
**An Architectural Approach for Supporting Accessible Hypermedia in Web-based Learning Systems**

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**Abstract**

The need for providing learners with web-based learning content that match their accessibility needs and preferences, as well as providing ways to match learning content to user’s devices has been identified as an important issue in accessible educational hypermedia literature. Several initiatives already exist trying to provide accessible web-based learning environments addressing a broad range of access needs and requirements. However, the design and development of web-based learning environments for people with special abilities has been addressed so far by the development of hypermedia and multimedia based educational content that is specially designed for the user targeted group, as well as the use of dedicated infrastructure supporting the delivery of learning content. Such approaches not only prevent their user groups (learners and their tutors) from accessing other available resources, but also keep them dependent from the specific e-learning platform. On the other hand, even if an open and scalable learning environment has been implemented, the supported content and learning scenarios are a-priori designed for the targeted group. As a result, the user group (learners and their tutors) is prevented from accessing other available resources and is also fully dependent from the specific e-learning platform.

In this paper we address the need for an architectural definition of a web-based learning system that satisfies the design steps and requirements identified following the current state-of-the-art accessibility approaches and techniques.

1. **Introduction**

During the last years, accessibility has been recognized as one of the main design requirements for web-based content and systems [1, 2]. In the eLearning sector several systems already exist trying to address the need of providing access to learning material for people with a broad range of access needs and requirements. The design and development of web-based learning environments for people with special abilities has been addressed so far by the development of hypermedia and multimedia based educational content specially designed for the user targeted group, as well as the use of dedicated infrastructure supporting the delivery of learning content. The main drawback of this approach is that content can be delivered only through the dedicated e-learning platform, thus limits the capability of reusing and repurposing learning content. On the other hand, even if an open and scalable learning environment has been implemented, the supported content and learning scenarios are a-priori designed for the targeted group. As a result, the user group (learners and their tutors) is prevented from accessing other available resources and is also fully dependent from the specific e-learning platform [3].

In this paper we address the need for an architectural definition of a web-based learning system that satisfies the design steps and requirements identified following the current state-of-the-art accessibility approaches and techniques.

The paper is organized as follows: In section 2 we discuss the accessibility dimensions in web-based learning, aiming to identify the main design considerations for accessible web-based learning systems. For each accessibility dimension we analyze the accessibility requirements, present the state-of-the-art accessibility approaches and techniques and discuss the open issues concerning web-based learning systems design. Finally, we present an architectural definition of a web-based learning system that addresses the design steps and
requirements identified following the current state-of-the-art accessibility approaches and techniques.

2. The dimensions of Accessibility in Web-based Learning

2.1. Designing Accessible Web-based Learning Systems

During the last years, e-learning has attracted a great attention from both academia and industry. However, only recently the issue of accessibility in e-learning systems has emerged. Accessible learning systems are systems that provide accessible learning content through accessible interfaces. In the case of Web-based Learning Systems, learning content has the form of hypermedia objects (also called learning objects). Accessible browsing interfaces in this case, are web browsers or interface applications supporting assistive technologies, e.g. screen readers or Braille displays. Thus, the process of designing accessible web-based learning applications involves two main actions, namely:

- Designing accessible hypermedia based learning content.
- Designing accessible interfaces for browsing this content.

Figure 1, presents the accessibility dimensions and design processes of web-based learning systems.

![Figure 1: Accessibility dimensions and design processes of web-based learning systems.](image)

In order for a content developer to design accessible hypermedia and for a system designer to design accessible interfaces, several steps should be followed. The first step is the identification of the target user group accessibility needs. This process should be based on the use of best practice guides and/or guidelines that relate disability categories with design requirements. The second step is to identify learning object accessibility properties. The accessibility needs or preferences for the target audience and the accessibility properties of the learning objects should be formalized in standardized descriptions (information models) in order to enable the matching of learning content with learner preferences. The formalization of those information models will act as a script to the web-based learning system in order to offer accessible services and at the same time enables reusability of both content and learner information across systems. The third step of the design process includes the design of the learning system’s accessibility features. The definition of those features should be based on the design requirements identified at the first step (Identification of Learner Accessibility Preferences).

After defining the accessibility features of the learning system the designer should address the following questions:

- What is the appropriate assistive technology related to learners’ accessibility needs?
- What specific content design techniques should be followed in order to ensure the appropriate rendering and to enable browsing of the content?

2.2. Open Issues and Current State-of-the-Art

As we already described, the design of accessible web-based learning systems is defined upon three dimensions.

2.2.1. Learner Dimension

This dimension includes the identification of learner accessibility preferences and the modeling of those preferences into reusable information records. This process can be based on the use of the IMS Learner Information Package (LIP) specification [4] or any other learner modeling specification. The IMS LIP specification provides the means to “package” learner information. Regarding accessibility, IMS LIP information model includes the “accessibility” element that describes learner accessibility information. Figure 2 presents the information structure of the IMS LIP accessibility element. The accessibility information is defined through the description of the following learner’s characteristics:

- Language Capabilities, that is, the definition of learner’s language proficiencies;
- Disabilities, as to what the learner is no able to do;
- Eligibilities, as to what the learner is able to do;
- Preferences, including learning preferences (e.g. issues of learning style), physical preferences (e.g. a preference for large print) and technological preferences (e.g. a preference for a particular computer platform).
In order to follow and/or test the hypermedia content against the above described requirements of the W3C WCAG, several tools already exist. The identification of learning content accessibility properties and the creation of a model for representing accessibility information for learning resources remains an open issue. Several initiatives already exist trying to define a metadata model for representing accessibility information for learning resources, including the CEN/ISSS Learning Technologies Workshop Accessibility Working Group [7], the Dublin Core Metadata Initiative (DCMI) Accessibility Working Group [8] and the IMS Accessibility Working Group [9].

### 2.2.3. System Dimension

This dimension includes the definition of system’s accessibility features along with the required assistive technology that the system should support. This process can be based on the use of the IMS Guidelines for Developing Accessible Learning Applications [10]. Those guidelines include several design requirements concerning:

- Flexible media delivery of text, audio, images and multimedia
- Developing asynchronous and/or synchronous communication and collaboration tools
- Developing accessible interfaces and interactive environments
- Testing and assessment

In the system dimension, there are several issues to be addressed including the separation of content from the delivery platform, enabling content interoperability across different systems, as well as the separation of content information from content presentation, so as to enable rendering to a diverse set of devices with different layout capabilities and/or requirements.

### 3. An architectural approach supporting accessible hypermedia

The proposed approach addressed in this paper aims to separate hypermedia content from the required specially designed for people with special needs training processes and/or the corresponding special equipment or assistive technology. Such an approach defines accessibility in a broader fashion than “providing accessible content to people with disabilities”, thus, enabling access for all to the same information resources.

Moreover, the support of hypermedia designed based on requirements for different target user groups, indicates that the proposed architecture approach is generic enough to enable a web-based learning system acting as a rendering device driven by the underlying pedagogy independently from the learning content to be delivered. The separation of information from presentation features in the hypermedia content, gives the flexibility to support individualized presentation styles based on learner preferences.
accessibility preferences, as well as support of multiple browsing devices e.g. mobile devices.

The main advantages of the proposed approach can be summarized as follows:
- No special hypermedia and/or multimedia content should be designed and developed in order to enable access from specific target groups.
- Users can access available information resources independently from their abilities or disabilities.
- Access to the same information sources, eliminates the feeling of isolation.
- Communication and collaboration between people with diverse access needs can be addressed since the information in not dependent to access devices or abilities.

Figure 3 presents the proposed architectural approach for a web-based learning system supporting accessible hypermedia based on the principles described in the previous sections of the paper. This figure shows the structural components of the system and their interconnection paths.

Figure 3: Accessible Web-based Learning System Architecture

The main components of this architecture are the following:
- Learning Process Design System. Existing Learning Technology Specifications are designed in order to ensure reusability of educational content within different authoring environments, content repositories and delivery platforms. The degree to which educational content can be reused in different contexts and re-purposed to serve different requirements depends on how it is stored, made available, and delivered. Common barriers to the reuse and adoption of learning materials include monolithic resources, tailored to specific requirements and able to address specific learning scenarios [11]. Instructional designers and content authors should be able to locate objects, change unsuitable components, combine them in a variety of different structures based on a diverse set of pedagogical approaches and exchange them among heterogeneous Content Management and Learning Management Systems. The only way that these goals can be achieved is to produce, package and deliver learning objects in a way that complies with emerging Learning Technology specifications, in particular IMS Learning Design [12]. Learning Design specification is based on the established method for modeling learning activities – Educational Modeling Language (EML) [13], and supports multiple users acting multiple roles, working alone or collaboratively in groups. The Learning Process Design System should be based on the use of IMS Learning Design specification in order to provide to an instructional designer the environment for defining learning scenarios. The idea is to define generic, domain independent learning scenarios that can be used by the content packaging system in order to create learning activities based on the use of the existing hypermedia content. With this approach learning scenarios are separated from the content, thus allows the web-based learning system to deliver learning activities using user oriented learning scenarios based on hypermedia no specially designed for the target user group.
- Content Packaging System. A software tool that enables the organization of web-based learning content in reusable packages that implement the training processes designed with the training process design system. The development of such packaging tool could be based on the commonly used IMS Content Packaging Specification [14] and the supported metadata for indexing the components of a training course could be based on the IEEE Learning Object Metadata Standard [15].
- Learning Resources Metadata Authoring & Management System. An environment that supports the metadata authoring and repository management. The main goal of this environment is to provide an easy-to-use and accessible from anywhere platform capable of authoring, storing, managing and deliver the educational metadata produced for supporting the accessible hypermedia content.
- Course Delivery System and Collaboration Services. A web-based course delivery platform and collaborative environment for virtual learning communities of users. This environment provides the communication tools and collaboration environment for the users to participate in a learning community and have access to the hypermedia content available in the repository of learning resources.

The above mentioned components handle information stored in three repositories, namely:
- Learning Resources Repository. This repository stores the learning resources. A learning resource can be from a simple hypermedia or multimedia resource to complex hypermedia structure. Such a repository can
be from a local repository to a network of distributed repositories.

- **Knowledge Pool Repository.** This pool stores the content packages defined by the use of the content packaging tool, representing desired learning activities designed with the learning process design system. Those content packages are also associated with the corresponding metadata for the resources included in the content packages.

- **Accessibility Style Sheets Pool.** This pool contains style sheets that need to be used in order to present the web-based courses to the users taking into account their accessibility preferences. These style sheets can be based on existing international accessibility specifications and recommendations, e.g. W3C Web Content Accessibility Guidelines and W3C Cascading Style Sheets recommendation [16].

So far, we presented an architectural definition of a web-based learning system that addresses all the design steps and requirements already identified based on the current state-of-the-art accessibility approaches and techniques. Open issue in the proposed architecture still remains the definition of an accessibility application profile for enabling the formalization of learning object accessibility properties, and the matching of learning content with learner accessibility preferences [17].

### 4. Conclusions

In this paper we presented the accessibility dimensions in web-based learning, trying to identify the main design requirements for designing an accessible web-based learning system. For each accessibility dimension we analyzed the accessibility requirements, presented the state-of-the-art and discussed the open issues concerning web-based learning systems design. Finally, we presented an architectural definition of a web-based learning system that addresses all the design steps and requirements identified based on the current state-of-the-art accessibility approaches and techniques. The proposed architecture is based on three design principles, namely:

- **Separation of hypermedia content from the delivery platform**
- **Separation of content information from presentation information**
- **Separation of hypermedia content from learning scenarios**

This approach has several benefits, including:

- **Support of hypermedia designed based on requirements for different target user groups, thus the proposed architecture approach is generic enough to enable a web-based learning system to act as a rendering device affected by pedagogy independent from the learning content to be delivered.**

- **Provides the flexibility to support individualized presentation styles based on learner accessibility preferences, as well as support of multiple browsing devices e.g. mobile devices.**

- **Limits the need for design and development of special hypermedia and/or multimedia content in order to enable access from specific target groups.**

- **Offers access to the same information sources, eliminating the feeling of isolation for people with disabilities.**

- **Provides the means for communication and collaboration between people with diverse access needs since the information in not dependent to access devices or abilities.**

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