# Adaptive Learning Environments and eLearning Standards

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**Abstract**

This paper examines the sufficiency of existing eLearning standards for facilitating and supporting the introduction of adaptive techniques in computer-based learning systems. To that end, the main representational and operational requirements of adaptive learning environments are examined and contrasted against current eLearning standards. The motivation behind this preliminary analysis is attainment of: interoperability between adaptive learning systems; reuse of adaptive learning materials; and, the facilitation of adaptively supported, distributed learning activities.

**Keywords:** adaptive, eLearning, standards, personalisation, interoperability

## 1. Introduction

In recent years we have witnessed an increasingly heightened awareness of the potential benefits of adaptivity in eLearning. This has been mainly driven by the realization that the ideal of individualized learning (i.e., learning tailored to the specific requirements and preferences of the individual) cannot be achieved, especially at a "massive" scale, using traditional approaches. Factors that further contribute in this direction include: the diversity in the "target" population participating in learning activities (intensified by the gradual attainment of life-long learning practices); the diversity in the access media and modalities that one can effectively utilize today in order to access, manipulate, or collaborate on, educational content or learning activities, alongside with a diversity in the context of use of such technologies; the anticipated proliferation of free educational content, which will need to be "harvested" in order to "assemble" learning objects, spaces and activities; etc.

There exist currently several systems which employ adaptive techniques to enable or facilitate different aspects of learning (Brusilovsky, 1999). An important observation one can make going over the related literature is that a dichotomy appears between typically commercial, standards-based eLearning systems on the one hand, and (typically research prototypes of) adaptive learning environments (ALEs) on the other, with little, if any, standards compliance. It is argued that this dichotomy is, in part, due to the lack of sufficient support for adaptive behaviour in existing eLearning standards.

In support of this argument, this paper explores the concept of adaptivity in the context of computational learning environments. Furthermore, it attempts a high-level assessment of the sufficiency of existing eLearning standards for driving the convergence of the two strands of systems outlined above. The intention is to provide a preliminary assessment of the adequacy of existing eLearning standards for specifying, and guiding the implementation of, adaptive behaviour within learning environments.

The motivation for seeking standardization in adaptive eLearning is directly linked to cost factors related to the development of ALEs and adaptive courses thereof (e.g., higher initial investment, higher maintenance costs) and the low level of reuse possible in the field today (due to proprietary models and representations of system knowledge, adaptation logic, etc.) (Conlan, Dagger & Wade, 2002). Our rationale can be briefly outlined as follows:

- To protect the high investment necessary for the development of adaptive learning material, one has to ensure that the latter is not bound by proprietary standards and formats. This is a main prerequisite for enabling the transfer of such material to new environments.
- Taking this concept one step further, one may need to ensure that different learning environments can interoperate in the context of adaptation. A typical exemplary setup might involve one holding an individual user's model and interaction / learning history, and another acting as a content repository.
- At the same level, but worth individual mention, is the case of content discovery and aggregation. This introduces an entirely new dimension, as content "characterization" through metadata provided by its initial author / designer, can now be augmented with aspects relating to the use of that content by individuals and groups, and collected as part of the adaptation "cycle". Furthermore, by combining findings from several compatible systems, which serve the same adaptive course to a multitude of users, it would be possible to make improvements to the course itself. These could be effected wither in a fully automated way, or in a "semi-automated" one, in cases where it would be preferable that no modifications are made to courses without prior approval by human experts.
- Departing from the "traditional" treatment of the learner as a solitary, mostly passive receptor of information, one would also need to account for adaptive support in the context of collaborative learning activities. Such activities may be carried out from within the same or "compatible" learning environments, which, in turn, points to a different level of interoperation requirements between such environments.

The rest of the paper is structured as follows. The next section, "Background", outlines the main concepts of adaptive personalization in learning environments. The next section, "Adaptation and eLearning Standards", starts with a brief account of the landscape of related eLearning standards, and goes on to discuss how these can accommodate adaptation, and where extensions or entirely new standards are required. Finally, the paper is concluded with a brief account of the main points put forward and their implications in the development of ALEs.

## 2. Background

### 2.1 What is Adaptive Learning?

The term "adaptive" is currently one of the "buzzwords" in the eLearning industry, and is being associated with a quite range of diverse system characteristics and capabilities. Therefore, it is necessary to qualify the qualities one attributes to a system when using the term. In the context of this paper, a learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process.

Adaptive behaviour on the part of a learning environment can have numerous manifestations. Instead of attempting to exhaustively enumerate all of these, we will provide a high-level categorization which suffices for the analysis in the following section. The broad and partially overlapping categories that we will be referring to are: adaptive interaction, adaptive course delivery, content discovery and assembly, and, finally, adaptive collaboration support. Each of these categories is briefly qualified below, followed by a brief overview of the models and processes that are typically instated in adaptive eLearning systems.

## 2.2 Categories of Adaptation in Learning Environments

The first category, *Adaptive Interaction*, refers to adaptations that take place at the system's interface and are intended to facilitate or support the user's interaction with the system, without, however, modifying in any way the learning "content" itself. Examples of adaptations at this level include: the employment of alternative graphical, color schemes, font sizes, etc., to accommodate user preferences, requirements or (dis-) abilities at the lexical (or physical) level of interaction; the reorganization or restructuring of interactive tasks at the syntactic level of interaction; or the adoption of alternative interaction metaphors at the semantic level of interaction.

The second category, *Adaptive Course Delivery*, constitutes the most common and widely used collection of adaptation techniques applied in learning environments today. In particular, the term is used to refer to adaptations that are intended to tailor a course (or, in some cases, a series of courses) to the individual learner. The intention is to optimise the "fit" between course contents and user characteristics / requirements, so that the "optimal" learning result is obtained, while, in concert, the time and interactions expended on a course are brought to a "minimum". In addition to time and effort economy, major factors behind the adoption of adaptive techniques in this context include: compensating for the lack of a human tutor (who is capable of assessing learner capacity, goals, etc., and advising on individualized "curricula"), improving subjective evaluation of courses by learners, etc. The most typical examples of adaptations in this category are: dynamic course (re-)structuring; adaptive navigation support; and, adaptive selection of alternative (fragments of) course material (Brusilovsky, 2001).

The third category, *Content Discovery and Assembly*, refers to the application of adaptive techniques in the discovery and assembly of learning material / "content" from potentially distributed sources / repositories. The adaptive component of this process lies with the utilization of adaptation-oriented models and knowledge about users typically derived from monitoring, both of which are not available to non-adaptive systems that engage in the same process.

The fourth and final category, *Adaptive Collaboration Support*, is intended to capture adaptive support in learning processes that involve communication between multiple persons (and, therefore, social interaction), and, potentially, collaboration towards common objectives. This is an important dimension to be considered as we are moving away from “isolationist” approaches to learning, which are at odds with what modern learning theory increasingly emphasizes: the importance of collaboration, cooperative learning, communities of learners, social negotiation, and apprenticeship in learning (Wiley, 2003). Adaptive techniques can be used in this direction to facilitate the communication / collaboration process, ensure a good match between collaborators, etc.

## 2.3 Models in Adaptive Learning Environments

All of the above categories of adaptation in learning environments are based on a rather well-established set of models and processes. The rest of this section presents brief accounts of some of the models that one typically encounters in ALEs.

- *The domain model*: Since most current ALEs are focused on adaptive course delivery, the domain-, or application- model is usually a representation of the course being offered. However, in those cases where more general learning activities are supported, the domain model may additionally contain information about workflows, participants, roles, etc. The most important aspect of adaptive-course models is that they are usually based on the identification of relationships between course elements, which are subsequently used to decide upon adaptations (Brusilovsky, 2003).
- *The learner model*: The term learner model is used to refer to special cases of user models, tailored for the domain of learning. The specific approach to modeling may vary between adaptive learning environments. Nevertheless, there is at least one characteristic shared by practically all existing systems: the model can be updated at interaction time, to incorporate elements or traces of the user’s interaction history. In other words, the learner model in ALEs, not only encapsulates general information about the user (e.g., demographics, previous achievements, etc.), but also maintains a “live” account of the user’s actions within the system.
- *Group models*: Similarly to user / learner models, group models seek to capture the characteristics of groups of users / learners. The main differentiating factors between the two are: (a) group models are typically assembled dynamically, rather that “filled in” dynamically, and (b) group models are based on the identification of groups of learners that share common characteristics, behaviour, etc. As such, groups model are used to determine and “describe” what makes learners “similar” or not, as well as whether any two learners can belong to the same group. This dynamic approach to identifying groups and user participation in them is already used widely in collaborative filtering and product recommenders, and bears great promise in the context of eLearning.
- *The adaptation model*: This model incorporates the adaptive theory of an ALE, at different levels of abstraction. Specifically, the (possibly implicit) adaptation model defines *what* can be adapted, as well as *when* and *how* it is to be adapted. The levels of abstraction at which adaptation may be defined, range from specific programmatic rules that govern run-time bahaviour, all the way to general specifications of logical relationships between ALE entities, that get enforced automatically at run-time. The most successful and widely known ALEs today use adaptation models that generically specify system behaviour on the basis of properties of the content model (such as relationships between content entities).

Although there would be probably little contention as to the enumeration of the models encountered in ALEs, the related literature reports a proliferation of approaches in their representation and utilization within different systems. It is argued that this is one of the major stumbling blocks that stand between adaptation and the eLearning mainstream today. Awareness of this problem has given rise to several research efforts, aimed at standardizing as much of the adaptation modelling process as possible, on the basis of existing standards (see, e.g., the "Workshop on Adaptive E-Learning and Metadata" carried out under the auspices of the WM2003 conference - http://wm2003.aifb.uni-karlsruhe.de/workshop/w05/). The "reuse" of existing eLearning standards and their "retargeting" for use in the context of adaptation, which is also a premise of this paper, is intended to: (a) facilitate the smooth and gradual transition from existing non-adaptive learning environments and courses to their adaptive counterparts, and (b) enable the graceful downgrading of adaptive content and activities when delivered over, or supported by, a "traditional" learning environment.

## 3. Adaptation and eLearning Standards

Due to lack of space, we will abstain from going into a discussion of the potential and known weaknesses of each of the existing standards in the context of adaptation. Instead, we will first delineate the main problems not addressed by today's standards and then proceed to identify what we consider as necessary additions / enhancements to them, as well as point out requirements that necessitate the evolution of new standards.

### 3.1 eLearning Standards Today

There currently exist numerous organisations, consortia, etc., that are working in the area of eLearning standards. For instance organisations like the Dublin Core Metadata Initiative, the IEEE, the IMS Global Learning Consortium, the Alliance of Remote Instructional Authoring and Distribution Networks for Europe, the Aviation Industry CBT Committee, the Advanced Distributed Learning Initiative, etc. are dedicated to, or have committees and working groups active in, the establishment of eLearning standards.

It is beyond the scope of this paper to enumerate all entities involved in the establishment of eLearning standards, or the standards themselves. Instead, the authors have opted to make selective references to some of the standards, where such references are relevant to the ongoing discussion. Nevertheless, it should be noted that the core of standards that have been analysed and are referred to in the subsequent sections are the various specifications of IMS[1], ADL SCORM[2], and the AICC specifications[3].

### 3.2 Adaptation-oriented "Domain" Modelling

Current standards and concepts for educational metadata focus on content-centred approaches and models of instructional design. Scenarios that concentrate on how to structure and organize access to learning objects are mirrored in concepts such as content packaging. Standards focus on search, exchange and re-use of learning material, often called content items, learning objects or training components. The Learning Object Metadata specification, in particular, aims at metadata to facilitate the generation of consistent lessons composed of de-contextualised and distributed learning objects (e.g., consistence in the level of difficulty). Its vision is to enable computer agents to

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[1] http://www.imsproject.org
[2] http://www.adlnet.org
[3] http://www.aicc.org

automatically and dynamically compose personalized lessons for an individual learner. The IMS Learning Design specification goes a step further, by providing a conceptual model that enables authors to describe processes and activities including social interaction. The MASIE Centre Report (MASIE Centre, 2002) identifies four main uses of metadata today: categorisation of content, generation of taxonomies, reuse, and dynamic assemblies. All uses are directly or indirectly relevant to adaptation / personalisation.

As already mentioned, current, generic ALEs that support adaptive course delivery require an additional level of information about the entities that make up a course, namely the interrelationships between the entities (Brusilovsky, 2003). The primary goal in seeking standardisation in this dimension, is to make it possible to have declarative definitions of relationships and concepts, leaving their procedural interpretation and implementation to each ALE. Using these, different systems may choose to provide different adaptive features or support different types of personalisation, much in the same way that systems differ in how they present standardised modules.

(De Bra, Aerts & Rousseau, 2002), for example, address the definition of higher-level concept relationship types and the automatic translation of instances of such types into lower-level adaptation rules for the AHA! adaptive eLearning system. Some of the relationship types discussed therein denote direct relationships between concepts and learning elements (e.g., concept A *is a prerequisite for* concept B, element X *exemplifies* concept C), while others bear a clear adaptation / knowledge inference flavour to them (e.g., element Y *when read provides knowledge towards* concept D, or, element Y *when read indicates interest in* concept E).

At a lower level than De Bra, we also need to be able to define "assets" associated with "learning objects / elements" which can have standardised relationships to each other and to the enclosing object. Consider, for example, two *mutually exclusive elaborations* of a given concept, one being *brief* and the other *detailed*; contrast that with two *complementary elaborations* of a given concept, the first being a *required brief* reading, while the second being an *auxiliary amendment* to the first.

Currently, defining relationships such as the ones described above, can be achieved through the use of Learning Object Metadata, if the following conditions are met:

- A "vocabulary" is developed defining the relationships between concepts, as well as the characteristics of these relationships (e.g., transitivity), so that their interpretation by application software is not open to interpretation.
- Every learning entity that is an individual "concept" has an associated LOM-compliant metadata record.
- The entity's metadata specify the entity's relationships with other entities, using the aforementioned relationship vocabulary and the entities' identifiers.

This approach has the benefit of compliance with current standards, and requires only the introduction of a new, adaptation oriented vocabulary for relationships. A similar approach would be to introduce dedicated (optional) adaptation-specific constructs in the main course description. The latter, however, would evidently require modifications to standards commonly used to define courses, which may be considered a much higher (as compared to the above approach) "entry cost" for introducing adaptation in eLearning standards. A third option would of course be to keep adaptation-related information / metadata separately than the description of the course itself. This has the benefit of rendering the two rather independent, but would most likely prove problematic in terms of course maintenance. This is especially the case as far as “synchronisation” between the two is concerned.

Thus far we have discussed the case of characterising relationships between existing course objects / elements. However, as pointed out in (Brusilovsky, 2003), some types of adaptation require a model that is different than (although connected to) the main course model. For example, a model of course concepts and their semantic relations may need to be maintained “separately” from the model of physical course-material organisation (e.g., files, navigation hierarchy). Apparently, whether the two are separate or not, there must exist associations from one to the other, so that the system knows which concepts correspond to given resources, and vice versa. Standardisation in this direction would evidently necessitate new standards: such concerns are beyond the traditional approaches to organising and describing course material and activities.

Examples of ALEs that extend existing standards to support adaptive course delivery include OPAL, OLO and KOD, among others. OPAL (Conlan et al., 2002), which delivers content personalized to the learner’s cognitive and presentation learning preferences using aggregation models based on ADL SCORM. The OLO (Rodriguez, Chen, Shi, & Shang, 2002) and KOD (Karagiannidis, Sampson & Cardinali, 2001) both address the topic of extending the metadata that accompanies “packaged” learning objects, with the intention to facilitate adaptation. Although the projects take considerably different routes, they are largely motivated by the same objective, to augment the “traditional” metadata with additional elements that are vital when one is to decide upon, and apply course-oriented adaptations. Furthermore, both projects attempt to “integrate” adaptation metadata with the traditional course information.

## 3.3 Learner and group modelling

Learner modelling in existing standards is addressed at a rather coarse-grained level, although all related specifications have explicit provisions for the evolution of a learner’s model, or profile, over time. An example of specifications in this strand is the IMS Learner Information Package specification, which incorporates the results of “top-level” educational activities, in addition to relatively static information about the user (e.g., demographic).

Although this information is of paramount importance for eLearning systems, the coarse-grained level of detail renders them of limited use in the context of ALEs. The main underlying problem is that ALEs require a “history” of the user’s interactions, in order to be able to tailor themselves to the particular needs of the individual user. Furthermore, this “history” is more often than not closely associated with the domain model itself (e.g., the course model). Consider, for instance, the very common desideratum (in ALEs) of basing adaptations no the user’s familiarity with a given concept. This requires the establishment of a new set of relationships, which codify a learner’s “status” with respect to a learning entity or concept. Such relationships may refer to directly observable learner behaviour (e.g., whether a learner *has read*, or *has not read* a node in the learning material), or to inferred status drawn from multiple sources, including results of exercises, etc. (e.g., *knows*, *does not know*, or *is ready for*).

The incorporation of information at this level of detail in the user model would apparently necessitate the extension of existing standards (or the introduction of new complementary ones). Additionally, it would be necessary to agree upon ways of deriving portions of the learner model from the domain / course model (at least for as long as the learner is "taking" a course), as well as upon when and how such detailed information gets "summarised" into the more coarse-grained model that exist today.

The discussion, thus far, has been restricted to the modelling of learner interactions in the context of encountering and assimilating course material. The conclusions drawn, however, are applicable to learner activities at more general scopes. For example, by recording users' social interactions and allowing for their characterisation by the users themselves, it becomes possible to adaptively facilitate a wide range of interpersonal exchanges, as well as targeted collaborative work.

It may be argued that such learner "history" information is an internal concern of ALEs, and, since it does not need to be specified prior to the deployment of learning material, it is not subject to standardisation. This, however, would most likely preclude use of the aforementioned information in adaptive behaviour other than course delivery. Consider the following examples in support of this view:

- An intelligent learner support agent sets out to discover auxiliary learning material for a given user. Having access to detailed information about what the user has already learned (or, what the user has not learned yet) the agent is far more likely to discover more contextually relevant items than would be possible otherwise.
- A newly created course is characterized by its authors as "fast" and "introductory". Nevertheless, in practice, students need to spend three times the anticipated time and effort before they can get an acceptable level of familiarity with the material; additionally, upon completion, students are capable of solving problems from an associated repository at all levels of difficulty. It should be clear that selecting this course purely on the basis of its associated metadata might lead to serious mistakes (e.g., in the process of content filtering). Adding information from its actual use provides a more "informed" view of the course and has the potential to lead to better personalization as a direct consequence.

Maintaining detailed information about a user's activities within an ALE also gives rise to a new opportunity in terms of group identification and modelling. Specifically, if one can refer to learner activities in a standardised way, then one can also identify dimensions of activities that should be used as predictors or measures for determining group membership. For example, one could identify that learners are to be grouped along the dimension "willingness to interact with peers", which is to be inferred from (among other things) the user's active participation in on-line discussion fora.

Much like the case of learner modelling, group modelling as discussed in this paper is not covered by existing standards and would require that either significant extensions be made, or entirely new standards be developed.

### 3.4 Adaptation modelling

The issue of modelling the behaviour of any adaptive system has two complementary but distinct dimensions, which we will examine separately: the specification of adaptation logic, and the specification of adaptation actions. The former is responsible for relating information available in one or more models and assessing whether adaptations are required. The latter refers to specifying the very actions that need to be effected by the system for a given adaptation to be achieved.

Attempting to standardise the way in which adaptation logic is expressed would be, in the authors' opinion, rather premature at this point in time. Existing approaches include simple rule-based engines, case-based reasoners, etc., all the way to powerful logic-based reasoning engines. Given this wide range of approaches in use, it is apparently unrealistic to aim at a single specification that could accommodate them all. On the other hand, developing a range of specifications should be undertaken only after evolution in the targeted approaches has reached a critical level of stability, ensuring validity and endurance of the specifications over time.

Unlike the case of adaptation logic, adaptation actions constitute a well-researched and rather "crystallised" field, especially as far as Adaptive Hypermedia Learning Systems are concerned (Brusilovsky, 2001). Furthermore, recent research (Paramythis & Stephanidis, 2004) has proven the feasibility of formalising and declaratively specifying (using an XML-based language) adaptation actions to be effected as part of an adaptation cycle. It is argued that such efforts could easily be extended, so as to arrive at a standard that allows for flexibility as far as adaptation logic in concerned, and defines a concrete way for coupling that logic with an extensible set of adaptation performatives for ALEs.

Of the existing standards, the only one that supports the explicit representation of dynamic behaviour on behalf of the system is the IMS Learning Design (LD) specification. In more detail, Levels B and C of the specification under discussion introduce the concepts of properties, conditions and notifications, which can be used to specify arbitrarily complex dynamic behaviours for a system. The main setbacks in employing the IMS LD for modelling adaptation in ALEs are rooted in the fact that specification of dynamic behaviour is achieved through the definition of programming flows (including condition variables), enriched with event semantics:

- The approach can be considered rather low-level: Specifying complex adaptive behaviours is tedious and error-prone.
- Conditionals may only refer to variables or states that exist in the context of a single IMS LD document (which makes it impossible to consult models external to the document).
- Dynamic behaviours cannot be defined at the system level (and applied in more than one contexts, or for more than one sets of learning materials / activities).
- The dynamic behaviour specified cannot be reused: there is tight coupling between the behaviour itself and the artifacts to which it refers.
- And, finally, the behaviour specification lacks semantic-level information which would allow an ALE to modify or affect it in any way.

Despite the above shortcomings, the IMS LD may be a very appropriate vehicle for introducing adaptive capabilities in non-adaptive eLearning systems. Specifically, an adaptation engine can be introduced in an LD-capable system, which would effect adaptations by generating or augmenting LD specifications "on the fly". In other words, such an engine would translate adaptation logic and actions into IMS LD compliant constructs, which would then be delivered to the user. By going through this process dynamically (at run-time), the system would also be able to incorporate into the generated constructs, current information derived from adaptation-specific models.

## 4. Conclusions

This paper has attempted a preliminary assessment of the adequacy of existing eLearning standards for supporting the introduction of adaptation techniques in eLearning systems. The analysis, however cursory due to space limitations, has pointed out that existing standards do have some provisions for adaptation, but require substantial extensions to accommodate common practice in ALEs.

It is argued that such extensions should happen in a way that keeps the "entry cost" of employing adaptation facilities in the development of eLearning materials, to as low levels as possible (mainly in terms of invested resources). An example of what would constitute, in the authors' opinion, a gradual and non-taxing path towards such employment, would be as follows. Authors should be able to provide an existing course with "traditional" metadata to an adaptive system, and get basic adaptation facilities (resulting from a "default" interpretation of the course structure and material by the system). Later on, authors could progressively add "adaptation metadata" as a stepwise approach to enabling / providing more advanced adaptation features.

The adoption of the new standards or extensions proposed in this paper is highly dependent upon the development of authoring tools that facilitate the creation of compliant resources. The creation of high quality-, standards compliant- learning material is already a quite demanding goal. The introduction of adaptation facilities will inevitably impose an additional "burden" on content creators. In order to bring the related cost / benefit ratio to non-prohibitive levels, it is necessary to have tools that: can assist authors in converting "static" material; support the authoring of adaptive content; enable the specification of adaptively supported activities in ALEs; etc.

Finally, a factor that will influence the adoption of such standards is the availability of software components that can support different aspects of the adaptation process at run-time (a typical example being user / student modelling components). The KnowledgeTree framework (Brusilovsky & Nijhaven, 2002) represents an integrative effort in this direction. The latter is intended to facilitate interoperation and reuse at the level of distributed, reusable learning activities (with the emphasis being on learning activities, as opposed to learning objects). Specifically, KnowledgeTree goes into the realm of run-time communication and interoperation standards, seeking to standardize the ways in which different specialized subsystems supporting aspects of the (adaptive) learning process can communicate and exchange information that would allow them to be aggregated into a "whole". The evolution of such efforts will hopefully bring about a generation of "off-the-shelf" components that can be easily integrated into an ALE.

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**Presenter information**

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