# Adaptive Learning Management System

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***Abstract**:* This article is an introduction to a new model for an adaptive Learning Management System. It presents the current e-learning standards and describes the elements that can be used to create the system: the sequencing control modes, sequencing rules, navigation controls, learning records and learning record stores. The model is based on artificial intelligent algorithms that analyze the data captured for each user and creates an adaptive navigation path through the learning content of the system, allowing each user to experience the content in different ways.

***Key-Words**:* adaptive navigation path, LMS (Learning Management System), SCORM, XAPI, XML, LRS (Learning Record Store)

## 1. Introduction

Learning Management Systems (LMSs) are web based applications used to store educational resources and provide users the ability to access this information in a controlled manner. LMSs are used by students to access information and by teachers to create and share educational content, grade and test students.
There are open source LMSs and proprietary LMSs, each with its advantages and disadvantages. The important thing is to be able to integrate content and learner history from one LMS to another. This can be done in a simple way if the systems are compliant with the same standards. Standards provide interoperability allowing the creation of course components completely independent of the learning management systems under which they are developed. Standards also assure the reusability, durability and accessibility of learning contents.
Another characteristic for a LMS that isn't implemented in most of the current LMSs is the ability to create adaptive navigation sequence through the content. There are standards for navigation and sequencing defined by ADL (Advanced Distributed Learning) for the SCORM 2004 4$^{th}$ Edition [3] but there isn't yet a standard to create dynamic navigation paths based on the learner progress and previous learning experience.
However, the ADL has developed another set of standards that could be used to create a more adaptive LMS, called The Experience API (XAPI). XAPI is the product of "Project Tin Can API" [4] and provides a way to store and retrieve extensible learning records, learner and learning experience profiles regardless of the platform used.
The scope of this article is not to present the full specifications for SCORM or XAPI (previously called Tin Can API) but to present an example of how they can be used to create an adaptive course model.
Before describing the proposed model and the technologies needed to implement it, it is important to review the capabilities of the current standards and how they can be used to create a more intelligent LMS.

## 2. Standards

The e-learning industry continues to develop new systems to create and maintain learning content. It has become difficult to maintain interoperability between applications that use different methods and tools to create content. The standards help with the communication between applications and allow the same e-learning objects to be used in multiple systems and even to create a multi-system workflow.

## 2.1 SCORM 2004 4th Edition

SCORM 2004 4th Edition was released in 2009 and is the newest version of Sharable Content Object Reference Model [5]. This version provides new means of navigation and tracking data that can be used to develop an adaptive course model.

The current SCORM standard uses SCORM data model elements (DMEs) to collect and store data about learners and their progress through the SCO (Sharable Content Object) [6]. Some of the information available to store about the learner's experience within a course is:

- How they performed and if they completed the course (completion status);
- How much total time they spent (total time);
- How much time they spent in a certain section of the course (session time)
- How they answered assessment items (interactions);
- If they passed or failed the course (success status);

A complete list of SCORM Data Model Elements is available in [6] and [7] and provides information about the element and how it can be used in a LMS.

It is important to understand the capabilities of the current standard to gather information about the learner because this data can be used in navigation and sequencing for a more personalized experience.

Sequencing and navigation is available in SCORM since SCORM 2004 and describes how sequencing between learning activities is defined and interpreted [8]. Sequencing rules are specified via XML in the course's manifest and every activity has a complete sequencing definition associated with it [16].

The rules for the sequencing definition model in SCORM 2004 can be divided into the following categories [2]:

- Sequencing Control Modes – Used to determine what type of navigation is allowed by the user. The most common navigation types are: free navigation via a table of contents and linear navigation via previous/next buttons is used.
- Constrain Choice Controls – Used to restrict activities the user may select.
- Sequencing Rules – Used to specify if-then conditions that determine activities available for delivery and activities to be delivered next.
- Limit Conditions – Used to provide attempt limits on activities.
- Rollup Rules – Used to specify if-then conditions that determines how status is rolled up to clusters throughout the activity tree.
- Rollup Controls – Used to determine which activities participate in status rollup and how their status is weighted in relation to other activities.
- Rollup Consideration Controls – Used to provide more precise control over status rollup than do the rollup controls.
- Objectives – Used to track and share the status of individual learning objectives across activities. Objectives are often used to control sequencing actions.
- Selection Controls – Used to specify a random subset of activities for delivery.
- Randomization Controls – Used to deliver activities in a random order.
- Delivery Controls – Used to deliver non-communicative content.
- Completion Threshold Controls – Used to track completion percentage.
- Navigation Controls – Used to control navigational UI elements.

Using these sequence rules presented above, it is possible to create an algorithm that will ensure the user navigates through the content in a controlled manner, based on the data tracked by the system about his previous learning experience.

However, this limits the algorithm to analyze only the data collected inside the current LMS. The internet is a vast resource for educational content and every learning action should be added to the learning profile of the user in order to ensure a more personalized course flow. The data stored and used in the sequencing algorithm should not be limited to the content of the LMS but the learning experience of the user through external contents and other LMSs as well. All of this data can be collected using the XAPI (Experience API) described in the next section of this article.

## 2.2 Experience API (Tin Can API)

The Experience API (XAPI) is a component of the Training and Learning Architecture (TLA) that enables tracking of learning experiences and learner's actions like reading an article or watching a training video [9]. The learning experiences of a user are delivered and stored in a Learning Record Store. A Learning Record Store (LRS) is a system that stores learning information. It can be a LMS but it can also be another system that does not have the full set of features needed by a LMS [4].

The Experience API provides a way for the Learning Activity Providers to structure and define the statement, state, learner, activity and objects that describe a learning experience and also a method for transferring this information across systems, but also for storing it and retrieving it from other systems that are not Learning Activity Providers.

Taking into consideration the fact that for a personalized experience across multiple learning management systems user data needs to be shared, the Experience API defines security methods for trusted exchange of information between the Learning Record Store, where the data is stored, and the trusted sources for this data.

At the core of the Experience API are statements based on Activity Streams like <Actor, Verb, Object> or "I did this." for all learning events. A statement is composed of three mandatory elements and other optional properties.

The mandatory elements are: actor, verb, and object. The actor represents who the statements is about and it can be a learner, teacher or group. The verb describes the action of the statement (for example: read, passed). The object can be an activity, an agent or another statement and represent what the actor interacted with, like an article or a test.

Other optional properties that can be used in a sequencing algorithm are:

- Id – This is a UUID assigned by the LRS or other trusted source.
- Result – This property is used to provide further relevant details to the verb describing the learning activity.
- Context – This property is used to give the statement more meaning and could also be used establishing the level of knowledge of the user for a specific section of a course or for a specific concept.
- Timestamp – The timestamp property specifies when the statement happened. If not provided, the LRS can set this time to the stored time. This could be a useful property for the adaptive navigation sequence because it helps establish the timeline and the duration for a section, concept or course.
- Stored – Specifies when the statement was recorded. This is set by the LRS.
- Authority – Used to provide information about whom or what has asserted that the statement is true.
- Voided – This property marks a statement as invalid. It should be very carefully analyzed because voiding a learning activity has a direct impact on the learning profile of the user.
- Metadata – This property allows the XAPI to be extended to any form of metadata that cannot be set using the existing fields. It can be useful to add certain information needed for the algorithm to create the learning profile of the user and establish the level of knowledge the user has reached for each section, course or learning concept.

The XAPI uses four sub-APIs to send and receive statements from an LRS [4]:

- The Statement API – This provides the basic communication mechanism that sends the statements from the source to the learning record store where they are later analyzed and used to create the learning profile for the user.

- The State API – This API is used to ensure the state persistence across devices.
- The Activity Profile API – This allows for arbitrary key/document pairs to be saved which are related to an Activity and also includes a method to retrieve a full description of an activity from the LRS.
- The Agent Profile API – allows for arbitrary key / document pairs to be saved which are related to an Agent and also includes a method to retrieve information about an Agent derived from an outside service, such as a directory service.

## 3. Adaptive navigation path

The standards described above provide the means to create either a LMS with simple navigation path or a more complex navigation path based on a sequencing algorithm.

To create an adaptive navigation path, the sequencing algorithm must use the information gathered with the XAPI and tailor a learning experience to each user by analyzing the learner's specific learning style and experience.

This article will present a first draft of an algorithm to create an adaptive navigation path through the content of a LMS.

Before describing the algorithm that generates the adaptive navigation path, it important to analyze the LMS requirements, from the content point of view.

The learning content should provide extra information that describes it and can later be used by the LMS's sequencing algorithm. For example, each learning object should be described by a concept or a list of concepts and a level of knowledge required for each concept. Also, the LMS should store information about the relationships between different concepts. This relationships should be able to provide enough information for the algorithm to extract the dependency between learning objects.

Another information about a learning object that should be provided if the type of learning style it uses. This can be automatically determined by the type of resource it uses (audio, video) or it can be manually provided by the content creator.

This information is needed because the algorithm is constructed based on three characteristics of the user:

- The learning style of the user

This is determined by analyzing the previous learning experience of users and by determining what type of resources they prefer and the type of learning objects they assimilate faster.

There are seven learning styles defined in [10]: visual, aural, verbal, physical, logical, social, and solitary.

Based on this characteristic, a user might choose a different path through the learning content, selecting only the compatible sections and course resources.

- The learning status of the user for a certain concept

This information is also obtained from the user's previous learning experience by tracking his progress through the content referred to the specific concept. It can be a numerical level (for example: from 1 to 10) or a rank (for example beginner, intermediate, advanced). No matter the scale used to describe the learning status it should be correctly interpreted by the sequencing algorithm.

- The overall learning status of the user

To obtain this information the LMS should analyze the overall progress of the user. This can be a made by establishing the average progress through all the concepts or courses the user has obtained up to that point.

All this information will be used to set the navigation path based on the level of knowledge of the user. A more efficient student will need to go through fewer sections in order to obtain a qualification than a less effective one and he/she will need to take a test with a different level of difficulty in order to finalize a course.

The sequencing algorithm will use artificial intelligence algorithms to analyze data from the user profile and provide the best navigation path. The conditions used to determine the next activity to be delivered to the learner should answer the following questions:

- Did the user achieve the level of knowledge needed to pass the current activity?
- Does the user need another type of resource, more suitable to his learning style or level of knowledge, in order to pass the current activity?
- Does the user need to review previous activities related to the same concept or other concepts that are needed for the current activity?
- What is the next activity compatible with the level of knowledge of the user for each concept and the overall progress of the user?
- What is the suitable activity for the user learning style?

The adaptive navigation path will ensure that the learning experience within the learning management system for a particular user can vary from other users, providing for each user the best navigation path to obtain a competency or a qualification. The system functions as an optimization mechanism for the learning process which will result in a faster assimilation of knowledge. It will take the role of the teacher that analyzes the students during the whole year and offers advice on which sections should be revised or thoroughgoing studied if the knowledge therein has been insufficiently understood and what content to access next in order to advance more quickly. The main advantage will be that the data used by the algorithm will include learning experiences from all other systems that follows the same standards and communicates the learning experience of the user to the Learning Record Store, which can be the actual learning management system or another system that does not have all of the functionalities a learning management system has. Having more information about the user's learning experience the navigation sequence created will prove more efficient.

## 4. Technologies

Technology is an important criterion that should be taken into account when analyzing a LMS because it is important that the system is accessible and works on any platform. Most LMSs are written in PHP or Java which is a good choice because they are not dependent on the operating system and can be used on any platform.
However, portability is not the most important factor that should determine the technology used to implement the system. A LMS should be easily updated and upgraded and it should also facilitate the integration with other systems: human resource management systems, enterprise resource planning systems, Active Directory, email, third party eLearning courses, ecommerce or mobile access systems.
This is fairly easy done with any system that is implemented based on components running as services. However, most LMSs are based on a system of plugins. The use of plugins raises the issue of compatibility with different versions of software. Each plugin is based on a set of technologies that could not all be compatible with the application core or other plugins that are being used.
The technologies used should also give the possibility to create the system standard compliant because it will ensure the interoperability, reusability, durability and accessibility of any courseware component developed within the system or outside the system.
To create a LMS with an adaptive navigational path it must be compliant with at least the current SCORM 2004 4$^{th}$ Edition standard and the newest standard, the Experience API. This means that the technologies used should be compliant with these standards. SCORM uses XML for the course's manifest file and the Experience API uses JSON Activity Streams to communicate learning statements through RESTful HTTP methods.

ISSN 2067 – 4074

## 4.1 XML

Extensible Markup Language (XML) describes a class of data objects called XML documents and partially describes the behavior of computer programs which process them [11]. The XML is used by SCORM to create XML files that describes the content. The use of XML is understandable as the documents are formal and concise, easy to create and there are many programs which process XML documents.

An XML document contains one or more elements with boundaries delimited by start-tags and end-tags or, for empty elements, by an empty-element tag. Each element has a type, identified by name, also called generic identifier (GI). The elements may have a set of attribute specification. Each specification has a name and a value.

The main elements in the SCORM 2004 manifest structure are: manifest, metadata, organizations, resources and imsss:sequencingCollection.

```
<resource identifier="oop_quiz_resource"
    type="webcontent" adlcp:scormType="sco"
    href="shared/assessmenttemplate.html">

    <file href="OOP/questions.js"/>
    <dependency identifierref="common_files"/>
</resource>
```

*Figure 1: An example of a resource element in the manifest file of a SCORM compliant content package*

Learning objects are also described by XML metadata files with <lom> as the root element and container elements like: general, lifeCycle, metaMetadata, technical, educational, rights, relation, annotation, classification.

The "classification" element is used to categorize the learning object within the context of a controlled vocabulary or classification system [12]. This element can be used to categorize learning objects by concept as needed to create an adaptive navigation path.

The SCORM standard provides a way to incorporate all the information needed about a learning object in order to be interpreted by the algorithm creating the navigation sequence.

## 4.2. Activity Streams

Activity Streams are used by the Experience API to format the statements of experience delivered and stored in LRS. In this case an activity steam is a list of recent learning activities performed by a user. However, the use of activity streams started to be adopted by major websites since the introduction of the Facebook's News Feed [13].

Activity Streams have provided a mean to unlock the vast amount of information generated every day by internet users and making it instantly accessible across systems. It can ensure that the learning activity a user has finished on a learning management system is instantly sent to all other systems and thus used in creating a personalized experience based on recent changes in the learning profile.

Activities are serialized using the JSON format which is a text-based open standard designed for human-readable data interchange [14].

A simple statement generated by the XAPI has the following format:

```
{
    "id":"31f12014-ccb4-21a2-44de-b23aa231a8db",
    "actor":{
        "objectType": "Agent",
        "name":"Actor example",
        "mbox":"mailto:user@example.com"
    },
    "verb":{
        "id":" http://adlnet.gov/expapi/verbs/attempted",
        "display":{ "en-US":"attempted" }
    },
    "object":{
        "id":"http://example.com/xapi/examplestatement",
        "definition":{
            "name":{ "en-US":"example statement" },
            "description":{ "en-US":"XAPI statement example." }
        }
    }
}
```

*Figure 2: Example of statement generated by the XAPI*

The simple syntax of the JSON statement makes it easy to parse and easy to be handled by web applications.

## 4.3. RESTful Web Services

RESTful Web Services are web services implemented using HTTP and the principles of REST. The APIs used by the XAPI use RESTful HTTP methods (GET, PUT, POST, and DELETE) to handle, send and receive statements from a LRS.

RESTful Web Services are based on four basic principles:

- The structure of the URI should be easily understood and usable.

This is done by defining directory-like URIs. In [4] are examples of the URIs structure used by each of the XAPI APIs:

http://example.com/XAPI/statements,http://example.com/XAPI/activities,http://example.com/XAPI/activities/state
These URLs are also called clean URLs, RESTful URLS, user-friendly URLS or SEO-friendly URLs because they do not contain a query string but only a path of the resource.

- Use HTTP methods explicitly

The HTTP methods used by RESTful web services are: GET, PUT, POST and DELETE, each of this having a specific CRUD function associated: GET-Read (Retrieve), POST-Create, PUT – Update (Modify), DELETE-Delete (Destroy).

- Stateless

A stateless web service means no data about the session is stored on the server side, simplifying the implementation and the design and improving performance. The HTTP headers and body of the request should contain all the necessary information needed by the web service to respond [15].

- Transfer XML or JSON

RESTful web services can use either XML or JSON to communicate with clients meaning it can work with a variety of clients, written in different programming languages and on different platforms and it is compatible with the JSON Activity Stream used by the XAPI.

## 5. Conclusions

The elements described in this article conclude that a LMS with an adaptive navigation path can be implemented using the current standards for tracking and storing the learning experience of the user but it also needs a more complex sequencing algorithm that interprets this data and generates a personalized learning experience for each user. The sections, courses and all resources the user has access to in the learning management system should be determined based on the learning profile. A learning profile needs to store information about learning styles, the overall level of knowledge achieved and also the level for each concept used in the courseware. The navigation sequence for a specific user should also be based on the qualifications and competencies gained.
The compatibility with any platform is an important criterion to ensure the system can be used by anyone. This means that the
web technologies used should inflict any integration restrictions.
The LMS should be able to integrate with external learning content and exchange data about the learning experience of the user which means it should use a highly adopted format for this communication. Further research should be made to develop and implement the sequencing algorithm presented in this article.

## Acknowledgements

Parts of this research have been published in the Proceedings of the 12th International Conference on Informatics in Economy, IE 2013

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