Modeling Adaptive Educational Methods with IMS Learning Design

Marcus Specht [1], *Daniel Burgos* [1]

[1] Open University of the Netherlands PO
BOX 2690, 6401 DL Heerlen
The Netherlands
www.learningnetworks.org, www.ou.nl

Abstract: The paper describes a classification system for adaptive methods developed in the area of adaptive educational hypermedia based on four dimensions: What components of the educational system are adapted? To what features of the user and the current context does the system adapt? Why does the system adapt? How does the system get the necessary information? Based on this taxonomy several classical methods of adaptive educational hypermedia are classified. In a second step the paper gives an overview of key features in IMS-LD for implementing adaptive educational methods and gives some examples. In the last section the work is integrated and IMS-LD features are identified which can be used for the four dimensions of the classification system.

Keywords: Adaptive learning, IMS Learning Design, Unit of Learning.

1 Introduction

In adaptive educational hypermedia a variety of research work on how to adapt curricula and learning content to individuals and groups of learners has been done (Leutner, 1992; Brusilovsky, 1996; Weber and Specht, 1997; Specht, 1998; De Bra and Calvi, 1999). Mostly the developed systems or prototypes use their own representations and internal persistent mechanisms for adaptive educational content. This leads to very little or no reusability and exchange of adaptive content between various adaptive solutions and only little integration of those solutions with widely used LMS systems. Some efforts for the exchange of adaptive content have shown that besides missing exchange formats also standardized engines for running adaptive content are missing. With IMS-LD the authors see the possibility to come a step further towards the reusability of adaptive content. In that sense this paper provides a proof of concept that the most widely used adaptive methods in educational systems can be represented and made reusable in IMS-LD.

In the following sections first a classification system for adaptive methods is introduced and several adaptive methods described in the literature are analyzed according to the presented classification system.

From our point of view adaptive methods in educational hypermedia applications can mainly be structured according to four main questions (Specht, 1998):

What parts or components in the learning process are adapted? This question focuses on the part of an adaptive application that is adapted by an adaptive method. Examples can be to personalize the pace of the instruction (Tennyson and Christensen, 1988; Leutner, 1992), adaptation of content presentations, the sequencing of contents and others. Extensions with new forms of information delivery allow the distribution of learning materials to different learning contexts relevant to the individual user or groups of users. In table 1 the column "What is adapted?" gives some examples of possible values of this parameters of an adaptive method.

What information does the system use for adaptation? In most adaptive educational hypermedia applications a learner model is the basis for the adaptation of the previously given parameters of the learning process. Nevertheless there are a several examples where the adaptation takes place not only to the learner knowledge, preferences, interests, cognitive capabilities, but also to tasks and learner goals. Especially in social recommender systems and new approaches from social software used for learning the information for adaptation of the individual process can come out of external information resources, collective logging information, or even contextual sensor information like the location of a learner. In table 1 the column "To which features?" gives several parameters to which an adaptive method can adapt.

Why does the system adapt? This question mainly focuses on the pedagogical models behind the adaptation (Pask, 1964; Frank, 1965; Salomon, 1975). Classical educational hypermedia systems mainly adapt according for compensation of knowledge deficits, ergonomic reasons, or adapt to learning styles for an easier introduction into a topic. The column "Why?" in table 1 gives some examples of adaptation goals.

How does the system gather the information to adapt to? There are a variety of methods to collect information about learners to adapt to. Mainly implicit and explicit methods like described in works from user modeling can be distinguished. A overview can be found at Jameson (Jameson, 2003). The last column in table 1 gives some examples of information acquisition methods for adaptive methods.

Table 1 gives an overview of possible values and combinations for those four dimensions. The approach was first introduced by Specht (Specht, 1998) and allows for new adaptive methods. As a classical example "Adaptive Sequencing" was described in the literature (Brusilovsky, 1996) where the sequence of learning object or learning units is adapted to the learner's knowledge, skills, or preferences. As the possible combinations from table 1 show the classification system allows describing a wide variety of possible adaptive methods, which use different adaptation means, targets and goals, and apply different methods for information collection.

What is adapted ?	To which features ?	Why ?	How ?
Learning goal • Content • Teaching method • Content Teaching style • Media selection • Sequence • Time constraints • Help Presentation • Hiding • Dimming • Annotation	Learner Information • Preferences • Usage • Previous knowledge, professional background • Knowledge • Interests • Goals • Task • Complexity Contextual Information • Environment • Location	Didactical reasons • Preference model • Compensation of deficits • Reduction of deficits Ergonomic reasons • Efficiency • Effectiveness • Acceptance	• Knowledge Assessment • Questionnaires • Tests • User Tracking • User Model Inference

Table 1: A classification schema for adaptive methods

Specht (1998) describes and experiments with different examples for adaptive methods that can be found in different research areas as Intelligent Tutoring Systems (Carbonell, 1970; Clancey, 1987; Anderson, Conrad et al., 1989), Adaptive User Interfaces (Carroll, 1984; Brusilovsky, Specht et al., 1995), Adaptive Hypermedia (Brusilovsky, 1996), Intelligent Multimedia or Intelligent Agents (Feiner and McKeown, 1993; Rickel and Johnson, 1997) for Learning. Examples found in the literature can be mostly classified to the scheme introduced above and in *Table 2*. The following section gives an overview with some examples. We will select some methods and discuss the possibilities to implement them in IMS-LD.

What?	To what?	Why?	How?
Adaptive Sequencing			
Sequencing Content or Learning Activities	Learner tested knowledge or navigation history	Compensation of Deficits or Encouraging	Tests, Tracking
Incremental Interface			
Complexity of Interface, Number of functionalities	Tasks, Skills, Domain Knowledge	Usability	User Tracking, Questionnaires
Adaptive Presentation			
Selection of media	Knowledge preferences goals	Compensation of deficits	Diagnostics for Media Reception
Adaptive navigation support			
Hyperlinks, Restriction of navigational freedom	Knowledge, background, preferences	Adaptation to zone of proximal development	Knowledge Assessment, Tests

Table 2: Examples of classified adaptive methods

2 IMS Learning Design and Adaptation

IMS Learning Design (IMS-LD from now onwards) (IMSLD, 2003) is a specification to model learning strategies and represent learning processes of users at runtime. Furthermore, IMS-LD is focused on the design of pedagogical models to manage learning activities which are linked to learning objects within a learning flow (Koper and Tattersall, 2005). Therefore, activities must be designed in parallel with the processes to use them, taking the users´ profile into account. The structure of an IMS-LD design consists of a learning flow with plays, acts, activities, activity structures and environments and is flexible enough to provide several personalized itineraries depending on the role assigned. Several examples are available at (OUNL, 2002; LN4LD, 2005).

The structure of IMS-LD is detailed in three different and complementary steps:

1. Level A is the main part of the specification as it provides the bottom-line to build any Unit of Learning with the elements Method, Play, Act, Role, Role-part, Learning activity, Support activity and Environment; Level A provides the basic structure of activities and processes along with the roles´ definition;

2. Level B incorporates some other elements to create more expressive lesson plans (for instance, based on adaptation, collaboration or monitoring) using Properties, Conditions, Calculations, Monitoring services and Global elements (Koper and Burgos, 2005; Specht and Burgos, 2006); Level B is the actual key for adaptation; and

3. Level C adds Notifications, and enables a mean to trigger some dependant activities. Every layer adds new possibilities for representing more complex educational scenarios and it is built on the previous one (Koper and Burgos, 2005). The combination of some of these elements is the key for modeling several adaptive methods.

Technically, the specification defines a XML document, called imsmanifest.xml, describing a pedagogic scenario in detail, and linking the actual resources in a variety of formats with it (Koper and Tattersall, 2005) and it is embedded in an IMS Content Packaging information package.

The current state of IMS-LD deals with a number of research groups in various topics, such as editor tools, runtime environments, runtime adaptation, and modelling adaptation in general. However, there is a gap between what is researched and the current state of the tools that allow for easy editing and playing of the Units of Learning (UoL) provided as one of the most frequents outcomes of the research. These editors can be IMS-LD based (Bolton, 2004; Miao, 2005) as also general editors (Altova, 2006), and they need a significant effort to create IMS-LD UoLs with a certain level of complexity focused on specific models, like adaptation or collaboration (Burgos, Tattersall et al., 2006). As a core problem the current tools allow instructional designers to create adaptive UoLs if they have a high understanding of the modeling possibilities of IMS-LD.

Several projects try to develop editors and run time environments that make the expressive power of IMS-LD more available to end users and therefore also allow for adaptive and flexible learning processes in standardized electronic learning support. For instance, the TENCompetence Project (TENCompetence, 2005) and Complutense University (UCM, 2006) develop a visual IMS-LD Editor each. There are also some initiatives to use adaptation along with IMS-LD, like in the domain of Game-Based Learning (Burgos, Moreno-Ger et al., 2007)

Furthermore, the three different layers of IMS-LD support the modeling of different aspects and also more complex classical adaptive methods (e.g., reuse of pedagogical patterns, adaptability, navigational guidance, distributed collaborative learning, contextualized and mobile learning, adaptation to stereotypes). The integration of different structural elements of IMS-LD, like Environment, Content, User groups and Learning flow can be modelled with several components, such as properties, conditions, global elements, calculations, and monitoring services.

Basically, with the combination of Properties, Calculations, Conditions, Global elements, Monitoring services and Notifications a variety of classical adaptive methods can be modelled. For instance, properties allow for making use of user features, group features, and adaptation to stereotypes (Rich, 1989). Beside the classical adaptation to individual learners especially the adaptation to learning groups or properties of roles offer new possibilities. The use of environments in IMS-LD allows for the adaptation and personalization of supporting learning environments for different learning activities.

In the following part, we describe some of the key elements in Level B and show how IMS-LD is capable of modeling and representing adaptation based on itinerary, content, interface and others, as well as the most of adaptive methods described in the literature today (Burgos, Tattersall et al., 2006).

2.1 Definition, set-up and use of properties (group, values…)

Properties are variables to store values. There are several types of properties: local, global, personal and role, and some combinations. A variable must be defined and initialized. In the following code example we define a property of type *string*, and a second one of type *integer*, and we initialize the integer to *0*:

```
<locpers-property identifier="LP-name">
  <title>your name</title>
  <datatype datatype="string"/>
```

```
  </locpers-property>
<locpers-property identifier="LP-age">
  <title>age</title>
  <datatype datatype="integer"/>
  <initial-value>0</initial-value>
</locpers-property>
```

When several properties are defined they can be grouped in a category. This process facilitates the data input providing one single confirmation button per group, instead of one per every property:

```
<property-group identifier="LP-group-profile">
  <title>User information</title>
  <property-ref ref="LP-name"/>
  <property-ref ref="LP-age"/>
</property-group>
```

After the definition, a property can be used to set and view values, using *global elements* - see *Subsection 2.3* later in this text. A property can also change the stored value internally, without any user input:

```
    <change-property-value>
      <property-ref ref="QuestionTrue1"/>
      <property-value>100</property-value>
    </change-property-value>
```

2.2 Conditions

In IMS-LD it is possible to define a basic conditional structure if-then-else or multiple structure with several chained basic if-then-else in a row, for instance to change the value of a property or to show and hide one element. In the example below, the value *100* is stored in the property *QuestionTrue* if the property *Answer* contains the value *Circle*. In other case, the stored value is *0*:

```
<if>
  <is>
    <property-ref ref="Answer"/>
    <property-value>Circle</property-value>
  </is>
</if>
<then>
  <change-property-value>
    <property-ref ref="QuestionTrue"/>
    <property-value>100</property-value>
  </change-property-value>
</then>
<else>
  <change-property-value>
    <property-ref ref="QuestionTrue"/>
    <property-value>0</property-value>
  </change-property-value>
</else>
```

Conditions can also be used to hide and show elements in the learning flow, for instance between two *Activity Structures*, in case there is a certain value (*Sports*) in a property:

```
<if>
  <is>
    <property-ref ref="LP-choose-activity"/>
    <property-value>Sports</property-value>
  </is>
</if>
<then>
  <show>
```

```
    <activity-structure-ref ref="AS-Sports"/>
  </show>
  <hide>
    <activity-structure-ref ref="AS-Music"/>
  </hide>
</then>
```

2.3 Global elements

Global elements provide a communication flow between the *IMSmanifest.xml*, where the different levels of IMS-LD are set-up, and other parts of the LD description. Mainly, they can get (*set*) an input from the user and they can show (*view*) a value of a property:

```
<set-property-group ref="LP-name" property-of="self"/>

<view-property-group ref="LP-name" property-of="self"/>
```

Furthermore, they can manage DIV layers (*classes*) in XHTML, for instance to show and hide specific content. In the following case the class called *Feedback_Right* is on the screen when the property *Answer* contains the value *Green*:

```
<if>
  <is>
    <property-ref ref="Answer"/>
    <property-value>Green</property-value>
  </is>
</if>
<then>
  <hide>
    <class="Feedback_Wrong"/>
  </hide>
  <show>
    <class="Feedback _Right"/>
  </show>
</then>
```

2.4 Calculations

IMS-LD is able to make some basic calculations (*sum, subtraction, multiplication* and *division*) the basic calculations can be combined for more complex ones. In the following example code, we define the sum of *Value_A* and *Value_B* and we divide the result by *2*, storing the final result in the property *Simple_Average*:

```
<change-property-value>
  <property-ref ref="Simple_Average"/>
  <property-value>
    <calculate>
      <divide>
        <sum>
          <property-ref ref="Value_A"/>
          <property-ref ref="Value_B"/>
        </sum>
        <property-value>2</property-value>
      </divide>
    </calculate>
  </property-value>
</change-property-value>
```

2.5 Monitoring service

The specification allows monitoring any kind of property assigned to a user, a group or a role, for instance. In order to start this action, firstly the component *monitor* must be set-up inside an environment (in this specific case):

```
<environment identifier="E-qualifications">
  <title>Which are the qualifications of the others?</title>
  <service identifier="S-qualifications">
    <monitor>
      <role-ref ref="Student"/>
      <title>Qualifications of the other students</title>
      <item identifierref="R-qualifications"/>
    </monitor>
  </service>
</environment>
```

Moreover, this property can also be traced with the *monitor* component. For instance, the following code allows reading (*view*) the property of a different student (*supported-person*), using a global element.

```
<view-property property-of="supported-person" ref="LP-qualifications"/>
```

In these lines, the monitoring service is defined for a learner (Student). This means that every student can view the content of the properties of other classroom partners. When a tutor needs to view students' properties, a similar structure can be designed, providing a proper tracking of each participant in a course.

2.6 Notifications

In Level C. An action is automatically launched depending on the state of a property or a previous action, i.e., when a student ends an assignment an email is sent to the tutor.

```
<learning-activity identifier="la-1" isvisible="true">
…
   <on-completion>
      <notification>
         <email-data email-property-ref="prop-email">
            <role-ref ref="role-1" />
         </email-data>
         <learning-activity-ref ref="la-2" />
            <subject>A notification is triggered</subject>
         </notification>
      </on-completion>
</learning-activity>
```

3 Adaptive Methods in IMS-LD

IMS-LD is able to manage different types of adaptation (Burgos, Tattersall et al., 2006): Learning flow, content adaptation, evaluation and interactive problem solving support are best supported. Group adaptation is supported via administrative tools for user grouping and group properties and modification of a course on-the-fly can be partially implemented based on current runtime environment restrictions. Also interface-based adaptation is possible as long as the modifications are made inside the Unit of Learning and not in the player tool itself. Several of these possibilities are also useful to manage complementary issues to adaptive personalized learning, like active learning, collaborative learning, dynamic feedback, run-time tracking, ePortfolio based approaches and assessment (Burgos, Tattersall et al., 2005).

In the previous section, we described the key elements in the Level B and Level C of IMS-LD to create adaptive Units of Learning, based on sequence, groups, content, evaluation and other features. To illustrate the appropriate combination of some of these elements to implement adaptive methods for learning support we show the UoL *Geo Quiz 3* (OUNL, 2002; OUNL, 2005). This UoL provides an adaptive sequencing of activities based on the results of a general quiz on geography with five questions and multiple answers. In this quiz, the user gets some score based on his answers. Once the quiz is finished, the system provides back a short report on his performance, and it shows several calculations, such as the average and the accuracy. In addition, the next activity to study depends on these results, and only one is shown out of four possible next activities. Furthermore, the sequence of the learning flow is adapted to the user's performance, that in turn it is based on a simple set of rules pre-defined in the UoL.

To carry out this simple example a number of elements described in the previous section have been used, i.e., conditions, variables, calculations and global elements.

The conceptual graph is shown in *Figure 1*.

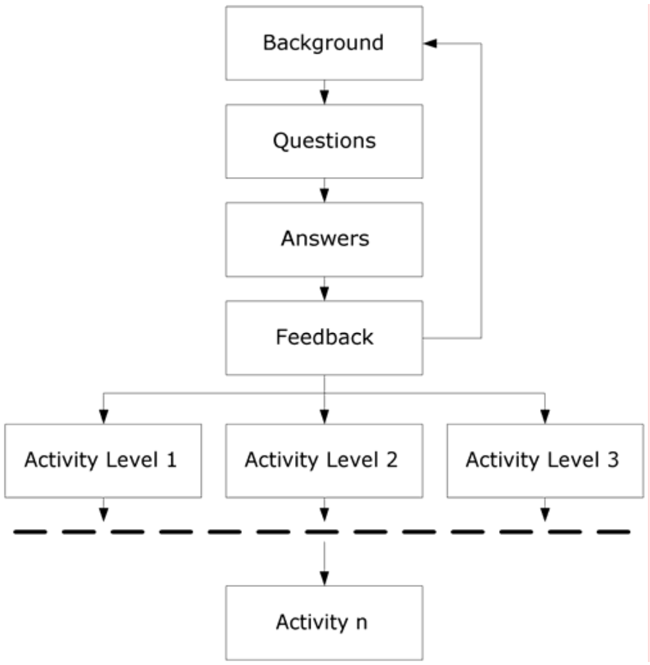

Figure 1: Adaptive sequencing in Geo Quiz 3

In the following code example an excerpt of the *imsmanifest.xml* file from *Geo Quiz 3* Unit of Learning shows how the learning flow shows the learning activity *flow 2* and hides the activities *flow 1* and *flow 3*. This next step is based on a score stored in the property *accuracy* that it has been calculated out of the quiz and is in the range between *49* and *76*. *Table 3* shows different features of IMS-LD dealing with several adaptive methods in this example

```
<!-- … ->
<if>
       <and>
        <greater-than>
          <property-ref ref="accuracy"/>
```

```
           <property-value>49</property-value>
      </greater-than>
      <less-than>
        <property-ref ref="accuracy"/>
          <property-value>76</property-value>
      </less-than>
      </and>
</if>
<then>
      <change-property-value>
          <property-ref ref="prop-feedback"/>
           <property-value>Well done! You get access to Level 2
        </property-value>
      </change-property-value>
      <show>
         <learning-activity-ref ref="flow2" />
      </show>
      <hide>
         <learning-activity-ref ref="flow1" />
         <learning-activity-ref ref="flow3" />
      </hide>
</then>
```

What?	To what?	Why?	How?
Adaptive Sequencing			
Selection and Visibility of predefined activity structures and learning flows	Preferences and knowledge stored in properties, conditions, visibility	Compensation of deficits or encouraging for individual scaffolding	Knowledge test and preference selection stored in properties
Adaptive Content Presentation			
Selection and Visibility of DIVs	Preferences and Learning Style, calculations, conditions, visibility, properties	Usability, Motivation	User Monitoring, Questionnaires
Adaptive navigation support			
Scaffolding Activity Structure	Peer Success in Learning Activities (Level B)	Blended Collaborative Learning Support	Local, and Global Properties, Monitoring, Notifications

Table 3: Features of IMS-LD in example *GeoQuiz 3* to implement different types of adaptive methods

4 Integration and Outlook

As shown with some specific examples IMS-LD enables a standardized way for designing personalized learning experiences in the sense of simple methods of adaptive educational hypermedia and representing them in an exchangeable format. In the following we try to map the dimensions of the adaptive methods classification model from the first part of this paper and map them on the parameters in IMS-LD to represent personalized learning.

What information is used for adaptation and how is this represented in IMS-LD?
Basically properties are a very open and flexible way to represent information about users ranging from preferences, knowledge, interests, and even more complex calculations can be used to compute more complex models. Using properties not only for single users but also for groups of users allows synchronizing collaborative learning activities in which we see a very interesting opportunity for future research in contextualized and mobile distributed learning as also current works in CSCL. Furthermore the possibilities of Level C in IMS-LD, allow for updating user and role properties based on arbitrary events in the collaborative learning or tutoring activities. Another strength of IMS-LD definitely lies in the role properties for role specific support and activity selection but also for adaptation to stereotypes. In that sense most of the more simple and linear models about the environment, learner and learner groups can be represented in a learning design. Furthermore the separation between runtime and design time clearly is a good basis for specifying the conditions and values of properties to trigger certain actions in the learning flow.

What can be adapted and how is this represented in IMS-LD? IMS-LD allows for description of learning processes and the connection of resources, activities and Units of Learning, furthermore like described in the specific examples IMS-LD can also be used for navigational guidance where dependent on properties certain elements in a navigation tree can be annotated or hidden and content adaptation in which certain elements are visualized or not. More research needs to be done on ways how to describe learning designs and adaptation rules on a meta-level, e.g. to describe rules for all activities and knowledge resources based on properties. On some issues a more generic adaptive method would be interesting to consider. In the sense of reusable patterns of adaptation on a meta-level that would allow to integrate and run adaptive content with different educational paradigms. Partly this is also discussed in [23].

Why does the system adapt and what is the pedagogical aim? The strength of IMS-LD for reuse of pedagogical patterns and applying them to different domain instantiations can easily seen in projects like AUTC (Harper, 2005) or LN4LD (Consortium LN4LD, 2004) where a variety of reusable patterns for collaborative and individual learning experiences have been developed. In the upcoming research our team aims at developing reference examples for adaptive methods taking into account group and individual learning models for adapting not only sequencing and content adaptation but also run time adaptation of pedagogical patterns. A main strength of IMS-LD in comparison to several adaptive educational systems is the pedagogical background coming out of EML and furthermore a more broad perspective on adaptive educational support. IMS-LD not only focuses on individual support for learners based on a single user model but is also a strong basis for the integration of usage data of peers and other users as also classical tutoring based workflows. So beside adaptive personalization also adaptive collaboration and tutoring scenarios can be implemented based on IMS-LD.

How does the system get the information about the user? As seen in the first example IMS-LD can support adaptability as also adaptivity. The integration with the IMS specifications on Questions and Tests Interoperability (IMS Global Learning Consortium, 2005b), Reusable Competence Definitions (IMS Global Learning Consortium, 2005c) and Content Packaging (IMS Global Learning Consortium, 2005a) is definitely a strong plus for both the integration with assessment on the level of knowledge, competences and goals as also the possibilities for content delivery. Current developments in the TENCompetence project aim at integration of both formal assessment components via IMS-QTI as also more informal and social competence assessment components based on peer ratings and social software mechanisms.

We foresee high potential for IMS-LD to be a powerful approach for modeling adaptive methods in education and will continue to investigate its potential with the implementation of specific examples as also the participation in the Adaptive Hypermedia community and the IMS bodies. Furthermore the work done in the TENCompetence project does not only consider and discuss adaptivity on the level of knowledge resources and learning designs but also on higher levels of competences development and the adaptation of incentive mechanisms or feedback in learning networks. From our point of view this is very important for an integrative perspective on adaptation and personalization in educational environments. In that sense, also IMS specifications on other levels, like IMS based on reusable competence definitions or portfolio, become important for upcoming research.

References

Altova (2006). *XML Spy Editor*. Retrieved Dec 18th, 2006 from http://www.altova.com.

Anderson, J. R., F. G. Conrad and A. T. Corbett (1989). Skill acquisition and the LISP tutor. *Cognitive Science* **13**: 467-505.

Bolton (2004). *Reload Project*. United Kingdom, The University of Bolton, The University of Strathclyde and JISC. Retrieved April 16th, 2006 from http://www.reload.ac.uk.
Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Models and User Adapted Interaction* **6**(6): 87-129.

Brusilovsky, P., M. Specht and G. Weber (1995). Towards adaptive learning environments. *Herausforderungen eines globalen Informationsverbundes für die Informatik: GISI 95*. F. Huber-Wäschle, H. Schauer and P. Widmayer. Berlin, Springer-Verlag**:** 322-329.

Burgos, D., P. Moreno-Ger, J. L. Sierra, B. Fernández-Manjón and R. Koper (2007). Authoring Game-Based Adaptive Units of Learning with IMS Learning Design and <e-Adventure>. *International Journal in Learning Technologies*.

Burgos, D., C. Tattersall and R. Koper (2005). *Utilización de estándares en el aprendizaje virtual*. II Jornadas Campus Virtual, Madrid, Universidad Complutense de Madrid.

Burgos, D., C. Tattersall and R. Koper (2006). *Representing adaptive eLearning strategies in IMS Learning Design*. International Workshop in Learning Networks for Lifelong Competence Development, TENCompetence Conference, Sofia, Bulgaria.

Carbonell, J. R. (1970). AI in CAI: An artificial intelligence approach to computer aided instruction. *IEEE Transactions on Man-Machine Systems* **MMS-11**(4): 190-202.

Carroll, J. M. C., C. . (1984). Training wheels in a user interface. *Communications of the Association for Computing Machinery* **27**: 800-806.

Clancey, W. J. (1987). *Knowledge based tutoring: The GUIDON program*. Cambridge, MIT Press.

Consortium LN4LD (2004). *Learning Network for Learning Design. Runnable Example Units of Learning*. Retrieved from http://imsld.learningnetworks.org.

De Bra, P. and L. Calvi (1999). AHA! An open Adaptive Hypermedia Architecture. *New Review of Hypermedia and Multimedia*(this issue).

Feiner, S. K. and K. R. McKeown (1993). Automating the Generation of Coordinated Multimedia Explanations. *Intelligent Multimedia Interfaces*. M. T. Maybury. Boston, AAAI Press/MIT Press**:** 117-138.

Frank, H. (1965). *Lehrautomaten für die Einzel- und Gruppenschulung*. Lehrmaschinen in kybernetischer und pädagogischer Sicht, Nürnberg, Klett.

Harper, B. (2005). AUTC: Information and Communication Technologies and Their Role in Flexible Learning, Australian Universities Teaching Committee.

IMS Global Learning Consortium (2005a). *Content Packaging Specification*, IMS Global Learning Consortium,. Retrieved from http://www.imsglobal.org/content/packaging/index.html.

IMS Global Learning Consortium (2005b). *IMS Question & Test Interoperability Specification*, IMS Global Learning Consortium, Inc. Retrieved from http://www.imsglobal.org/question/.

IMS Global Learning Consortium (2005c). *IMS Reusable Definition of Competency or Educational Objective Specification*, IMS Global Learning Consortium,. Retrieved from http://www.imsglobal.org/competencies/index.html.

IMSLD (2003). *IMS Learning Design*. Boston, The IMS Global Learning Consortium. Retrieved November 3rd, 2006 from http://www.imsglobal.org/learningdesign/index.cfm.

Jameson, A. (2003). *Systems that adapt to their users: An integrative Overview*. Tutorial presented at 9th International Conference on User Modelling, Johnstown, PA, USA.

Koper, R. and D. Burgos (2005). Developing advanced units of learning using IMS Learning Design level B. *International Journal on Advanced Technology for Learning* **2**(3).

Koper, R. and C. Tattersall, Eds. (2005). *Learning Design - A Handbook on Modelling and Delivering Networked Education and Training*. Heidelberg, Springer Verlag.

Koper, R. and C. Tattersall (2005). *Learning Design: A Handbook on Modelling and Delivering Networked Education and Training*. Berlin Heidelberg, Springer.

Leutner, D. (1992). *Adaptive Lehrsysteme; Instruktionspsychologische Grundlagen und experimentelle Analysen*. Weinheim, Beltz.

LN4LD (2005). *Units of Learning developed by several authors at Learning Network for Learning Design of The Open University of The Netherlands*. Retrieved March 6th from http://imsld.learningnetworks.org/course/view.php?id=20 and http://dspace.ou.nl.

Miao, Y. (2005). *Cosmos LD Editor*.

OUNL (2002). *DSpace*, Open University of The Netherlands. Retrieved December 16th, 2006 from http://dspace.learningnetworks.org.

OUNL (2005). *Learning Network for Learning Design*. Retrieved March 6th, 2007 from http://imsld.learningnetworks.org.

Pask, G. (1964). The adaptive teaching system. *Teaching machines and programming*. K. Austwick. Oxford, London, Pergamon Press.

Rickel, J. and L. W. Johnson (1997). Integrating Paedagogical Agents in a virtual Environment for Training. *to appear in the journal Presence.*

Rich, E. (1989). Stereotypes and User Modeling. *User Models in Dialog Systems*: 35-51.

Salomon, G. (1975). Heuristische Modelle für die Gewinnung von Interaktionshypothesen. *Adaptiver Unterricht*. R. Schwarzer. München, Kösel**:** 127-145.

Specht, M. (1998). *Adaptive Methoden in computerbasierten Lehr/Lernsystemen*. Trier, University of Trier.

Specht, M. and D. Burgos (2006). *Implementing Adaptive Educational Methods with IMS Learning Design*. Adaptive Hypermedia 2006, Dublin, Ireland.

TENCompetence (2005). *TENCompetence Project*. Retrieved July 31st, 2006 from http://www.tencompetence.org.

Tennyson, R. D. and D. L. Christensen (1988). MAIS: An intelligent learning System. *Instructional Designs for microcomputer courseware*. D. H. Jonassen. Hillsdale, N.J.:Erlbaum.

UCM (2006). *Complutense University. <e-Ucm> Research Group*. Retrieved December 18th, 2006 from http://www.e-ucm.es.

Weber, G. and M. Specht (1997). *User modeling and Adaptive Navigation Support in WWW-Based Tutoring Systems*. User Modeling, Chia Laguna, Springer.