

# SEMANTIC LEARNING MODEL AND EXTENDED STUDENT MODEL: TOWARDS AN AHAM-BASED ADAPTIVE SYSTEM

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## ABSTRACT

In adaptive hypermedia systems, we distinguish AHAM as the most popular reference model which is based on the Dexter model. Our work consists on building an adaptive system following this model. In this paper, we deal both with the domain and the user's model. On one hand, the domain model called Semantic Learning Model (SLM) is described taking into account the pedagogical structure resulting from our pedagogical segmentation process. On the other hand, our user's model called eXtended Student Model (XSM) based on an ad hoc integration of the AHAM's user's model as well as the IMS/LIP and IEEE/PAPI standards.

## KEY WORDS

AHAM, pedagogical segmentation, Student model, and adaptive hypermedia

## 1. Introduction

When moving from traditional learning to educational e-systems, students are more and more involved in the learning process; technological systems (mainly Internet) are the new vectors that disseminate knowledge and feedback between the learning process actors, i.e. the tutors and the learners [1]. Nowadays, adaptability has turned into a requirement, especially because every learner is considered as a unique case in the learning process and that the one-size-fits-all mechanism can not be applied to the individualized learning [2]. Hence, courseware should be constructed according to learner's needs. The adaptability algorithm is responsible of this construction called the curriculum sequencing [3]. For example, Intelligent Tutoring system [4] uses curriculum sequencing mechanisms to help student find an optimal path through the learning material.

The process is twofold:

- Find the relevant topics and select the most satisfactory one
- Construct dynamically page contents based on the tutor decision for what the learner should study next.

This mechanism influenced the work on adaptive navigation support in educational hypermedia [5]. In adaptive education hypermedia, the focus is on the learner. In fact, adaptability implies the integration of a student model in the system. Adaptive Hypermedia (AH) [5] was born as a trial to combine intelligent tutoring systems and educational hypermedia.

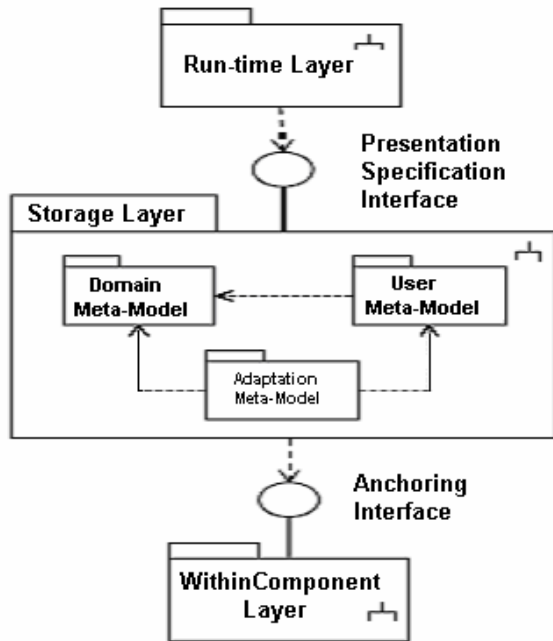
AH provides two major functionalities[6]:

- The Adaptive presentation is a functionality that helps the hypermedia take advantage of information included in the student's model of a connected ITS. Two distinct methods allow to perform this feature: the comparative explanation method used in LISP-Critic [7] and the explanation variants method used in LISP-Critic [7], Anatom-Tutor [8] and Sypros [9]. The first one scaffolds upon previously acquired knowledge, while the second organizes the domain knowledge by topics and levels of mastery.
- The Adaptive navigation support aims at helping users to find their paths in hyperspace by adapting the navigation and displayed functionalities to the goals, knowledge, and other explicit characteristics of an individual user[6].

In adaptable education systems, the tutor is involved as an expert. Some research [10] tries to model the tutor's expertise in order to automate the learning process as much as possible. Modelling this expertise is a restrictive process because we postulate that it is impossible to formalize all of the tutor's know-how. Moreover, when modelling the learner, the tutor intervention in the learning process should be taken into account.

In adaptive hypermedia systems, many reference models exist such as Dexter [11], Amsterdam [12], Dortmund Family of hypermedia models [13] and more recently, AHAM [14] and Munich [15] models based on the Dexter model. Figure 1 [15] presents a general architecture of an adaptive hypermedia application based on the Dexter model. It is composed of three layers:

- The Run-Time layer allows to access, view, and manipulate the hypermedia network.
- The storage layer contains components interconnected by relational links. It is divided into three sub models: the domain meta-model, the user meta-model and the adaptation meta-model (a set of rules implementing the adaptive functionality).
- WithinComponent layer contains the content and structure within the hypermedia nodes.



**Figure1.** Architecture of Adaptive hypermedia applications

In this article, we will address issues concerning the storage layer. The other elements will be tackled elsewhere.

We will first highlight the AHAM user's and domain's models limitations and propose to replace these models by our domain (SLM, Semantic Learning model [16]) and user (XSM, eXtended Student Model) models so as to try to solve these issues.

## 2. The AHAM limitations

### 2.1 Domain model

In AHAM [14], the domain model is exclusively composed of concepts (atomic or composite). This appears to be a very strong limitation since (i) it seems that no typology of concepts exists to sustain this model and that (ii) there is no way to describe any related elements that is not a concept. For example an example, that cannot be considered as a concept because its role is to explicit the concept it relates to, is not taken into consideration in AHAM.

Another strong limitation resides in the kind of links that are used : if we agree that a concept can be "part-of" or a "prerequisite" to another concept - for instance because it is included in its definition - we are less enthusiastic about an "inhibitor" link that in our view looks rather useless because

no link would perform the same job. The same goes for the link "link" that conveys no information.

Our proposal [17] consists in modelling a knowledge domain by representing it a finite number of *presentation chains* each containing at least a concept and its definition. Each concept could be further explicitated and detailed through a series of arguments (such as an analogy, an illustration, a contra-example, etc.) that were graphically regrouped to constitute the above mentioned presentation chain.

Besides, we propose to define relations between and inside pedagogical chains that will be described in the next section.

### 2.2. User model

In AHAM [14], the student model is simply built around a table structure that includes specific concepts from the domain model and other entities like user's background, job title, preferences and platform properties. Concepts are annotated with attributes: knowledge, read, ready to read. This is insufficient to render the system interoperable, thus the idea to extend the model and take into consideration the actual two main standards: IEEE Public And Private Information (PAPI) [18] and IMS Learner Information Package (LIP) [19].

## 3. Semantic Learning Model

In the framework of the segmentation of a single document, segmenting a document consisted precisely in identifying and marking the concepts and their related presentation chains so as to construct meaningful and contextually pertinent pedagogical elements. We could say that the biggest granularity of a document is the document itself while the smallest is any of the identified elements.

The entities it can be composed of are the following:

- A *Concept* is a semantic element explicitly defined in the text. Its definition is composed of either already identified concepts or of prerequisites defined elsewhere. It is characterized by a presentation order, a label, a gender, a type, a complexity degree and content.
- An *Argument* is a semantic element that refers to a concept and is used to familiarize, clarify or reinforce the concept. An argument is characterized by its pedagogical function and role, according to an existing typology [17].
- A *Solved problem* is a special type of argument that refers to several concepts.
- A *Simple Text* is a simple element used to handle unmarked text.

The resulting semantic network highlights the definitional relationships between the concepts and the links between a concept and the pedagogical entities that are related to it in order to reach a pedagogical goal [20].

In order to deal with multiple source documents, we have further refined our approach (fig 1) and devised a new model baptized the Semantic Learning Model (SLM).

### Components

A component is an abstract representation of learning items whatever its level of granularity is. It can be either:

1. An asset: The lower level of granularity of a document is an Asset. Assets can be pictures, illustrations, diagrams, audio and video files, animations, and also text fragments. This content is stored in the WithinComponent layer.
2. A pedagogical information: A pedagogical information is a group of assets expressing the same meaning. For example, a figure associated with its comment is a pedagogical entity.
3. A pedagogical entity: It's an information entity associated with a pedagogical role. Four roles are specified: concept, argument, solved problem and simple text but for the model to be parametrizable, the role can be anything else as long as it is previously defined by the pedagogue. Two special types of concepts are relieved: prerequisite and concept root.
4. A pedagogical context: it represents the semantic structure (or network) in which presentation chains are grouped with eventual unmarked text or simple text. A presentation chain is composed of a concept and a set of arguments related to it. Each of those arguments has a specific relationship with its concept. We distinguish three kinds: reinforcement, familiarization and clarification. Each presentation chain has a presentation order. In this phase, semantic network is built before or during the pedagogical context creation. Pointers to pedagogical entities are organized following the semantic network structure.
5. A pedagogical document: the pedagogical document includes the pedagogical context associated with prerequisites.
6. A pedagogical schema: Many pedagogical documents are grouped in order to make a curriculum. A curriculum is a concept root. This group is called pedagogical schema.

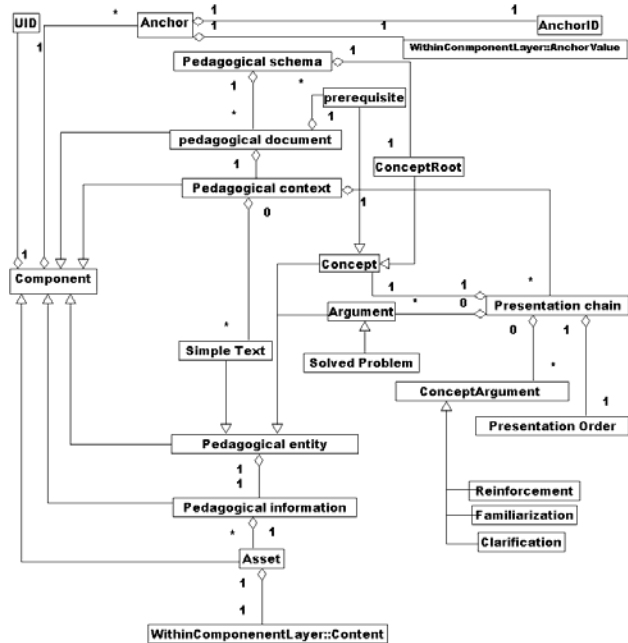


Figure 2. Semantic Learning Model

## 4. The student model: eXtensible Student Model

The current specification of PAPI splits the learner information into 6 areas: personal information and preference information, performance, relations, portfolio and security. IMS/LIP is a specification that describes the learner's characteristics to personalize the content. Conversely, LIP divides the learner information into 9 areas: interest, affiliation, QCL (Qualifications, Certifications and licenses), activity, goal, identification, competency, relationship, security key, transcript and accessibility. This specification is much more detailed than PAPI and provides almost a complete users' profile. But none of them differentiate the access rights allowing the user to modify all areas.

Because we believe that the entire responsibility of the learning process should not be delegated to the learner, we propose to classify the areas according to the actors' intervention: machine driven, learner driven, system driven and tutor driven. Some areas must be reviewed by the tutor such as competency in the case of LIP and performance in the case of PAPI.

The structure of our model according to this classification is as follows (cf. Figure3):

**4.1 Machine driven** includes the system properties and the learning constraints such as delivery mode, accessibility and security.

**4.1.1 Delivery mode** defines the document format such as video, image or text and the police size (for partially-sighted persons for example).

**4.1.2 Machine properties** determines the memory size, the power of the processor, network characteristics (bit rate, etc.).

**4.1.3 Accessibility** is meant in terms of language, disabilities, and preferences. It can be mapped entirely with the accessibility field of IMS/LIP but only the part preferences with the Preferences field of IEEE/PAPI.

**4.1.4 Security** refers to the learner's security credentials, such as passwords, challenge/responses, private keys and public keys. It can be mapped entirely with the security field of IEEE/PAPI and IMS/LIP.

Table 1 resumes the mapping between machine driven fields of XSM, IMS/LIP and IEEE/PAPI.

XSM	Security	Accessibility	Machine properties	Delivery mode
IMS/LIP	Security key	Accessibility	-	-
IEEE/PAPI	Security	Preference	-	-

Table 1. Machine driven mapping

**4.2 Learner driven** includes all information that we think a learner can provide such as demographic data, interest, affiliation general goal and stereotype.

**4.2.1 Affiliation** relates to membership of professional organisations. Only the correspondence with the affiliation field of IMS/LIP is identified.

4.2.2 *General goal*: The learner can only define his general goal. All sub goals are determined by the tutor (or his knowledge). In fact, in the case of traditional learning, the student can choose the curriculum, courses he wants to attend but never chapters and sections. The course organisation must remain the tutor's responsibility. Only the correspondence with the goal field of IMS/LIP is identified.

4.2.3 *Demographic data* corresponds to all personal information relevant to learning such as age, gender, name, address, etc. The identification field in the case of IMS/LIP consists on both biographic and demographic data. This biographic data will be mapped with the stereotype field which will be described later. The Personal field in the case of IEEE/PAPI can be mapped entirely with this field.

4.2.4 *Interest*: contains information about hobbies and recreational activities. Only the correspondence with the goal field of IMS/LIP is identified.

4.2.5 *Stereotype*: This field is initialized by the learner but revised by the tutor. It is composed of the knowledge level, cognitive style and learning style.

- 1) Cognitive styles [21] refer to the preferred way an individual processes information. It is described as a personality dimension which influences attitudes, values, and social interaction. A number of cognitive styles have been identified:
  - Field independence versus field dependence: It refers to a tendency to approach the environment in an analytical, as opposed to global, fashion. Field independent individuals are likely to learn more effectively under conditions of intrinsic motivation (such as self-study) and are influenced less by social reinforcement.
  - Scanning - differences in the extent and intensity of attention resulting in variations in the vividness of experience and the span of awareness
  - Levelling versus sharpening - individual variations in remembering that pertain to the distinctiveness of memories and the tendency to merge similar events
  - Reflection versus impulsivity - individual consistencies in the speed and adequacy with which alternative hypotheses are formed and responses made
  - Conceptual differentiation - differences in the tendency to categorize perceived similarities among stimuli in terms of separate concepts or dimensions.
- 2) Learning styles [22] specifically deal with characteristic styles of learning. Kolb [22] proposes a theory of experiential learning that involves four principal stages: concrete experiences (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). The CE/AC and AE/RO dimensions are polar opposites as far as learning styles are concerned and Kolb postulates four types of learners (divergers, assimilators, convergers, and accommodators) depending upon their position on these two dimensions. For example, an accommodator prefers

concrete experiences and active experimentation (AE, CE).

Table 2 resume the mapping between learner driven fields of XSM, IMS/LIP and IEEE/PAPI.

XSM	Affiliation	General goal	Demographic data	Stereotype	Interest
IMS/LIP	Affiliation	Goal	Identification:: demographic data	Identification :: biographic data	Interest
IEEE / PAPI	-	-	Personal	-	-

**Table 2.** Learner driven mapping

4.3 **System driven** includes interaction history, elicitation of data, portfolio and proficiencies.

#### 4.3.1 Interaction history

For each user and item corresponds an annotation in which the system determine the state of learning this item: read, unread, knowledge (or proficiency), waiting (for learning a special prerequisite). From this table (table 3), proficiencies can be deducted.

	Item1	Item2	Item3
U1	Read	unread	Readyto read
U2	knowledge	knowledge	waiting

**Table 3.** Interaction history

Relationship (IMS/LIP) and relations fields can be mapped with this field. The only difference is that those relationships have not specific terminology.

#### 4.3.2 Elicitation of data

The new items are rated by the filter boat. For each item, the system calculate the learning score specific to each learner (table 4). For users of level X, we can predict the learned score using collaborative filtering techniques [23] to choose the most appropriate item.

Level	Item1	Item2	Item3
X			
U1	85%	95%	10%
U2	70%	-	80%

**Table 4.** Elicitation of data

4.3.3 *Portfolio*: It is a collection of a learner's accomplishments and works that is intended for illustration and justification of his/her abilities and achievements. It can be mapped entirely with the transcript field of IMS/LIP and the portfolio field of IEEE/PAPI.

Table 5 resumes the mapping between system driven fields of both XSM, IMS/LIP and IEEE/PAPI.

<b>XSM</b>	Proficiency	Elicitation of data	Interaction	Portfolio
<b>IMS/LIP</b>	Competency	-	Relationship	Transcript
<b>IEEE/PAPI</b>	Performance	-	Relations	Portfolio

**Table 5.** System driven mapping

#### 4.4 Tutor driven

We firmly believe that the tutor must determine sub goals that have to be reached to attain the long term goal specified by the learner. The same is valid for prerequisites.

Prerequisites can be mapped with the Qualifications, Certifications and Licenses's field of IMS/LIP. A sub goal can be an activity in the case of IMS/LIP.

Table 6 resumes the mapping between tutor driven fields of XSM, IMS/LIP and IEEE/PAPI.

<b>XSM</b>	Prerequisites	Sub goal
<b>IMS/LIP</b>	QCL	Activity
<b>IEEE/PAPI</b>	-	-

**Table 6.** Tutor driven mapping

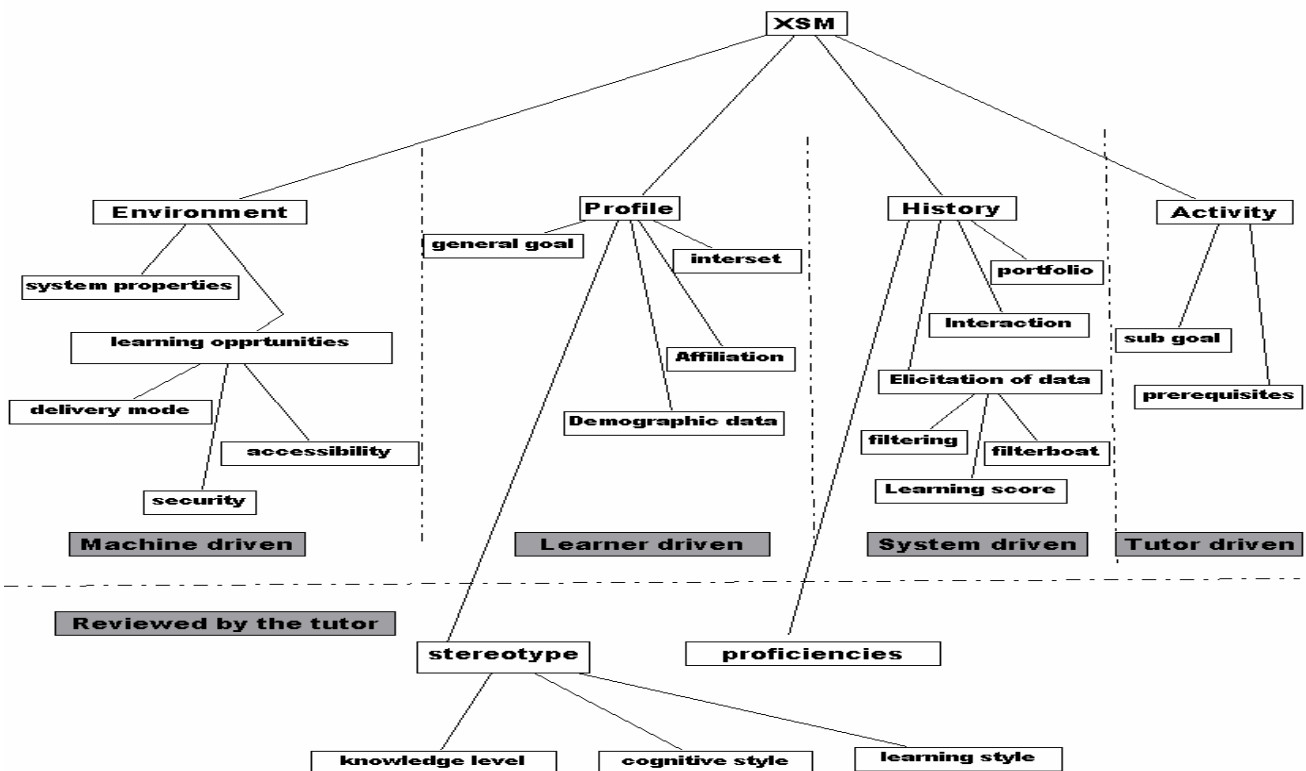
#### 4.5 Reviewed by the tutor

Some fields like the stereotype and proficiencies must be reviewed by the tutor as it is the case for examinations in

traditional learning. When using MCQ depending on the response (wrong or right), we can use an atomic evaluation though the tutor is still the evaluation's conceptror [24]. In other cases, it seems difficult to evaluate if a concept is mastered or not.

### 5. Conclusion

In this paper, we introduced a part of the storage layer of our AHAM-based adaptive system. More precisely, we dealt with the student model called XSM (eXtensible Student Model) based on the AHAM's user model, IEEE/PAPI and IMS/LIP. We dealt also with the domain model called SLM (Semantic Learning Model) based on the pedagogical segmentation principle. This pedagogical segmentation was performed using our authoring tool Phoenix [25] (Pedagogical Hypertext Object-oriEnted for kNowlege and Information eXchange). This tool allows authors to structure their documents and decide what kind of entity (concept/argument/solved problem/simple text) each segment is. The result of the segmentation process is a phoenix document: a zipped file that contains an XML document structured according to the author's segmentation and eventual images and video clips. When the author wants to load his document into a Learning Object Repository (KPS [26] (Knowledge Pool System) in our case in the context of ARIADNE [27]), in order to perform SLM, this document must follow a decomposition process [28]. By this token, we can step by step have more and more resources following SLM available in the KPS.



**Figure 3.** XSM

## References:

- [1] T. Mitrovic, *Current trends in intelligent educational*, <http://pipin.tmd.ns.ac.yu/nastava/izlaganja/intelligent-tutors.pdf>.
- [2] G. H. Gregory, & C. Chapman, *Differentiated Instructional Strategies: One Size Doesn't Fit All* (Corwin Press, 2001).
- [3] Y. Shang, H. Shi, & S. S. Chen, An Intelligent Distributed Environment for Active Learning, *Proc. www10*, Hong Kong, 2001.
- [4] P. Brusilovsky, A framework for intelligent knowledge sequencing and task sequencing, *Proc. 2<sup>nd</sup> International Conference ITS'92*, Montreal, Canada, 1992, 499-506.
- [5] P. Brusilovsky, Adaptive hypermedia: From intelligent tutoring systems to Web-based education (Invited talk), *Proc. 5<sup>th</sup> International Conference on Intelligent Tutoring Systems*, ITS 2000, Montreal, Canada, 2000.
- [6] P. Brusilovsky, Methods and techniques of adaptive hypermedia, *User Modeling and User Adapted Interaction*, 6, 1996, 87-129.
- [7] G. Fischer, T. Mastaglio, B. Reeves, & J. Rieman, Minimalist explanations in knowledge-based systems, *Proc. 23<sup>rd</sup> Annual Hawaii International Conference on System Sciences*, Kailua-Kona, HI, 1990, 309-317.
- [8] I. Beaumont, User modeling in the interactive anatomy tutoring system ANATOMTUTOR, *User Models and User Adapted Interaction*, 4 (1), 1994, 21-45.
- [9] M. Gonschorek, & C. Herzog, Using hypertext for an adaptive helpsystem in an intelligent tutoring system, *Proc. 7<sup>th</sup> World Conference on Artificial Intelligence in Education*, Washington, DC, 1995, 274-281.
- [10] J. Hernandez, & J. Noguez, Affective Behavior in Intelligent Tutoring Systems for Virtual Laboratories, *Proc. 7<sup>th</sup> World Conference on Artificial Intelligence in Education*, Amsterdam, Netherlands, 2005.
- [11] F. Halasz, & M. Schwartz, The Dexter Hypertext Reference Model, *Proc. NIST Hypertext Standardization Workshop*, Gaithersburg, 1990, 95-133.
- [12] L. Hardman, C. Bulterman, & G. Rossum, The Amsterdam Reference Model, *Communications of the ACM*, 37(2), 1994.
- [13] K. Tochtermann, & G. Dittrich, The Dortmund Family of Hypermedia Systems, *Journal of Universal Computer Science*, 1996.
- [14] P. De Bra, G. J. Houben, & H. Wu, AHAM: A Dexter-based Reference Model for Adaptive Hypermedia, *Proc. ACM Hypertext'99*, Darmstadt, 147-156, 1999.
- [15] N. Koch, & M. Wirsing, The Munich reference model for adaptive hypermedia applications, *Proc. 2<sup>nd</sup> International conference on Adaptive Hypermedia and Adaptive Web-based systems*, Malaga, Spain, 213-222, 2002.
- [16] E. Fernandes, H. Madhour, S. Miniaoui, M. Wentland, Towards a Semantic Learning Model Fostering Learning Objects Reusability, *Proc. ICHSL 2005*, Morocco, 2005.
- [17] Wentland Forte, M. McMurray, E. Simillion, F. (Sept. 1995). "Tools for generating conceptually networked educational hypertext", *CAEE'95*, Bratislava, Slovakia.
- [18] IEEE Public And Private Information (PAPI), available on [jtc1sc36.org/doc/36N0186.pdf](http://jtc1sc36.org/doc/36N0186.pdf).
- [19] IMS Learner Information Package (LIP), available on [www.imsglobal.org/profiles/index.cfm](http://www.imsglobal.org/profiles/index.cfm).
- [20] M. Wentland, Modélisation d'un domaine de connaissance et orientation conceptuelle dans un hypertexte pédagogique, *PhD Thesis from University of Lausanne*, 1994.
- [21] S. Messick, *Individuality in Learning*, San Francisco: Jossey-Bass, 1976.
- [22] D. A. Kolb, *Experiential Learning*. Englewood Cliffs, NJ: Prentice-Hall, 1984.
- [23] B. Sarwar, G. Karypis, J. Konstan, and J. Riedl, Item-based Collaborative Filtering Recommendation Algorithms, *WWW10*, Hong Kong, 2001.
- [24] Geneval, <http://www.ujfgrenoble.fr/CAFIM/pages/genevalrariadne.html>.
- [25] E. Fernandes, H. Madhour, S. Miniaoui, M. Wentland, Phoenix: An XML based tool for Elearning environment, *Proc. EdMedia05*, Montréal, Canada, 2005.
- [26] E. Duval, E. Forte, K. Cardinaels, B. Verhoeven, R. Van Durm, K. Hendrikx, M. Wentland Forte, M. Macowicz, K. Warkentyne, & F. Haenni, The ARIADNE Knowledge Pool System, *Communications of the ACM*, 44 (5), 2001.
- [27] ARIADNE Foundation, available on <http://www.ariadne-eu.org>
- [28] E. Fernandes, H. Madhour, S. Miniaoui, M. Wentland, Phoenix tool: a support to Semantic Learning Model, *Proc. ICALT05*, Taiwan, 2005.