Adaptation in current e-learning systems

Mª del Puerto Paule Ruiz a,⁎, Mª Jesús Fernández Díaz b, Francisco Ortín Soler a, Juan Ramón Pérez Pérez a

a Dpto. Computer Science-University of Oviedo, Spain
b Chelsea Public Schools-Massachusetts, USA

Received 15 December 2005; received in revised form 22 December 2006; accepted 2 July 2007
Available online 18 July 2007

Abstract

One key element to consider when developing e-learning systems is the adaptation of the system to the cognitive characteristics of the students. However, making this adaptation is not a simple process; it implies the study and conjunction of technical and pedagogical aspects.

This article was written from the point of view of a designer who, without being an expert on the cognitive elements, tries to design e-learning systems that include an adaptation for them. This article attempts to provide the answers to some design questions as a starting point to further develop e-learning platforms.

© 2007 Elsevier B.V. All rights reserved.

Keywords: e-learning; e-learning standards; Cognitive adaptation; Educational systems

1. Introduction

The technological revolution has immersed the traditional educational model in a transformation process; in a relatively short period of time it has gone from being based on paper and pencil to using a vast number of audiovisual media and technology, however, it is not the use of audiovisual media that has facilitated the change in the methods and organization of the learning processes but the use of the new technologies.

New technologies have impacted schools and universities all around the world at all levels. Nowadays, basic operations such as enrolment and obtaining grading information can be done using the university website. Not only that, but students can also access information and communicate with each other using the same website, and, more importantly, teaching itself can be done online.

The height of the Internet has caused an increase in the number of e-learning platforms that evolved from mere repositories of didactic resources to learning systems. When using e-learning systems, students have to interact with the system if they want to learn, this is not always true in traditional classroom settings (lecture), in which due to overcrowded classrooms, the students adopt a passive role and leave the active roles to their professors [2].

The organization of the information in the e-learning systems according to the needs of the students is very important. Currently, students have then to select what is important; this selection can be too overwhelming cognitively for the students and may lead them to quit the training process. It is our understanding that most e-learning systems make a great deal of information available to the student.

It is particularly important that the e-learning systems are able to integrate different paces of content and navigation in order to be able to respond to diverse needs of the students and to avoid the cognitive overload. The adaptive hypermedia [4], which appeared as an attempt to overcome this challenge [13], Adaptive Hypermedia Systems (AHS) are systems that deliver personalized views or versions of hyperdocuments [15] and these systems use a user model and a concept model within the learning environment to decide what content and type of navigation present, as well as how to best present these contents. Adaptive Educational Hypermedia [5] caters to needs of each
individual student, adapts to their goals [10]; knowledge level [16]; background; interest [6]; preferences; stereotypes [38]; cognitive preferences [9] and learning styles [35]. But also, in order to facilitate instruction and due to the large amount of information available in e-learning contexts, contents need to be very structured and systems need good guiding systems through these contents. That is the reason why current hypermedia systems make adaptations in the contents and/or in the navigation system depending on the characteristics of the user.

The trouble is to find out the parameters that configure the user model and to make this configuration in real time. Most systems use deterministic and static parameters that are obtained from user profiles, as an example, the user answers questions such as age or previous knowledge. Another systems may even use cognitive concepts such as learning styles or learning strategies. In this paper, we would focus on systems that include adaptation at the cognitive model and more specifically adaptation at the learning styles.

In order to develop systems that include adaptations at the cognitive model, it is necessary to perform the following tasks [31]:

1. Select a good taxonomy of learning and cognitive styles.
2. Develop techniques to introduce the adaptation into the system and to classify the user.
3. Design the adaptation by selecting technologies and techniques that are adequate for the selected learning styles.
4. Design the educational content.

From the point of view of a designer, we consider that the more important tasks are numbers 1, 2 and 3 but with some changes:

1. Select a good taxonomy of learning styles to classify the user.
2. Develop techniques to introduce the adaptation into the system and design the adaptation by selecting the developed techniques that are adequate for the selected learning styles.
3. Implementation of the designed adaptation on a computer.
4. Select the technologies that are adequate for the adaptation.

The following sections will analyze in detail each of these questions.

2. Selection of taxonomy of learning styles to classify the user

The user model has to be modeled with some parameters, which can be determined by diagnosing the needs, interests, and difficulties of the user, and logically the system has to adapt accordingly. Most systems use deterministic parameters like age, or previous knowledge, and some of them may even use cognitive concepts such as learning styles or learning strategies. Learning styles are different ways in which a person can learn. It is commonly believed that most people favor some particular method of interacting with, taking in, and processing information. The concept of learning styles is related to an understanding of learning as an active process. If we see learning as an active process, it is clear that each individual will have a different understanding of the information presented depending on personal characteristics. Psychologists have proposed several complementary taxonomies of learning styles [7] [17] [34] [18] [25].

When we review the research done on learning styles, we can find many different approaches. These approaches determine different styles and their characteristics, propose assessment tools to classify individuals into their specific styles, and specify the most adequate materials to respond to a particular style. These taxonomies offer a theoretical base to design e-learning systems. Many of these taxonomies are specific for a particular educational period and context.

In order to get a classification of the user, the systems have to use some type of method to assess the learning style of each individual. Some systems perform a dynamic accommodation, they analyze the individuals’ behavior when interacting with the system in order to infer their learning style and accommodate to their needs. For example, the Arthur system [20] divides the courses in concepts; when the user has finished with the first concept which was presented using a learning style that was chose at random, the system assesses the student’s success, and if this is not higher than 80%, the systems change the learning style.

Other systems use assessment tools that classify users according to their learning styles. These tools can be questionnaires based on the different classifications of learning styles or they can also be questionnaires in which users themselves define their preferences. When selecting a questionnaire we need to take into account a number of elements [24]

- The questionnaire needs to have an instrument that classifies the individuals into the different categories that the model suggests.
- The questionnaire has a reasonable number of items in the assessment tool.
- The cost of the tool and testing materials.

The Feijoo.net is a system [29] developed in University of Oviedo and that uses the CHAEA Test [7] for determining the learning style of the students. The CHAEA Test consists of 80 items that clearly classify individuals in each of the four learning styles that proposes: Active, Reflexive, Theoretical, and Pragmatic. It may be a rather long test, however, one of its strengths is that it is quick to administer, it only requires 15 min. Feijoo.net determines if a new student is trying to access the system, and in that case the questionnaire is presented to the

---

1 Task 4 is related with the creation of the content that the teachers or professors have to do.
student. Once the student finishes the test, the results are sent to the system, and processed to obtain the predominant style which is then stored for future use, the results of the questionnaire are also shared with the students for their information. When students are not new to the system, they are not required to take the test again.

Systems that rely on a dynamic accommodation analyze the interaction of the individual with the system as well as the results of the strategy used. However, in our opinion, these systems present one difficulty, this is the selection of the factors that are going to be observed during the interaction since it is very difficult to determine what students’ actions are indicative of their learning style. On the other hand, a possible inconvenient of the systems that use questionnaires to determine the learning style of the user is that the results obtained by the questionnaire may not be totally reflective of the way a particular individual learns in a specific learning style category. This problem may be overcome when users are asked to modify certain aspects of the profile obtained by the questionnaire.

In general, most systems that incorporate learning styles are based on the principle that the performance of the students increases when their learning styles are matched with the adequate educational strategies. Research that indicates so can be found in [30] [26]. The first study conducted by these authors shows the results of an evaluation of a course that makes accommodations using the learning style test CHAEA, this is a comparative analysis between an accommodated course and a course without accommodation. For the second study participants used two interfaces – one ‘normal’ and one adaptive – and were randomly matched or mismatched to their Field Depend/Field Independent cognitive style. These studies show some interesting results such as the lack of interface preference for those users who were matched to their cognitive style, while those who were mismatched were significantly more likely to prefer the normal interface. However, the content of the course that respects the learning style of the user makes the learning more efficient.

3. Develop techniques and design the adaptation

Many systems that work with learning styles use different methods and techniques that are used in the Adaptive Hypermedia Systems [11]. It is important to remember here that methods explain how to obtain specific results, and techniques are the specific manner in which methods are implemented [3] [13], for example Brusilovsky proposes a number of techniques that are explained with detail in [3].

In connection with the design of the adaptation, there are two different systems:

1. Systems that use learning styles to guide the design of the educational contents. These systems are based on offering the users the type of materials that are preferred by individuals classified in their specific learning style.

2. Systems that use learning styles to guide the adaptation of the structure of the contents to the mental processes of each individual (particular styles of thinking, perceiving or remembering) that falls in a certain category.

The first type of systems would present different resources depending on the learning style and/or accommodate the sequence of the resources following a specific strategy for each style. Tangow [8] and Inspire [22] [32] and Feijoo.net fall in this first category of systems.

The systems Tangow and Inspire offer a different sequence of alternative contents for the same concepts. In Inspire, concepts are represented by “example”, “activity”, “theory”, and “exercise”; in Tangow, they are represented by “example” and “explanation”. For example, for Reflexive users in Inspire and for Sensitive users in Tangow, the instruction strategy is lead by “example”, this means that students are presented first with an example and only after that are they presented with the other representations of the concept. Inspire and Tangow use techniques of adaptive navigation support with annotation of link.

Feijoo.net proposes to create a content that is common to both styles, Theoretical and Active. Afterwards, a specific content is created for each style. Concepts are represented by “theory”, “example”, “exercise”, and “activity”. The concept “exercise” consists of “text”, and a “solution” and depending on the style, the concept “solution” may have an “activity” associated to it. In summary, each style has a common and a specific content for every concept, and different paths of contents are generated to be visualized depending on the style. As Fig. 1 illustrates, the sequence for a theoretical student would be “theory”, and “examples”, with the option of also doing “activities”; however, the sequence for an active student would be “theory”, “exercises” with their “text” and “solution” (in case they want to access it), plus “activities” and the option of going to “examples”. Feijoo.net uses techniques of variation of fragments, arrangement of fragments and insertion/elimination of fragments in order to present the contents for each style.

The second type of systems are based on the accommodation of the navigation tools in order to make it easier for the users to structure the information and guide the navigation according to their learning styles. The AES-CS system is an example of this second type of systems. AES-CS [36] provides the field dependent students with support navigation tools such as graphic organizers, position markers, and advanced organizers in order to help students organize the structure of the knowledge domain. The system guides them through the educational materials using navigation tools. Field independent students are provided with an option of “student control”, for these students the system shows a menu from which they can follow the course in any order. AES-CS includes the technique of conditional text

---

**Fig. 1. Sequence for theoretical and active learning styles.**
4. Implementation of adaptation on a computer

In general, the most of systems implement the adaptation on a computer two different ways:

1. The first kind is based on the use of rules that activate one another when certain actions happen, these rules can also create new rules, e.g: AHA! (http://aha.win.tue.nl) [14] and MOT (http://www.is.win.tue.nl/~acristea/mot.html) are both systems that belong in this first category. Both systems have been developed by the Technological University of Eindhoven. MOT is an improved version of AHA!. The main problem with AHA! is that in case it has to be applied to a new domain or concept map, it has to be generated again from the beginning and no reuse is possible. In order to avoid this problem, MOT creates an adaptive language that is able to build rules. The problem when using this new language is that the new generic strategies should be interpreted in order to make it possible to translate them into rules IF–THEN of AHA! and, eventually apply them to all the concepts.

2. The second kind is the creation of proprietary objects with a particular format created for each application. AuldLinky [1] is a system that belongs in this category. This system is a FOHM server (Fundamental Open Hypermedia Model), it provides dynamic links in run-time. FOHM defines a data model and operations that are applicable to the three domains of the hypertext: navigational, spatial, and taxonomic. It also incorporates context objects and behavior objects. Context objects are important because they provide a restriction in the number of available objects, in such a way that for every context the results of each query are different. In this way, if we use context objects to define the learning style of a user, the learning strategies, and a specific type of resources will be chosen accordingly to the context. The behavior objects make it possible to update some elements of the system such as the level of knowledge of the individual, which is included in the user profile; in order to obtain the information for the update an assessment test needs to be completed. The adaptation is done through queries with AuldLinky which accordingly to the context objects analyze the model and select the adequate strategy for the context.

In general, the use of rules is important to support the adaptive capabilities of the system, however, in our opinion it makes the exchange of information among different systems more complicated since new knowledge is generated, however, that knowledge is not accessible from any other system but from the one that generated it, and consequently, they generate an adapted knowledge that can not be reused. Regarding the creation of proprietary objects for each application, it may be that the philosophy of work that is underlying these systems is correct and very efficient. However, due to the fact that these systems are using objects, which have been specifically created for them, the exchange of these objects among applications is difficult since these objects do not follow any format.

3. The third kind is the use of Learning Objects [37]. A Learning Object is an element of a new type of computer-based instruction grounded in the object-oriented paradigm of computer science. One of the goals of the Learning Objects is the reuse of object-oriented products.

The main advantage that Learning Objects offer is that information is shared, for example a user in France may have created an HTML content and may have packed it into an Learning Object, this Learning Object may be located in server in Belgium, and a user in Spain may access this Learning Object which is placed in a repository of objects in Belgium. The advantage is clear: there is some information that is shared and thus the redundancy and duplicity of information is minimal.

Another advantage of Learning Objects is that they may be anywhere and its content can be incorporated to any system that follows a number of specifications. A number of specifications for exchanges have been established in order to make possible the reuse of educational resources and the interoperability among heterogeneous software systems.

The goal of achieving homogeneity among systems and contents is important in order to increase the following aspects [12]:

- Effectiveness in the reuse of contents
- Adaptability of contents and learning environments in accordance with the knowledge requisites and the student’s preferences.

The standards are the instruments that will give flexibility to the e-learning systems, in content as well as in structure. Besides, e-learning standards must also be used to support the pedagogical process. The use of standards is necessary in order to assure a proper connection and compatibility among different systems; therefore, it is important to guarantee a meta-data language (information related to the contents of the course) that is common and rich enough to be able to convey all the necessary information related to the learning process that needs to be integrated by the system in order to do track the student’s progress.

Currently the most common used e-learning specifications are:

1. **ADL SCORM**. ADL (http://xml.coverpages.org/) (http://www.adlnet.org) (Advanced Distributed Learning), SCORM is a set of specifications that apply to the development, packing, and delivery of educational materials and courses; its first version was published in the year 2000 (although there is a previous beta version from 1999). The standard SCORM is based on the work of AICC (http://www.aicc.org/) and IEEE LTSC (http://ltsc.ieee.org/) and the IMS (http://www imsproject.org/), and it attempts to capture the best of each specification.

2. **IMS-LD**(http://www.unfold-project.net). Newly created developing specification. It adds new aspects related to
communication aspects and collaborative elements. It offers support for many students and permits communication between them, it takes the role of the teacher, it makes possible the combination of learning resources with pedagogical activities and the interactions between people with different roles (Figs. 2 and 3).

4.1. Our proposal of implementation

We propose an approach based on the use of Learning Objects and the methods and techniques of Adaptive Hypermedia. Each Learning Object covers one or more learning goals in such a way that courses can be developed by combining different Learning Objects, while the methods and techniques of the Adaptive Hypermedia can be used for the presentation and navigation. Consequently, the learning process is fragmented in a series of activities that the student has to complete following particular guidelines. This fragmentation offers a great flexibility since a great amount of combinations can be generated from all the Learning Objects that constitute an entire course. This allows for the development of complex courses in such a way that the learning strategy can be more flexible.

---

**Fig. 2.** Course of photoshop in SCORM format (imsmanifest.xml).

**Fig. 3.** Course of photoshop in IMS_LD format (imsmanifest.xml).
However, the adequate selection of Learning Objects requires the use of Ontologies (http://en.wikipedia.org/wiki/Ontology_(computer_science)) for e-learning in order to tag, to find and to recover the Objects in the web. These ideas are related with Semantic Web (W3C)(http://www.w3.org/2001/sw/). It is necessary to obtain the proper concepts, vocabulary and definitions to get a class of Objects. The international community is searching a consensus about the most used terms in the e-learning. Currently, the terms are very unclear and it is impossible to class the Object with one adequate meta-data (information related to the contents of the Object).

The absence of clear Ontologies has caused the use of Folksonomies. A folksonomy is defined (http://en.wikipedia.org/wiki/Folksonomy) as an Internet-based information retrieval methodology consisting of collaboratively generated, open-ended labels that categorize content such as Web pages, online photographs, and Web links. Two widely examples of websites using folksonomic: Flickr (http://www.flickr.com/) and Del.icio.us (http://del.icio.us/). The folksonomies are has some criticisms and it is very important to apply them in the correct context.

We have introduced a folksonomy to class the Learning Object in the Feijoo.net system. The Feijoo.net systems uses the CHAEA Test for determining the learning style of the students, and the proposed folksonomy is based on the criterion of the CHAEA Test, which defines four type of learning styles: active, reflexive, theoretical and pragmatic. The Feijoo.net system has been updated in order to work with Learning Objects packed with SCORM. The goal was to add adaptation to learning styles of CHAEA test not breaking with the specification SCORM, so the adaptation is got using the different tags of manifest.

We define common organization and several sub-organizations for each learning style. The common organization has the common resources to both learning styles (active and theoretical). So, there are one default organization, and as many organizations as learning styles. If the student has assigned one learning style then, the system processes the common organization and the specific sub-organization, and if the student has not assigned any learning style then the organization is the default organization (Fig. 4).

We decided to do the adaptation of this way because it is faster in run-time. The load of the file is very quickly, although the file can be very long. However, the composition of the content with the SN (Sequencing and Navigation) of SCORM is very complicated and very slow in run-time. In our opinion, it is very difficult to interpret the rules of SN and how they work. They have very thorny tags and these tags sometimes are not clearly defined.

5. Select the technologies that are adequate for the adaptation

Regarding the technologies in which the systems are implemented, the tendency has been and still is to use Java platform and related technologies.

Many Web-based systems that work with learning styles and implement the different methods and techniques of the Adaptive Hypermedia Systems present the content and the navigation either using Java applets or alternatively generating HTML pages to which CSS page styles are applied. In our view, these implementations have a disadvantage, and this is that they limit, at times, the interaction with the user and, in our opinion, it is better to use other development techniques that promote a better interaction, such as AJAX [23]. AJAX offers new forms of presenting and interacting with the resources (an example can be seen on http://maps.google.com). There are components of a web page that do not change, so that the entire web page does not have to be reloaded each time the user makes a change. This is meant to increase the web page’s interactivity, speed, and usability.

The main mechanism in which AJAX relies is Reflection[33]. Reflection [28] is defined as the capability of a computational system to reason about or act upon itself, adjusting itself to changing conditions. The computational domain of a reflective language is enhanced by its own representation, offering its semantics and structure as if they were comput data. In case the resource is a map, thanks to this mechanism, a user could add a map of any part of the world without having to create a specific application to show this map. This is possible because the application makes it possible to generate the code for any map in any part of the world on demand, which means that if a user in the USA wants to see Canada, the code of the map of Canada will be accessible in the form of data and will be executed in run-time.

![Fig. 4. Organization with adaptation.](image1)

![Fig. 5. Source of SCORM file with AJAX.](image2)

![Fig. 6. System without reflection.](image3)
In order to add AJAX in the Learning Objects, it is necessary to have installed the AJAX engine and to add the localization of the engine as a resource in the manifest of the SCORM file. The resources know the localization of the AJAX engine and they invoke it when it is necessary (Fig. 5).

Reflection is also a mechanism that can facilitate the creation of rich interfaces and can also be used at the architectonic level to incorporate standards or guidelines of e-learning. This permits to achieve independence between representation and behaviour. And, consequently, it is possible to manipulate any current or future standard without creating specific motors for each standard. This is possible because reflection permits to associate different representations to one common functionality that is executed when the system is ran, thus avoiding duality of the modules. Figs. 6 and 7 show the development of the architecture of the system.

As you can see in Fig. 6, the incorporation of a new standard will create a new processing module that has to be developed independently from the existing ones. However, as you can see in Fig. 7, the incorporation of a new standard does not make necessary to develop a new module, since the structure, behaviour and adequate run-time environment of Learning Objects are specified in its information. So, when the software system runs them, the information in the Learning Object can be converted in run code through reflection. The run code contains the attributes and the methods of the object. For example, the adequate run-time contains the data that indicate how the object has to be launched in such a way that once the system transforms this information into code to launch the object; the system is able to run the learning object.

The introspection is a kind of reflection that permits to make and process objects in run-time. The code source in Java (Fig. 8) shows how the introspection works. As you can see in this code, the name of the class is an argument in command line. I search the constructor of the class with the sentence c = Class.forName (clase).getConstructor(null). Now, I can instance an object with de sentence c.newInstance(null), and I can invoke one method of the class, that can be made in run-time with computational reflection.

6. Conclusions and future work

It is very important to model the user in an e-learning system, since the success of the system will somehow depend on it.

We have shown in this paper how important and convenient it is that the educational resources created by the systems are reusable. The e-learning standards have made it possible to make a reality the exchange and reuse of these resources and also the interoperability between systems. However, their use is not yet as widely spread, as it would be desired.

SCORM is the e-learning standard with a bigger circulation in the market; nevertheless the functionality described in the specification is very poor compared to the richness of the learning experience[21]. Besides, this functionality is not enough for a successful e-learning since it is limited to a single student working alone with the computer[19], without taking the web’s communication abilities into account. It has been proved that the cooperation in learning is positive and that is why the IMS-LD specification incorporates communication aspects and collaborative elements.

It is necessary to change the implementation of the systems that adapts to the user the content and the presentation and we propose an approach based on the use of Learning Objects and

```java
public class Introspection {
    public static void main(String args[]) throws Exception {
        if (args.length==0) {
            System.out.println("Typical Solution.");
            new Creador().unMетодo();
            new CreadorB().unMетодo();
        } else {
            System.out.println("Introspection:");
            // * It is very important: We do not need to make new constructors
            // 1 get the name of the class as argument in command line
            String class name=arg[0];
            System.out.println("I am making a product and I use it.");
            System.out.println("I make a product: ");
            // * We get the constructors
            Constructor c=Class.forName(class).getConstructor(null);
            // * We make the object
            Producto producto=(Producto)c.newInstance(null);
            // * I invoke one method of object
            producto.unMетодo();
        }
    }
}
```

Fig. 8. Source code of introspection.
the methods and techniques of Adaptive Hypermedia. However.
This proposal is based on folksonomy, because there is not a
clear Ontologie for e-learning.

The mechanism of reflection makes it possible to establish
new forms of presenting and interacting with educational
resources, and also facilitates the incorporation of new
standards of e-learning in the educational systems, because it
associates different representations to a one specific content.
Also, the reflectivity makes the process of adaptation stronger
since it is possible to create a specific code depending on the
characteristics and needs of the user at the time of the execution.

The use of reflection by the systems will bring a change in
the use of language of development, opening the way for
dynamic languages [28]. Python is one of the most common.

We are researching how to apply reflection to determine the
user model. Currently, in most hypermedia adaptive systems the
adaptation of the system is based on the use of rules that are
started depending on the model or profile of the initial user.
The adaptation mechanism has to be previously coded in the system
in order to respond to the characteristics and needs of the
particular user that is using the application. In our opinion, the
reflection will make the mechanism of adaptation stronger,
since, on one hand, it is not necessary to have coded all
mechanisms that allow the adaptation to adapt to the user and
consequently, this makes possible, in our view, not only to
generate the code for the current user of the application, but also
to include new forms of adaptation in running time, creating
from the information of the adaptation the code that will
implement it correctly.

Acknowledgements

This work has been partially funded by the Department of
Science and Technology (Spain) under the National Program for
Research, Development and Innovation, project TIN2004-
03453.

References

Adaptive Links. Available in http://eprints.ecs.soton.ac.uk/9667/01/
Adaptive_SCorm_Final.pdf.
[2] M. Area Moreira, What is the role of the Internet in the pedagogical change
at the level of College Education (Spanish), Proceedings of III
International Conference of Communication, Technology and Education,
Mayfield (Eds.), Intelligente Hypertext: Advanced Techniques for the
World Wide Web, Lecture Notes in Computer Science, vol. 1326,
Nykänen, S. Pohjolainen, P. Hietal (Eds.), Intelligent Computer and
Communications Technology — Learning in On-Line Communities,
Proceedings of the Tenth International PEG Conference, Digital Media
Institute, Tampere University of Technology, Tampere, Finland, 2001,
pp. 8–12.
based learning, Journal of Continuing Engineering Education and Life-
Long Learning, special issue on Internet based learning and the future of
development of a learning model, Journal of the American Society for
[10] R. Cliford, Adaptive Hypermedia for Music Instruction. 7th International
on learning Styles and Adaptive Hypermedia. (available in http://wwwis.
wit.tue.nl/~acrictea/USI/USI8.ppt.
[12] O. Comezaña Portilla, F.J. García Peñalvo, Web Educational Platforms:
Leggett (Eds.), In Proceedings of the ACM Conference on Hypertext and
Hypermedia, Darmstadt, Germany, 1997, pp. 147–156.
for Adaptive Hypermedia Applications Hypertext'99, the 10th ACM
Conference on Hypertext and Hypermedia, Darmstadt, Germany, 21–25
February 1999, pp. 147–156.
[17] R. Dunn, K. Dunn, Teaching Students through their Individual Learning
Online Education Using Learning Objects, Routledge/Falmer, London,
2004.
[20] J.E. Gilbert, C.Y. Han, Adapting instruction in search of ‘a significant
contribution of IMS Learning Design to the creation of reusable learning
resources (Spanish). RED. http://www.um.es/red/MS/.
[22] M. Grigoriadou, K. Papanikolaou, H. Komilakis, G. Magoulas, INSPIRE:
an intelligent system for personalized instruction in a remote environment.
Proceedings of 3rd Workshop on Adaptive Hypertext and Hypermedia,
and Adaptive Hypermedia. (available inhttp://wwwis.onelmoon.com/
differences in Adaptive Educational Hypermedia Systems. Workshop on
Interactive Hypermedia and Adaptive Learning, Prentice Hall, New Jersey,
1984.
Styles: Is it necessary? Workshop on Individual Differences in Adaptive Hy-
permedia, The University of Technology, Netherlands August 23–26,
[27] D.A. Kolb, Experiential Learning Experience as the Source of Learning
and Adaptive Hypermedia. (available inhttp://wwwis.onelmoon.com/
Adaptive_SCorm_Final.pdf).
[30] K. Papanikolaou, M. Grigoriadou, Accommodating learning style char-
acteristics in Adaptive Educational Hypermedia Systems. Workshop on
Empirical Evaluation of Adaptive Systems. Netherlands August 23–26,


Maria-del-Puerto Paule-Ruiz is a Full Professor in the Computer Science Department of the University of Oviedo. Her research interests include Object-oriented Systems, e-learning systems, adaptable and adaptive educational systems, learning objects, software architecture in the e-learning systems, and e-learning specifications. She received her Ph.D from the University of Oviedo in Computer Science. She can be contacted at paule@uniovi.es.

Maria-Jesus Fernandez-Diaz currently works as a School Psychologist for Chelsea Public Schools in Massachusetts, USA. Her areas of interest are education and e-learning. She obtained her Master’s Degree in Psychology from the University of Salamanca, Spain, and completed doctoral courses in Educational Psychology at the University of Oviedo, Spain. She can be contacted at mariage10@yahoo.com.

Francisco Ortín-Soler a Tenure Associate Professor in the Computer Science Department of the University of Oviedo. His research interests are Computational Reflection, Object-oriented abstract machines, Aspect Oriented Software Development, every kind of adaptable and adaptive systems, and integral object-oriented systems. He received his Ph.D from the University of Oviedo in Computer Science Engineering. He can be contacted at ortin@uniovi.es.

Juan-Ramón Pérez-Pérez is a Full Professor in the Computer Science Department of the University of Oviedo. His research interests include Object-oriented Systems, e-learning systems, groupware and collaborative and cooperative learning, adaptable and adaptive systems and its implementation to software development. He received his Ph.D in Computer Science from University of Oviedo. He can be contacted at jpp@uniovi.es.