile. We use a simplified version of Vermunt's Inventory of Learning Styles (ILS) questionnaire (Vermunt 1998) as a pre-test to determine the student's learning style: those students with MD and AD patterns are classified as MD (or capable of auto-learning regulation) and those with RD and U as RD (not capable of auto-learning regulation).

Once the student has been profiled, the next step in the general pattern is to actually access the content. This step is the target of the adaptation process. In each run of the UoL, the experience is modified to fit the corresponding student profile. The different approaches taken to verify this step are explained in the following sub-sections.

The next step is to assess the results achieved by the learner. This process, labelled as *post-test* in Figure 1, assesses the outcomes of the learning process and the suitability of the learner profile. We accept as a hypothesis that if the student did not learn the proper lessons during the learning experience, the profile may be incorrect. So the information gathered in the tests is used to enhance the profiling of the student, thus establishing the feedback loop indicated in the figure.

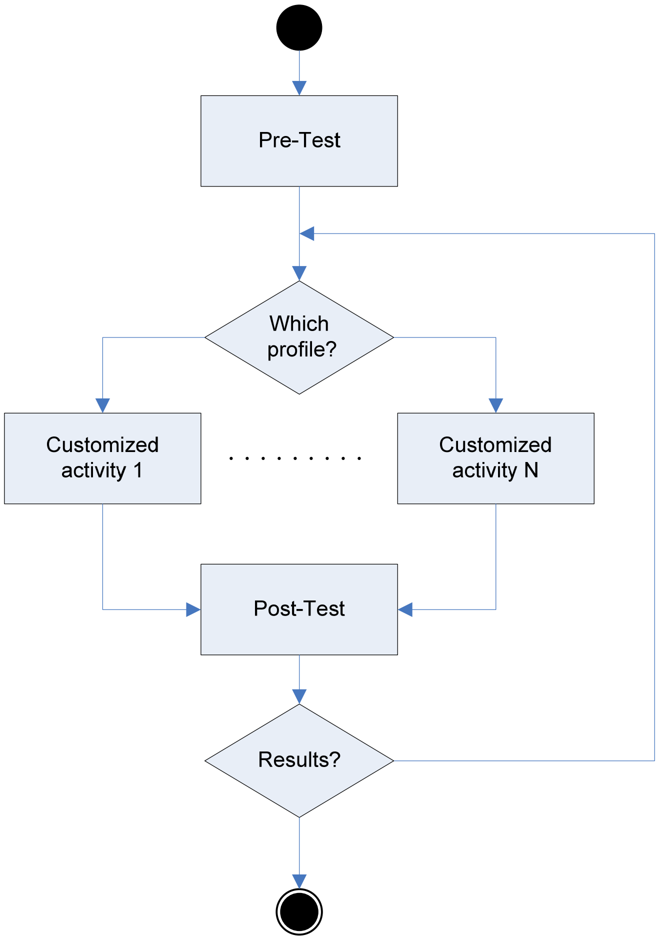

Figure 1: Structure of a generic adaptive learning experience including a feedback loop that can be used to modify the profile.

3.2 Case 1: UoL-driven Adaptation

This proposal might be considered the most "conventional" approach as it exclusively focuses on the adaptation mechanisms offered by IMS Learning Design specification. Using the specification to model the learning process of the case study is a straightforward solution. The pre-test stage in such a UoL presents the student with a questionnaire that assesses his or her initial knowledge and learning style. After all the answers are collected, the values for the initial knowledge and the learning style are calculated and stored in three different properties as shown in Figure 2.

```
<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all fall-related test properties (range [0..1]) -->
    </imsld:sum>
    <imsld:property-value>5</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
    <imsld:property-ref ref="PrevKnowledgeInFallProtection"/>
    <imsld:property-value>true</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>

<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all electricity-related test properties (range [0..1])-->
    </imsld:sum>
    <imsld:property-value>5</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
    <imsld:property-ref ref="PrevKnowledgeInElectricityProtection"/>
    <imsld:property-value>true</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>

<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all properties related to
           meaning-directed factors in the ILS test -->
    </imsld:sum>
    <imsld:property-value>12</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
    <imsld:property-ref ref="LearningStyle"/>
    <imsld:property-value>meaning-directed</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>
<imsld:else>
  <imsld:change-property-value>
    <imsld:property-ref ref="LearningStyle"/>
    <imsld:property-value>application-directed</imsld:property-value>
  </imsld:change-property-value>
</imsld:else>
```

Figure 2: An excerpt of the IMS LD description of the Unit of Learning

When it comes to delivering the content, game-based learning and exploratory learning experiences could be perfect for MD and AD learners who like to explore a problem from different angles and discover new connections among old and recently acquired concepts. For these students, games would be a preferable option rather than traditional content. In this case, the game part of the course is formed by a pair of small games, each of them covering one theme from the syllabus (see Figure 3)

There is, however, a concern that, even though videogames can be a good alternative for motivating certain students, there may be some students or even certain learning situations where gaming alone is not a suitable learning option. Thus, depending on the learning style, we can decide whether we should use videogames among the learning activities programmed or if we should also use another type of content, as in Figure 3. It should be noted, however, that for the sake of simplicity in the other cases described in this work, we will focus in Units of Learning with a stronger presence of videogames. Nevertheless, we believe educational games are an excellent medium to gradually steer RD and U learning strategies towards the preferred MD and AD ones.

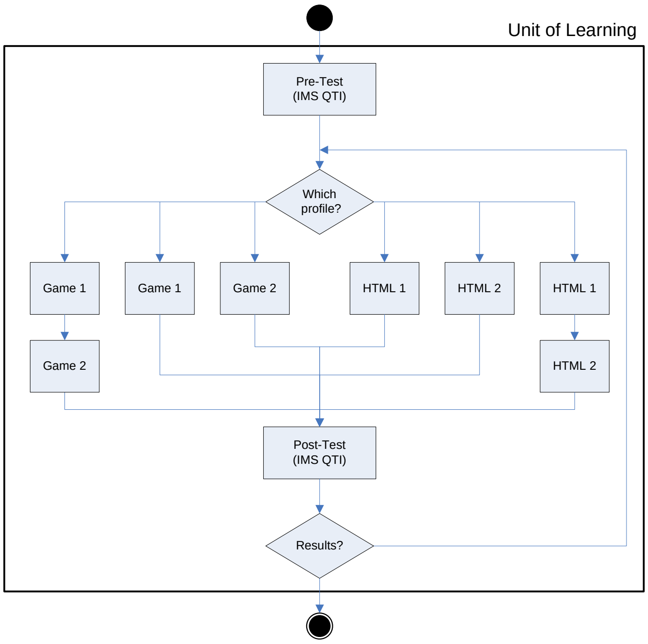

Figure 3: An adaptive Unit of Learning with a choice of content type (game-based for meaning-directed students or traditional for reproduction-directed) and with different learning paths skipping the subjects that the student is already familiar with.

In implementing the UoL described in this section we have used the <e-LD> editor (Martínez-Ortiz, Moreno-Ger et al. 2006a), developed in our group at Complutense University. The pre-test and the post-test activities were supported by using the IMS QTI specification (IMS Global Consortium 2005b) using the <e-QTI> editor (Martínez-Ortiz, Moreno-Ger et al. 2006b), also developed in our group. Content presented as HTML o PDF formats was directly included in the UoL as *webcontent*. Finally, the educational videogame was directly included as Java Applets and embedded in an HTML document included as webcontent, since in this approach the games are used as self-contained non-adaptive pieces of content. In fact, it would even be possible to simply repurpose an existing (and not necessarily educational) game and include it in the learning experience (Burgos, Tattersall et al. 2005). The resulting UoL can be directly executed in any IMS Learning Design player that supports integration with an IMS QTI service. As of now, any player that uses the latest version of the CopperCore Runtime environment would support this. For this purpose, we used the official release of the SLeD player (OUUK 2005).

3.3 Case 2: Game-driven Adaptation

As we have already described in the previous section, the IMS Learning Design specification provides the means to establishing a full adaptive cycle covering all the aspects of the general pattern proposed in this paper. However, both the elaboration of the profile and the assessment of the learning experience are limited to traditional constructs such as directly setting the values of some properties obtained through the results of simple tests presented to the student.

The UoL driven approach described above treats videogames as traditional HTML or PDF content, i.e. as black-boxes. That means a waste of very valuable information produced during the student-game interaction. We believe videogames are a rich medium that opens the gate to more innovative processes for gathering data about the student that may be used to assess learning outcomes. This hints that games could play a more significant role in the Unit of Learning.

Our second sample Unit of Learning includes one single activity consisting of a game that implements the entire adaptive cycle. In this approach the game starts with a first stage in which the player's avatar maintains in-game conversations with some colleagues. Then he arrives at the construction site where he receives the foreman's instructions (see Figure 4). After that, the player's avatar begins performing the corresponding tasks.

Figure 4: A screenshot of the game. The foreman queries the player about his preferences and the game will be adapted depending on the response of the player.

Depending on the player's choices during these conversations, the game detects in the first place the student's previous experience (conversations with fellow workers) and whether the learning style tends towards a Meaning-Directed or a Reproduction-Directed profile. Depending on the profile inferred, the game will change its behaviour accordingly:

- The foreman successively assigns construction tasks to the player, which are the same mini-games used in the previous section. If the student is already familiar with one of the subjects, the foreman will not even mention the task.
- Having identified a potential issue with RD students feeling lost in the game environment, these students receive from the foreman two in-game books with detailed instructions on how to proceed inside the game. These books can be accessed at any time during the game session.
- For the MD profile, the players are free to explore all the possibilities and risks of their actions, with very little indication from the system.

Additionally, once the tasks have been completed, there is another stage in the game in which the student must implement the electrical installation of the upper floor of the building without any help or guidance. The game checks to see if the student takes all the due preventive measures. Successfully completing the installation without incurring in any safety hazards is equivalent to passing a knowledge test and the game finishes successfully. On the other hand, if an infringement is detected, the player is notified and the game goes back to the scene in which the foreman assigns the initial tasks. Regardless of the initial profile, the stage of the game corresponding to the infringement that was detected will be compulsory this time.

Figure 5: The game implements the full adaptive cycle, querying the student about learning preferences and previous knowledge and then presenting different paths. The in-game exam is compulsory in all cases.

The result, as depicted in Figure 5, is a game that implements the entire adaptive cycle into the game experience, employing the UoL just as an interoperable deployment mechanism and metadata container.

Regarding implementation, even though this approach admits games developed by third parties, we used the <e-Adventure> engine (Moreno-Ger, Sierra et al. In press) for this purpose, which follows the document-oriented approach to the production and maintenance of content-intensive educational applications (Sierra, Fernández-Valmayor et al. 2006). This engine, as detailed in(Martínez-Ortiz, Moreno-Ger et al. 2006c), can be used to develop adaptive games that follow different paths depending on the interactions of the player. Games in <e-Adventure> are *point and click* adventure games (Ju and Wagner 1997) in which the content of the course is delivered by the conversations with other characters, the interaction with objects and (optionally) the consultation of in-game books. In our case, the responses of the player in conversations with fellow workers and with the foreman modify the flow of the game by activating alternative paths and potentially skipping some scenes. In the approach described in this section, the sample UoL containing the game can be also deployed into any IMS LD player, since the main learning activities are of an in-game nature.

3.4 Case 3: A Blended Approach

Educational games allow instructors to devise creative methods for gathering student information and practical assessments that go further than simple *multiple-choice* tests. However moving all the educational logic into the games implies that the pedagogical model is "hidden" in a format only understood by the designer of the game. This means the modification of pedagogical aspects is out of the reach of the instructors who may want to fine-tune the behaviour of the learning experience.

On the other hand, the IMS Learning Design specification was proposed to facilitate the exchange of pedagogical models and instructional designs in a common format, so it could be understood by all participants and even be processed by a machine (Koper and Olivier 2004).

Our third Unit of Learning seeks a balance between making the pedagogical model explicit using IMS Learning Design and leveraging the power of videogames as a medium to provide richer interactions beyond traditional tests.

In this approach the UoL contains the following activities:

- The initial activity is the same as the one described in section 3.2. Within this activity, the student is classified into one of the possible profiles and the variables in the Unit of Learning are set as in Figure 2.
- The next activity in the UoL is another version of the game, which is launched and modified according to the student's profile, presenting the same learning paths described in section 3.3.
- The next activity is the in-game exam, which it is maintained inside the game due to its high pedagogical value as a practice-oriented assessment mechanism. However, in this case we consider that deciding on the threshold between passing and failing the exam is a relevant part of the pedagogical model. Therefore this decision should be under control of the LD environment instead of residing inside the game. So instead of sending the student back to the beginning of the game as soon as one mistake is made, the exam is always completed. When the game ends the control returns to the LD environment and the results of the in-game exam are sent back in the form of the number of mistakes in each subject (defined as properties in the UoL). The decision about whether that number of mistakes is enough to send the student back to the beginning of the game is modelled in the Unit of Learning, which may decide to launch the game activity again as depicted in Figure 6.

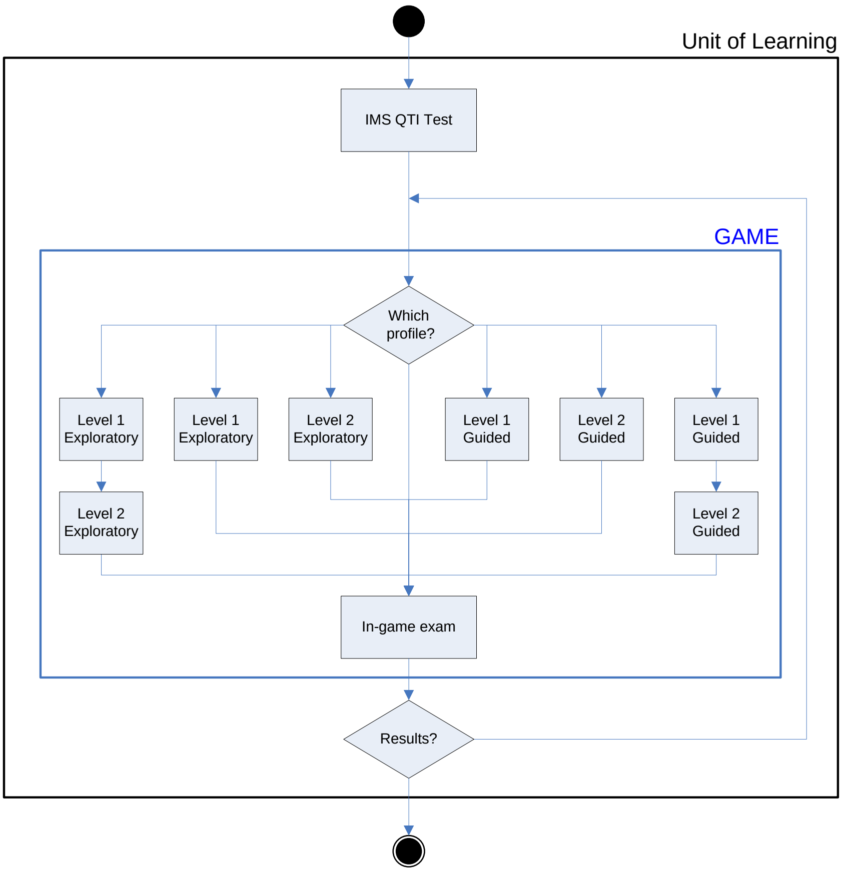

Figure 6: The blended approach. We still include adaptation inside the game and maintain the in-game exam, although the pedagogical model is modelled outside the game.

However, this approach requires the existence of a communication mechanism between the game and the environment in which the UoL is being executed. To support the server side of this two-way communication we have modified the SLeD player and CopperCore Runtime (Vogten and Martens 2005) following the same design principles employed in the integration of IMS QTI and other services in CopperCore (Vogten, Martens et al. 2006).

On the game side, the implementation using <e-Adventure> engine provides the mechanisms required to support a complete adaptive cycle in collaboration with a Virtual Learning Environment (VLE) as described in (Martínez-Ortiz, Moreno-Ger et al. 2006a).

When the <e-Adventure> engine is deployed as a Java Applet, it checks whether it was launched by a compliant Virtual Learning Environment. If that is the case, it queries the VLE about the current state of the Unit of Learning. Depending on the information received from the environment, the game changes its initial state, thus modifying the flow of the game. In this particular case, the game was designed to query about the learner profile, which is stored in three properties of the Unit of Learning as described in section 3.2. Depending on their values, the game will be adapted as described in Figure 6.

On the other hand, as the communication mechanism is bi-directional, the game can also broadcast events to the VLE. Again, this information is formed by attribute-value pairs that are aligned with properties in the Unit of Learning. In this case, the properties sent to the IMS LD environment contain the number of errors made in each part of the in-game exam (infractions regarding fall prevention and electrical safety).

4 Conclusions and Future Work

In this paper we have proposed three different approaches to address adaptation, taking into account previous knowledge and learning styles, using Learning Design, student profile information and educational videogames. The first approach is the most conservative, simply allowing the inclusion in a Unit of Learning of alternative activities (possibly including videogames) mainly based on learning style information: some activities may be more appropriate than others for a certain learning style.

The second approach focuses on using videogames as an adaptive educational medium, as we can obtain a lot of information from the student-game interaction. However, this means hiding the pedagogical model inside the game, which is arguably a bad approach given the current trend towards the use of standardized and interoperable content. Even if the videogames are an ideal medium for gathering information about the student, the game should make this information available to the VLE, so a communication process has to be established between them, which is the basis of the third approach.

The three Units of Learning described in this work exemplify these three approaches, and show how using IMS LD or adaptive games alone can yield an adaptive learning experience, but usually at the cost of sacrificing part of the power of each aspect. The blended approach, however, leverages the characteristics of both environments and thus has the best potential. However, this is precisely the approach that is not supported by most IMS LD environments available today. For this approach to be useful and widely adopted the communication mechanism needs to be available in a broad number of VLEs or the Units of Learning will not be interoperable, thus eliminating one of the main objectives of the IMS LD specification. For this reason, the most important line of future work is the integration of this type of communication service into the set of commonly used specifications, precisely in the line of the work of the Open University of the Netherlands regarding the integration of services in the implementation of IMS LD environments (Vogten, Martens et al, 2006).

Another important reflection is that the discussion in this paper has been limited to a specific (and simplified) adaptation pattern that relies heavily on tests and knowledge assessments to profile students. However, games are a rich medium and the supporting technologies presented in this work are capable of managing a much more fine-grained adaptation mechanism. It is technologically possible to monitor the activity of the learner inside the game and automatically infer the profile by observing the behaviour of the student inside the game (does the student wander around? Is he or she stuck at some point? How much did it take to solve a particular riddle?). Intuitively, there would be a relation between in-game behaviours and learning styles, and this would deserve its own line of work from the fields of pedagogy and cognitive science.

It is also important to note that the profiles employed in this work follow a very simplified model. Analyzing the advantages and shortcomings of different models categorizing learning styles is still an open research question which falls beyond the scope of this work. The general model, however, is independent of those models, as long as capturing the information for the model, performing the adaptation, and then refining the model is a common pattern in adaptive learning.

Finally, it should also be noted that the general pattern presented here explicitly includes the acquisition of the information for the learner profile as a task to be performed in the Unit of Learning. In production environments, this will not be the usual case, as the VLE is likely to store information centrally about the profiles of the students registered so that it can be used to adapt different UoLs. In any case, this is more of a technical detail rather than a pedagogical aspect, because how that profile is used to adapt the learning experience remains part of the instructional design, and thus belongs to the definition of the UoL.

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