Supporting Accessible Technology-Enhanced Training: The eAccess2Learn Framework

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Abstract—During the last years, the design and development of technology-enhanced training systems for disabled groups of learners has attracted the attention of the technology-enhanced learning community. However, although a number of such systems have been designed to meet accessibility needs and preferences for those groups, most of them anticipate special-purpose e-training material and keep their e-training activities local to the particular system in use. As a result, neither reuse of existing digital training resources (widely available nowadays in web-based repositories) nor sharing of best technology-facilitated training practices among the communities of educational practitioners and training organizations is supported by these systems. Within this context, in this paper, we present the eAccess2Learn Framework which aims at providing tools and services that facilitate the design and development of accessible e-training resources and courses that bare the potential to be interexchanged between different e-training platforms and programs, thus making them potentially exploitable and reusable between different disabled user groups.

Index Terms— Authoring tools, e-learning standards, learning environments, learning objects.

1 Introduction

During the past years, accessibility has been recognized as a key design consideration for technology-enhanced training systems ensuring e-inclusion of people with disabilities in the training process and consequently preventing risks of "digital exclusion" [1], [2]. As a result, a number of systems have been proposed, such as e-Learn-Vip (http://www.e-learn-vip.org), SYNENNOESE [3], and DEAL (http://www.deal-leonardo.eu), aiming to meet the training needs of people with disabilities. However, most of these systems: 1) are typically supported only by digital training resources that are specially designed to meet the accessibility requirements of a particular user group and 2) their training activities are not represented in such a way that they can be identified and interexchanged between the various systems [4].

The main drawbacks of these approaches are that 1) the development of special-purpose digital training resources is costly and, thus, their limited sharing and reuse increases the barriers of certain categories of learners with disabilities in accessing technology-facilitated training services, and 2) valuable experiences from the best technology-facilitated training practices, gained through local use, cannot be easily identified and adopted by larger communities of educational practitioners and training organizations. Therefore, there is a strong need for technology-supported solutions to the above-mentioned problems. Within this context, in this paper, we present the eAccess2Learn Framework, which aims to provide tools and services that facilitate the design and development of accessible e-training resources and courses that bare the potential to be interexchanged between different e-training platforms and programs, thus making them potentially exploitable and reusable among different disabled user groups.

The paper is organized as follows: Following this introduction, in Section 2, we discuss the issue of accessibility in technology-enhanced training and we present the current initiatives and approaches on enhancing accessibility in technology-enhanced training systems. Section 3 describes our proposed framework for facilitating the design and production of accessible e-training resources and courses that can be interoperable between different e-training platforms and systems and we present the tools and services of the proposed framework. Section 4 presents a case study of applying the proposed framework for the design and development of accessible e-training resources and courses for two disabled user groups, namely, low-vision and motor-disabled people. Finally, we discuss our conclusions and our ideas for future work in this field.

2 Background

2.1 Technology-Enhanced Training and Accessibility

The issue of accessibility in relation to technology-enhanced training is understood as ensuring that learners are not prevented from accessing technology-supported resources, services, and experiences in general due to their disability [5], [6], [7], [8]. There have been many generic definitions of the term accessibility, mainly focused on reducing barriers to accessing the web and ensuring equal access to all users [9], [10]. According to Harper and Yesilada [11]: "*Web accessibility conjures the vision of designers, technologists, and researchers valiantly making the World Wide Web (Web) open to disabled users.*" The IMS Global Learning Consortium offers an education-specific definition of both disability and

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accessibility: "*the term disability has been redefined as a mismatch between needs of the learner and the education offered. It is, therefore, not a personal trait, but an artifact of the relationship between the learner and the learning environment or education delivery. Accessibility, given this redefinition, is the ability of the learning environment to adjust to the needs of all learners. Accessibility is determined by the flexibility of the education environment (with respect to presentation, control methods, access modality, and learner supports) and the availability of adequate alternative-but-equivalent content and activities*" [12]. It is important to point out that this definition of disability has been adopted by the ISO/IEC Standard 24751 "Individualized Adaptability and Accessibility in E-Learning, Education, and Training." ISO/IEC 24751 is intended to meet the needs of learners with disabilities and anyone in a disabling context and provides a common framework to describe and specify learner needs and preferences on the one hand and the corresponding description of the digital learning resources on the other hand, so that individual learner preferences and needs can be matched with the appropriate user interface tools and digital learning resources [6], [7], [8].

In relation to the aforementioned definition, there are three main approaches for enhancing accessibility in technology-enhanced training:

- The first and most common approach is to create universally accessible resources that meet all the accessibility requirements. The main drawback of this approach is that, typically, resources may be accessible by everyone but optimal for no one [13].
- The second approach used by a number of educational content providers is to create multiple versions of the resources, customized based on the different needs and expectations of the anticipated individual user. While this solves some of the problems with the first approach, it causes new problems, such as the increased costs that eventually result to poor maintenance of these resources, compared to their default version, eventually, providing learners with disabilities with out-of-date and different versions of the digital content [14].
- The third approach is to build universally accessible systems, that is, systems that can handle learner-centered configurations of resources and/or tools/applications. This is known as the AccessForAll Approach [15]. The AccessForAll Approach requires accurate descriptions of both the learners' preferences and/or needs, as well as of the available resources and/or the tools/applications characteristics. However, early systems implementation suffered by the lack of interoperability considerations (that is, sharing resources, activities, and their underlying training practice between systems was not guaranteed), adding extra barriers to the AccessForAll Approach.

The emergence of learning technology specifications, such as the IMS Accessibility for Learner Information Package [16], the IMS AccessForAll Metadata [12], and the IMS Guidelines for Developing Accessible Learning Applications [17], and web accessibility standards, such as the Web Content Accessibility Guidelines [18], [19], the User Agent Accessibility Guidelines [20], the Authoring Tool Accessibility Guidelines [21], bare the potential toward improving this situation, although global adoption is still in the very early stages and extra effort is needed to ensure synchronization and further adoption of these specifications in real-life applications.

2.2 Accessibility Dimensions

As we already implied, the design of accessible technology-enhanced training systems is defined upon three dimensions, namely, the description of learners' preferences and/or needs, as well as, the characteristics of resources and tools/applications. Furthermore, another important dimension, which is well recognized in studies of accessible systems design, is the context of use [22], [23], [24]. In this section, we further discuss these four identified key dimensions in accessible technology-enhanced training systems design.

2.2.1 Learner Dimension

This dimension includes the expression of the individual learner accessibility preferences and the modeling of those preferences into reusable information records. One way to achieve this is by using the IMS Accessibility for Learner Information Package Specification (IMS AccLIP) [16]. IMS AccLIP adds a new element on IMS Learner Information Package (IMS LIP) [25] to allow learner <accessibility> preferences to be explicitly defined. Rather than targeting at the implicit description of the learner's disabilities, it allows users to explain explicitly how they interface and use a technology-enhanced training system, with their preferences being grouped into <display>, <control>, and <content> elements [16]. This offers a flexible user-controlled process for the definition of the learners' characteristics in relation to the preconditions under which the learner interacts with the system, although it does not handle the conditions and features of the current learning situation, needed to be handled by the context dimension.

2.2.2 Resources Dimension

This dimension includes the design of resources that are accessible from a specific target group with given disabilities and their tagging with appropriate metadata. The common way for generating accessible digital resource has been by applying the W3C Web Content Accessibility Guidelines 1.0 and their evolution W3C Web Content Accessibility Guidelines 2.0 [18], [19]. On the other hand, typically, educational resources are described with the IEEE Learning Object Metadata Standard (IEEE LOM) [26], so as to be searched, found, and retrieved through established web-based repositories. However, IEEE LOM does not directly support the description of educational resources in terms of their relevance to accessibility characteristics. Efforts have been made to develop Application Profiles of the IEEE LOM Standard that can be used for tagging educational resources with accessibility relevant information [27].

Another way to characterize accessible educational resources with metadata is by using the IMS AccessForAll Metadata Specification (IMS AccMD), which aims to provide with metadata that expresses the resource's ability to match the needs and preferences of a certain learner's IMS AccLIP profile. It is intended to assist with resource discovery and also to provide a way that can support the substitution and augmentation of a resource or a resource component with equivalent or supplementary components as required by the accessibility needs and preferences expressed in a learner's IMS AccLIP profile [12]. The main disadvantage of this approach is that it relates the description of resources to the description of the learner's condition characteristics in a rather hard-wired way thus, reducing the interoperability only between systems that adopt both the IMS AccLIP and the IMS AccMD specifications.

2.2.3 Tools/Applications Dimension

This dimension includes the definition of tools'/applications' accessibility features in relation to the required assistive technology that the tool/application should support. This process can be based on the use of the IMS Guidelines for Developing Accessible Learning Applications, which include the following design considerations [17]:

1. accessible delivery of text, audio, images, and multimedia,
2. developing accessible synchronous and asynchronous communication and collaboration tool,
3. developing testing and evaluation tools, including self-assessment and multiple-choice testing,
4. developing accessible authoring tools, and
5. legal issues for accessible distance learning.

An example of a well-known system that conforms to the IMS Guidelines for Developing Accessible Learning Applications is the ATutor (http://www.atutor.ca) Open Source Course Management System (CMS), developed by the Adaptive Technology Resource Centre of the University of Toronto. ATutor is an accessible course management system built around the IMS AccessForAll specifications, which aims to allow access to all potential learners, instructors, and administrators, including those with disabilities who may be accessing the system using assistive technologies.

2.2.4 Context Dimension

This dimension includes the definition of the conditions and features of the learning situation in hand. Context has been defined by Dey [28] as "*any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.*"

In relation to learning, context can be described as "*the current situation of a person related to a learning activity*" [29]. Learning context is an important issue in technology-enhanced training today, especially when adaptations and/or customized support is anticipated. Additionally, learning context can be used for making meaningful and accurate recommendations for learning systems configurations and consequently lead to better learning experiences [30], [31].

3 The Proposed eAccess2Learn Framework

As already discussed, an important drawback of accessible technology-enhanced training systems has been the lack of interoperability of the educational resources and the educational practices between different systems and platforms. For this purpose, we propose the eAccess2Learn Framework, which adopts the current learning technology specifications and web accessibility standards, aiming to support the main stages of a typical e-learning chain (namely, creation, publication, discovery, acquisition, access, use and reuse of accessible digital training resources and courses), while retaining their interoperability between various e-training systems and platforms.

3.1 Objectives

The key objectives of the eAccess2Learn Framework are the following:

- Representation of established training practices in a machine-readable way using international specifications (such as the IEEE LOM [26] and the IMS Learning Design [32]), so that both digital training resources and e-training courses can be reused and interexchanged between different platforms and systems.
- Design of a set of reference e-training strategies, as best practice examples for technology-enhanced training of people with disabilities and represent them in a formal machine readable manner using the IMS Learning Design.
- Develop tools for learning design and authoring of educational metadata that implement the state-of-the-art learning technologies specifications and standards appropriately modified to deal with the special requirements of disabled people training.
- Development of a web-based repository with accessible e-training resources and courses, as well as generic e-training strategies facilitating their storage, search, and retrieval.

3.2 eAccess2Learn Stakeholders

The eAccess2Learn Framework identifies three main stakeholders in technology-enhanced training, namely:

- **E-Training Content Suppliers**, that is, the entity responsible for designing and developing independent e-training resources in the form of "learning objects" [33]. For the purpose of our work, a learning object is defined as "*potential reusable digital or nondigital resources or a collection of linked resources that are characterized by metadata, and have been designed and developed for a specific audience, their scope is to achieve one or more specified learning goals and they are used in order to support one or more educational activities which feature specified criteria that measure the achievement of the learning goals that have been defined*" [34]. The e-training content suppliers need to 1) be able to convert their existing e-training resources and/or create new digital resources that meet accessibility requirements of people with disabilities, and 2) be able to characterize these resources with metadata that are meaningful in relation to the

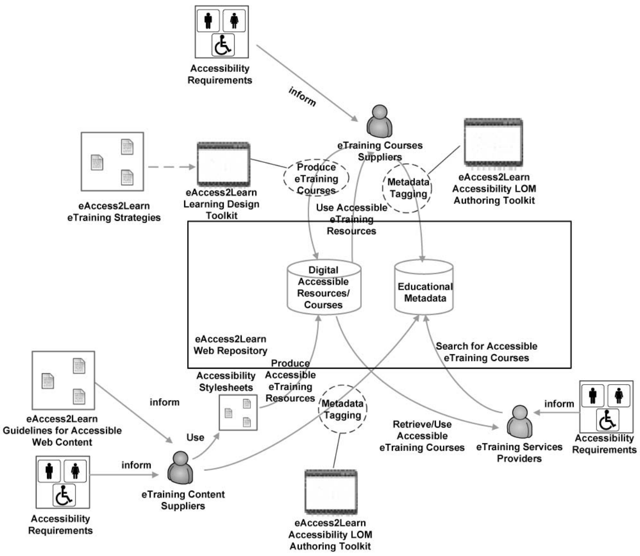


Fig. 1. The eAccess2Learn Framework overview.

accessibility characteristics of the resources. Thus, the eAccess2Learn Framework provides them with a set of guidelines and the technological means for developing accessible e-training resources and tagging them with appropriate educational metadata.

- **E-Training Courses Suppliers**, that is, the entity responsible for designing e-training courses based on a predefined scenario (course template) that reflects the adopted training approach. For the purposes of our work, an e-training course is defined as: "*a sequence of learning activities conducted entirely through the web, targeting specific educational objects and lasting for 8 to 16 didactical hours in total*" [35]. Moreover, we adopted the following definition for the concept of an e-training course template: "*an eTraining Course Template can be defined as a pedagogical model for an eTraining course, focused on the sequence of generic learning activities that will support teachers and designers to develop particular kinds of learning experiences, one of the aims of an eTraining Course Template is to enable the features of a successful eTraining course to be applied to other eTraining Courses so these may also promote successful outcomes for learners*" [36]. Thus, the eAccess2Learn Framework provides the e-training course suppliers with a methodology and the technological means for defining their e-training strategies and for representing them in a common machine understandable format following the IMS Learning Design specification [32]. Furthermore, the eAccess2Learn Framework provides them with a set of best practice examples of generic e-training course templates which they can use and modify according to their e-training strategies, and offers them access to a web-based repository of e-training resources (in the form of learning objects characterized with appropriate educational metadata), which can both facilitate them in the design and the development of their e-training courses.
- **E-Training Services Providers**, that is, the entity responsible for designing e-training programs as a synthesis of e-training courses and delivering them to people with disabilities. The eAccess2Learn Framework provides them with access to a repository of e-training courses (represented in the form of IMS Learning Designs) which they can use to search and retrieve e-training courses, so as to integrate them to their course management systems.

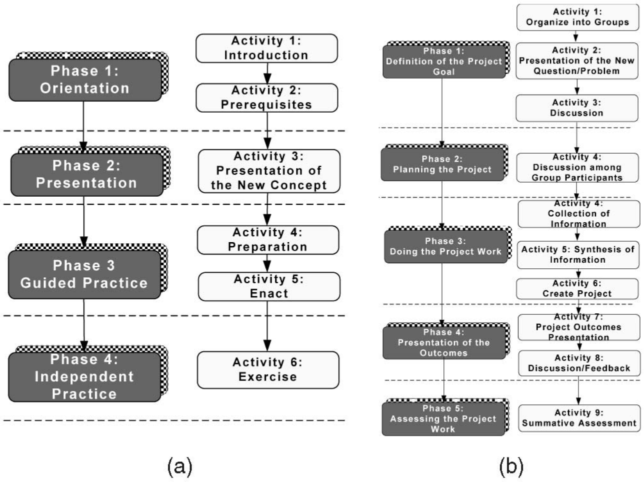


Fig. 2. Examples of eAccess2Learn e-training course templates. (a) Competence-based learning—learning activities flow. (b) Project-based learning—learning activities flow.

Fig. 1 presents the identified stakeholders, their interconnections, as well as, their needs and the tools/services that the eAccess2Learn Framework offers them to support these needs.

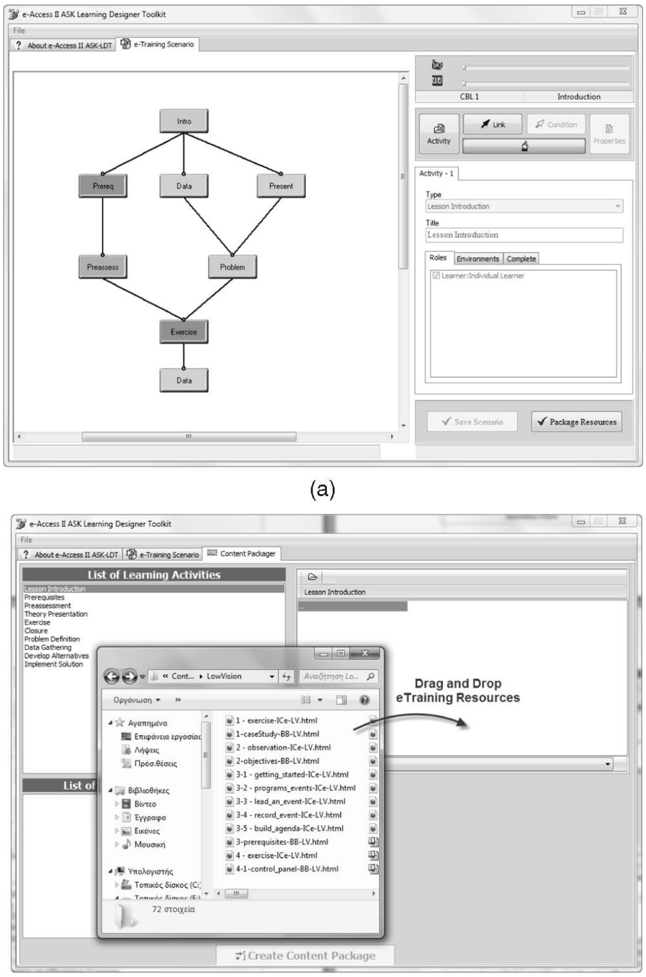
3.3 eAccess2Learn Tools and Services

The eAccess2Learn Framework provides to the main stakeholders identified in Section 3.2, a set of key services and tools that are described next in detail.

3.3.1 eAccess2Learn Learning Design Toolkit for Designing E-Training Course Templates and E-Training Courses

This is a software tool that enables the e-training course suppliers 1) to express their e-training strategies, in the form of e-training course templates, using a common machine understandable way, and 2) to design and develop e-training courses using a reference set of predefined e-training course templates. As a result, a set of e-training course templates, which are following different e-training strategies (suitable for disabled people training), can be designed to facilitate the development of e-training courses that adopt these strategies. Fig. 2 presents the learning activities flow of two typical e-training course templates, namely, the "competence-based training" and the "project-based learning" templates. The eAccess2Learn Repository includes a reference set of e-training course templates, which are produced by active e-training course suppliers based on their best practices.

Fig. 3 presents snapshots of the eAccess2Learn Learning Design Toolkit, which provides e-training courses suppliers with a graphical user-friendly interface for creating e-training courses conformant with IMS Learning Design Specification [32] and packaging them along with their



(a)

(b)

Fig. 3. eAccess2Learn learning design toolkit. (a) Creating a new e-training course based on a predefined course template learning activities. (b) Assigning e-training resources to e-training course.

related e-training resources. Furthermore, by using the eAccess2Learn Learning Design Toolkit, e-training courses suppliers can exchange e-training strategies and/or courses, assess their application at a local/national/global context of use, and reflect to the feedback for further improvements to either e-training strategies or e-training courses.

3.3.2 eAccess2Learn Guidelines and Style Sheets for Developing Accessible Web-Based Training Content

This is a service that includes the provision of 1) a set of mandatory guidelines, based on the W3C Web Content Accessibility Guidelines 1.0 [18], which can be followed by the e-training content suppliers to ensure that their newly produced e-training resources meet accessibility requirements for visually impaired and motor-disabled people and 2) a set of cascading style sheets (CSS) for HTML-based content that facilitate e-training content suppliers to transform the presentation of the HTML elements (e.g., text size/color, foreground/background color, buttons, links, etc.) of their existing e-training resources, so as to be understandable and navigable from low-vision, color-blind, and motor-disabled people.

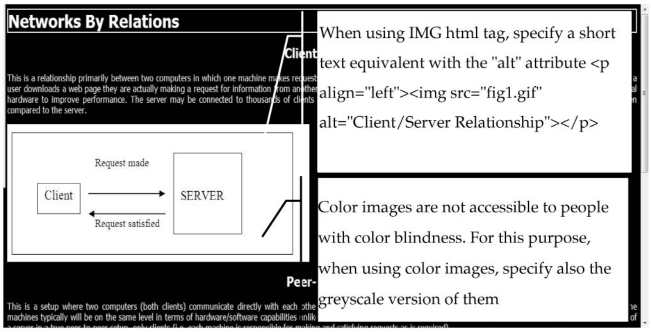


Fig. 4. Implementation example of the eAccess2Learn guidelines.

The eAccess2Learn guidelines aim to address three general dimensions, namely, the presentation, understandability, and navigability of the e-training resources. These dimensions are similar with the different themes of accessible design that the Web Content Accessibility Guidelines address [18], [19]. Fig. 4 presents an implementation example of the eAccess2Learn Guidelines for developing accessible web-based training content. More specifically, since text is considered potentially accessible to all users as it can be handled by 1) screen readers, 2) nonvisual browsers, and 3) braille readers [18], [19], nontextual information (images, applets, sounds, multimedia presentations) should be followed by textual equivalents. Additionally, especially for color-blind people, information conveyed with color should be also available without it, through alternative descriptions.

Moreover, the presentation of the content in HTML pages should be controlled with style sheets rather than with presentation elements and attributes applied directly to the HTML elements [18], [19]. For this purpose, three different style sheets have been developed for controlling the presentation of HTML-based content for three disability categories, namely, motor-disabled, low-vision, and color-blind people. Fig. 5 presents the application of the eAccess2Learn Accessibility Style Sheets to the same HTML content. The HTML content is accordingly transformed to be understandable and navigable for visually impaired (low vision and color-blind) and motor-disabled people. More precisely, when the style sheet for color-blind people is applied, the HTML page is transformed so only black and white colors are used. In case the style sheet for low vision is applied, the HTML page is transformed so the font size becomes larger and the contrast between background and foreground becomes higher. Additionally, the hyperlinks and the buttons of the HTML page are transformed to become larger and with higher contrast compared to the background. Finally, when the motor-disabled style sheet is applied, the hyperlinks become larger, to enable persons with motor disabilities to click more easily on the hyperlinks.

3.3.3 eAccess2Learn Accessible Learning Objects Metadata Authoring Toolkit

This is a software tool that facilitates the e-training content suppliers and e-training courses suppliers to author educational metadata for their e-training resources and e-training

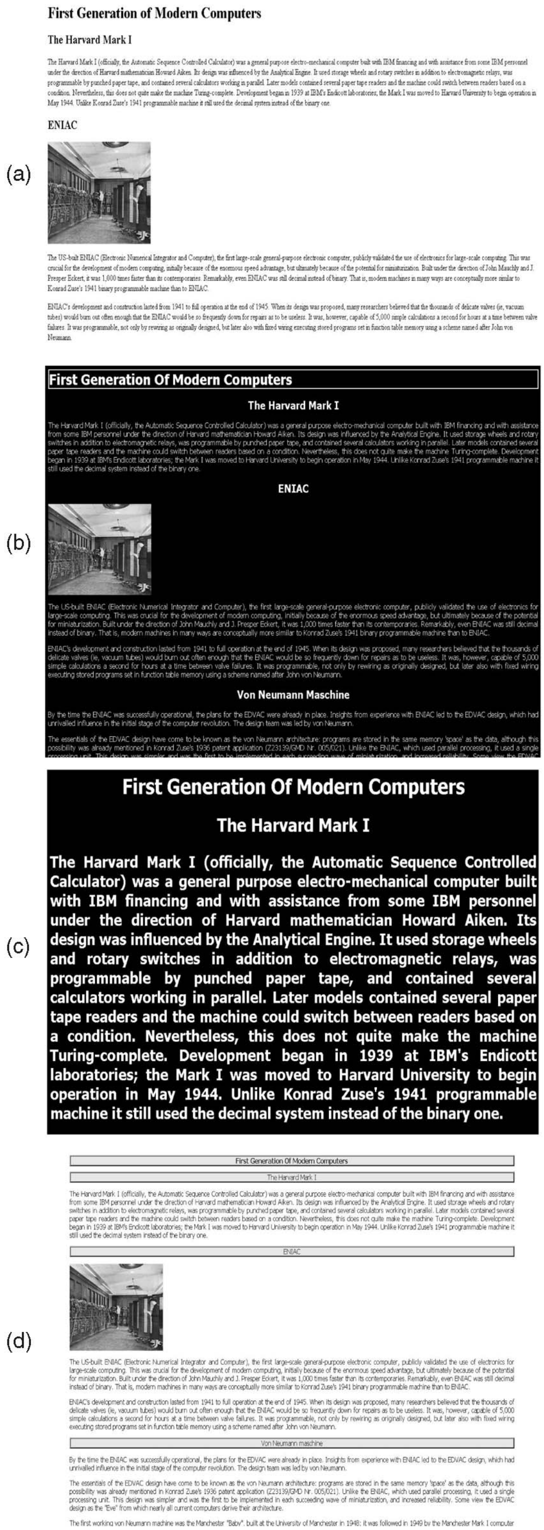


Fig. 5. Application of the eAccess2Learn accessibility style sheets. (a) HTML content without eAccess2Learn style sheets applied. (b) HTML content with eAccess2Learn style sheet for color-blind people applied. (c) HTML content with eAccess2Learn style sheet for low-vision people applied. (d) HTML content with eAccess2Learn style sheet for motor-disabled people applied.

courses, as well as organizing and offering e-training resources and courses through the eAccess2Learn Web Repository. Fig. 6 presents screenshots of the eAccess2Learn Accessible Learning Objects Metadata Authoring Toolkit.

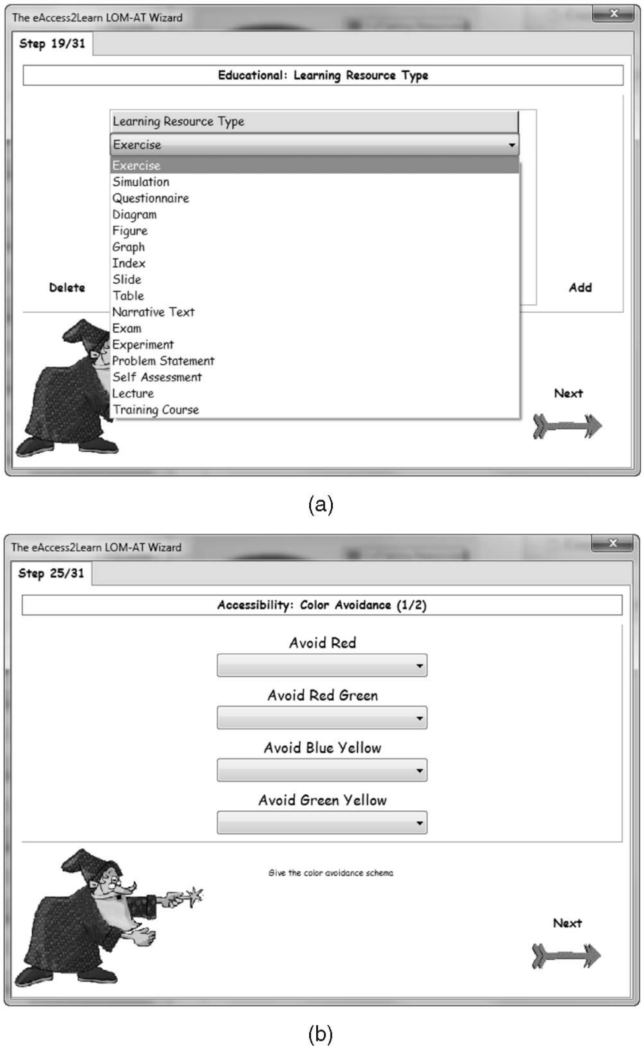


Fig. 6. eAccess2Learn accessible learning objects metadata authoring toolkit. (a) Authoring educational metadata (learning resource type metadata element) using the authoring wizard. (b) Authoring accessibility metadata using the authoring wizard.

This toolkit aims to provide e-training content suppliers and e-training courses suppliers with a user-friendly authoring wizard for describing their e-training resources and courses with educational and accessibility metadata conformant with the IEEE Learning Objects Metadata Standard [26]. Moreover, by using the eAccess2Learn Accessible Learning Objects Metadata Authoring Toolkit, e-training course suppliers can create and offer descriptions of available e-training courses with emphasis to accessibility aspects, so as to enable e-training services providers to make more informed decisions during the design of their e-training programs.

In order to handle the accessibility characteristics of the e-training resources and courses, we have proposed extensions to the IEEE LOM standard through an IEEE LOM Application Profile, which was reported in [37]. More specifically, we have proposed the extension of Category 4.8 (Technical) with information about the use of colors in learning objects, so visually impaired people can be able to access appropriately developed e-training resources. Table 1 summarizes these extensions.

TABLE 1
Extensions of IEEE LOM—Technical Category

Nr	Name	Explanation	Size	Value Space	Datatype
4.8	Color Avoidance	Preferences regarding the use of color in the described learning object	1		
4.8.1	Avoid Red	Indicates that the described learning object avoids red color	1	Yes No	Vocabulary
4.8.2	Avoid Red Green	Indicates that the described learning object avoids red and green colors together	1	Yes No	Vocabulary
4.8.3	Avoid Blue Yellow	Indicates that the described learning object avoids blue and yellow colors together	1	Yes No	Vocabulary
4.8.4	Avoid Green Yellow	Indicates that the described learning object avoids green and yellow colors together	1	Yes No	Vocabulary
4.8.5	Avoid Orange	Indicates that the described learning object avoids orange color	1	Yes No	Vocabulary
4.8.6	Avoid Red Black	Indicates that the described learning object avoids red and black colors together	1	Yes No	Vocabulary
4.8.7	Avoid Purple Grey	Indicates that the described learning object avoids purple and grey colors together	1	Yes No	Vocabulary
4.9	Color Difference	Indicates the maximum contrast in the described learning object	1	0…100	Integer
4.10	Color Brightness	Indicates the color brightness of the colors used in the described learning object	1		
4.10.1	Minimum	Indicates the minimum color brightness of the colors used in the described learning object	1	0…100	Integer
4.10.2	Maximum	Indicates the maximum color brightness of the colors used in the described learning object	1	0…100	Integer

Additionally, we have proposed extensions to the value space of the metadata element [Kind] in Category 4.7 (Relation) with information about the relationship of e-training resources with visual, text, or auditory alternatives. Table 2 summarizes these value space extensions.

TABLE 2
Extensions of IEEE LOM—Relation Category

Nr	Name	Explanation	Size	Value Space	Datatype
4.7	Relation	This category defines the relationship between this learning object and alternatives learning objects, if any	smallest permitted maximum: 100 items		
4.7.1	Kind	Nature of the relationship between the described learning object and the target learning object	1	ispartof haspart ... hasvisual alternative hastext alternative hasauditory alternative	Vocabulary

3.3.4 eAccess2Learn Web Repository

This is a web-based platform enabling e-training content suppliers and e-training course suppliers to share their e-training resources and e-training courses. Moreover, the eAccess2Learn Web Repository (http://www.eaccess2learn.eu) offers to the e-training services providers the ability to search and retrieve e-training courses, which they can integrate to their services. Additionally, the eAccess2Learn Web Repository is conformant with Web Content Accessibility Guidelines 1.0 [18], enabling direct access from users with certain disabilities, namely, motor-disabled and visually impaired users. The functionalities of the eAccess2Learn Web Repository can be summarized as follows:

- **Submit and Store:** E-training content suppliers and e-training courses suppliers are able to submit and store e-training resources and courses to the eAccess2Learn Web Repository along with their related educational metadata, which has been previously developed by using the eAccess2Learning Accessible Learning Objects Metadata Authoring Toolkit.
- **Search and Retrieve:** All user categories of the eAccess2Learn Web Repository are able to search and retrieve e-training resources and courses by using searching criteria, which are matched with the educational metadata of these resources and courses.
- **Download:** All user categories of the eAccess2Learn Web Repository are able to download e-training resources and courses and use them through other e-training systems and platforms. Moreover, the users are able to download the metadata record of an e-training resource or an e-training course and import it to other e-training systems and platforms or repositories, so as to be searchable and retrievable.
- **Rate/Comment:** All user categories of the eAccess2Learn Web Repository are able to provide their ratings and comments for the e-training resources and e-training courses stored in the eAccess2Learn

Web Repository. These ratings and comments could be related with the impressions of the users who have used a specific e-training resource/course.

Fig. 7 presents screenshots of the eAccess2Learn Web Repository functionalities. More precisely, the searching mechanism of the eAccess2Learn Repository is presented, where the users can search e-training resources and courses by using searching criteria, which are matched with the educational metadata of these resources and courses. Next, the searching results are presented, where the users can browse and download e-training resources and courses by previewing their educational metadata. The next screenshot presents the uploading mechanism of the eAccess2Learn Web Repository, where the users (e-training content suppliers and e-training courses suppliers) can upload their e-training resources and courses along with their related educational metadata records, so as to be searchable and retrievable from the searching mechanism of the repository. Finally, the last screenshot presents the rating/commenting mechanism, where the users can 1) provide their ratings and comments about e-training resources and courses included in the eAccess2Lern Web Repository and 2) browse the ratings and comments of other users of the eAccess2Learn Web Repository.

4 Case Study: Applying the eAccess2Learn Framework to the Technology-Supported Training of Motor Disabled and Visually Impaired People

In this section, we present a case study of applying the eAccess2Learn Framework to the technology-supported training of two different disabled user groups, namely, motor-disabled and low-vision people. The main objectives that we aim to address through this case study are the following:

- **Objective 1:** To validate the transformation of existing e-training resources to be fully accessible for both selected disabled user groups by using the eAccess2Learn Guidelines for Developing Accessible Web-Based Training Content.
- **Objective 2:** To validate the transformation of the presentation of the same e-training resources with the use of the eAccess2Learn Accessibility Style Sheets for Developing Accessible Web-Based Training Content so as to be understandable and navigable for both selected disabled user groups.
- **Objective 3:** To validate the interoperability of the educational metadata of the e-training resources and courses produced by the eAccess2Learn Accessible Learning Objects Metadata Authoring Toolkit.
- **Objective 4:** To validate the interoperability of the e-training courses produced by the eAccess2Learn Learning Design Toolkit.
- **Objective 5:** To validate the reuse of e-training resources within different e-training courses produced by using the eAccess2Learn Framework Tools.
- **Objective 6:** To validate the reuse of the e-training course templates within different e-training courses, as well as among different disabled user groups (namely, motor-disabled and low-vision people) by using the eAccess2Learn Framework Tools.

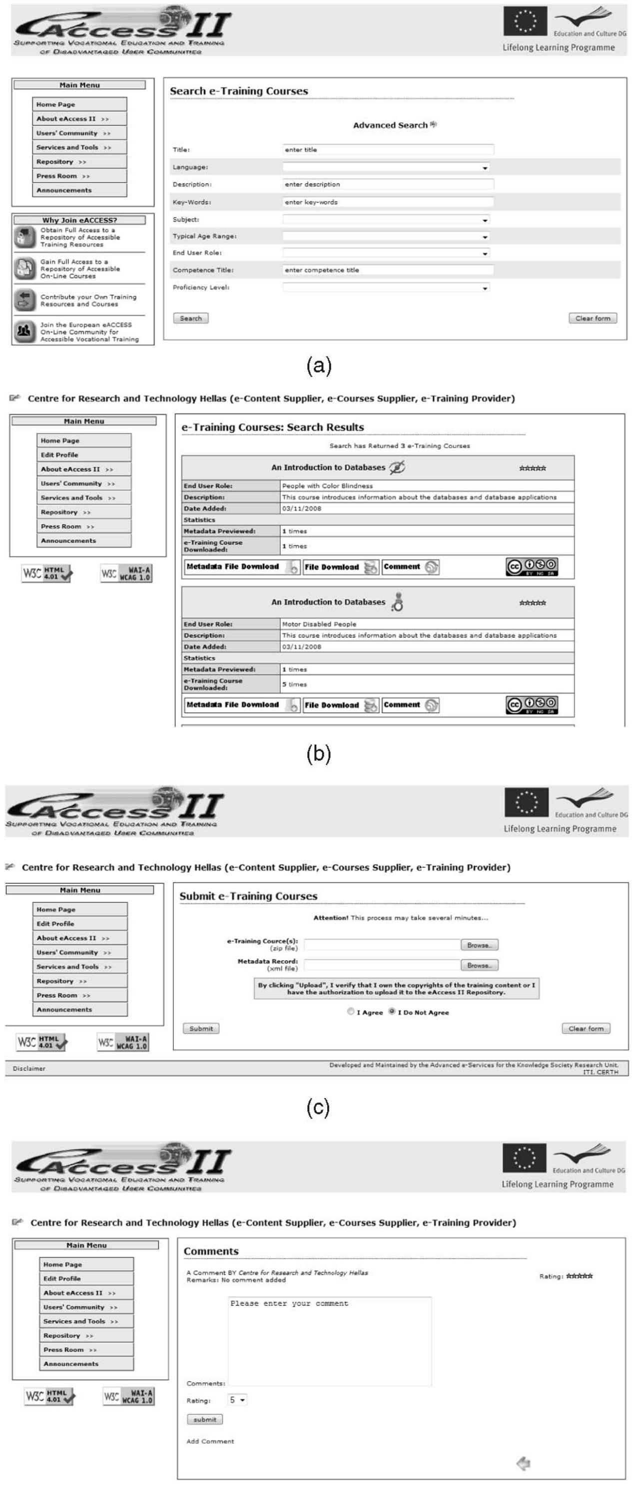


Fig. 7. eAccess2Learn web repository functionalities. (a) Searching mechanism for e-training resources/courses. (b) Browse and download e-training resources/courses from eAcces2Learn web repository. (c) Submit and store e-training resources/courses to eAcces2Learn web repository. (d) Submit and store e-training resources/courses to eAcces2Learn web repository.

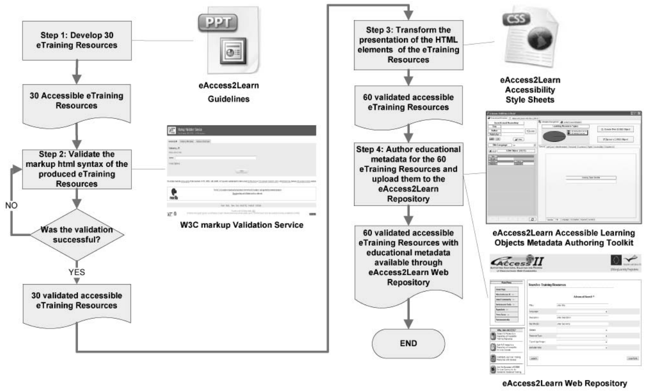


Fig. 8. Workflow diagram of the steps followed by each participant during the workshops with the e-training content suppliers.

First, the services and tools of the eAccess2Learn Framework was used by 26 e-training content suppliers, during specially designed two-day workshops, which were held in four Vocational Education and Training (VET) Organizations located in four European countries, Greece, Romania, Bulgaria, and Cyprus. Each participating e-training content supplier developed 30 accessible e-training resources (in the form of HTML pages) for each disabled user group (by using the eAccess2Learn Guidelines and Style Sheets for Developing Accessible Web-Based Training Content) and authored educational metadata for these e-training resources (by using the eAccess2Learn Accessible Learning Objects Metadata Authoring Toolkit), producing a total of 780 e-training resources for each disabled user group (namely, motor-disabled and low-vision people). More specifically, the steps that were followed during the workshops are presented below and they are depicted in Fig. 8 as a workflow diagram:

- **Step 1:** During this step, each participant developed 30 accessible e-training resources by following the eAccess2Learn Guidelines for Developing Accessible Web-Based Training Content. The outcome of step 1 was 30 accessible e-training resources.
- **Step 2:** During this step, each participant validated and corrected the markup HTML syntax of the developed e-training resources using the W3C Markup Validation Service.
- **Step 3:** During this step, each participant transformed the presentation of the HTML elements of the 30 developed accessible e-training resources by using the eAccess2Learn Accessibility Style Sheets, so as to be understandable and navigable for low-vision and motor-disabled people, producing 30 accessible e-training resources for each disabled user group (60 in total).
- **Step 4:** Finally, each participant characterized with educational metadata the developed accessible e-training resources for both disabled user groups and uploaded them to the eAccess2Learn Web Repository by using the uploading mechanism of the repository.

After the end of the workshops, we validated the accessibility conformance ***(addressing objective 1)*** of the

TABLE 3
Mean Ranking of E-Training Resources Validation by Two Disabled User Groups

Disabled User Group	Satisfaction		
	Presentation	Undestandability	Navigability
Motor Disabled	4.86	4.92	5
Low Vision	4.76	4.87	5

produced e-training resources using an automated accessibility validation tool, namely, the IBM's aDesigner (http://www.alphaworks.ibm.com/tech/adesigner). All produced e-training resources (780 in total) passed the accessibility validation against the W3C Web Content Accessibility Guidelines 1.0. These validation results provided us a strong indication that the eAccess2Learn Guidelines for Developing Accessible Web-Based Training Content could be successfully applied for the transformation of existing e-training resources to fully accessible for motor-disabled and low-vision people.

After that, we asked 32 motor-disabled people and 32 low-vision people to review 50 e-training resources per disabled user group, so as to receive their feedback about the transformation of the HTML content of the produced e-training resources when the eAccess2Learn Style Sheets are applied ***(addressing objective 2)***. More precisely, we asked them to complete appropriately designed questionnaires with questions investigating their satisfaction about the presentation, undestandability, and navigability of the HTML elements (e.g., text size/color, foreground/background color, buttons, links, etc.) of the produced e-training resources. For each question, a five-point likert scale was used where 5 denoted "very satisfied" and 1 denoted "not at all satisfied." Table 3 presents the mean ranking for each disabled user group for different categories of satisfaction. These categories were selected from the different themes of accessible design that the Web Content Accessibility Guidelines addresses [18], [19], as explained in Section 3.3.2.

The next experiment conducted was designed to validate the interoperability ***(addressing objective 3)*** of the produced educational metadata records of the e-training resources produced. For this purpose, we used two well-known educational metadata editors which conform to the IEEE LOM Standard, namely, were the Reload Metadata Editor (http://www.reload.ac.uk) and the LomPad tool (http://helios.licef.ca:8080/LomPad/en/index.htm), and we imported the produced XML metadata records to these tools. All 780 e-training resources educational metadata records were imported correctly to both the Reload Metadata Editor and the LomPad tool. The validation results provided us evidences that the educational metadata records of the produced e-training resources retain their interoperability with other educational metadata editors, which conform to the IEEE LOM Standard.

Next, the services and tools of the eAccess2Learn Framework were used by 21 e-training courses suppliers, during specially designed two-day workshops, which were also held in the same VET Organizations described before. Each participating e-training courses supplier developed,

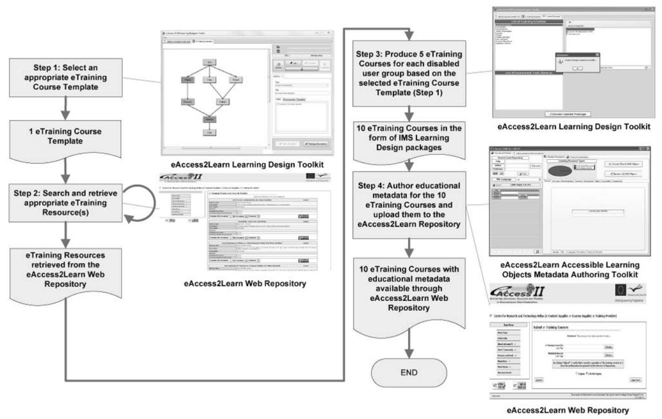


Fig. 9. Workflow diagram of the steps followed by each participant during the workshops with the e-training courses suppliers.

using the e-training resources previously produced and uploaded to the eAccess2Learn Web Repository, five e-training courses for each disabled user group (namely, motor-disabled and low-vision people) by using the eAccess2Learn Learning Design Toolkit. More specifically, the steps that were followed during the workshops are presented below and they are depicted in Fig. 9 as a workflow diagram:

- **Step 1:** First, each participant selected one e-training course template from the reference set of e-training course templates (developed by typical e-training course suppliers based on their best practices), which are embedded in the eAccess2Learn Learning Design Toolkit, so as to develop his/her e-training courses based on that template. The selection of the e-training course template from each participant was based on the following criteria: 1) the conformance of the e-training course templates educational objectives with the educational objectives that each participant was aiming to address with its e-training courses, and 2) the accessibility needs of the two targeted disabled user groups.
- **Step 2:** Next, each participant used the searching mechanisms of the eAccess2Learn Repository, so as to search and retrieve appropriate e-training resources suitable for 1) the learning activities of the selected e-training course template, 2) the accessibility needs of each disabled user group, and 3) the subject domains that have been selected by each participant for the development of their e-training courses.
- **Step 3:** During this step, each participant used the eAccess2Learn Learning Design Toolkit to produce five e-training courses, represented in the form of IMS Learning Design Packages for each of the two disabled user groups, based on the selected e-training course template and the e-training resources selected from the eAccess2Learn Web Repository.
- **Step 4:** Finally, each participant characterized with educational metadata the developed e-training courses for the two disabled user groups and uploaded them to the eAccess2Learn Web Repository by using the uploading mechanism of the repository.

TABLE 4
Reusability of E-Training Resources

Disabled User Group	eTraining Resources			Re-usability percentage
	Total	Common Resources	Unique Resources	
Motor Disabled	780	214	566	27.43%
Low Vision	780	267	513	34.23%

After the end of these workshops, we validated the interoperability ***(addressing objective 3)*** of the produced educational metadata records of the e-training courses produced by following the procedure described before. All 105 e-training courses educational metadata records were imported correctly to the Reload Metadata Editor as well as to the LomPad tool. The validation results provided us evidences that the educational metadata records of the produced e-training courses retain their interoperability with other educational metadata editors, which conform to the IEEE LOM Standard.

Furthermore, we validated the interoperability of the produced e-training courses with other learning design tools ***(addressing objective 4)***, which conform to the IMS Learning Design Specification. The tools, which were selected for this purpose, were the ReCourse Learning Design Editor (http://tencompetence-project.bolton.ac.uk/ldauthor/index.html) and the Reload Learning Design Player (http://www.reload.ac.uk/ldplayer.html). All 105 e-training courses were correctly imported to both the ReCourse Learning Design Editor and the Reload LD Player. The validation results provided us evidences that the produced e-training courses retain their interoperability with other learning design tools, which conform to the IMS Learning Design Specification.

The next experiment was designed to measure the reusability of the e-training resources ***(addressing objective 5)*** within the e-training courses produced for the two disabled user groups. In order to measure that, we searched for common preexisting e-training resources (that is, reused within two or more e-training courses) and for unique preexisting e-training resources (that is, used only in one e-training course). Table 4 presents the reusability results of the e-training resources and the reusability percentage according to the total number of e-training resources developed for each of the two disabled user group.

As we can notice from Table 4, 27.43 percent of the total e-training resources developed for motor-disabled people were reused within two or more e-training courses for this disabled user group. Additionally, 34.23 percent of the total e-training resources developed for low-vision people were reused within two or more e-training courses for this disabled user group. These results provided us evidences that the proposed eAccess2Learn Framework can facilitate the process of reusing e-training resources within different e-training courses, which are addressing a specific disabled user group.

The final experiment was to measure the reusability of the e-training course templates within different e-training

TABLE 5
Reusability of E-Training Course Templates within Different E-Training Courses

Disabled User Group	eTraining Courses			Re-usability percentage
	Total	Developed based on common eTraining Course Template(s)	Developed based on unique eTraining Course Template(s)	
Motor Disabled	105	105	0	100.00%
Low Vision	105	105	0	100.00%

TABLE 6
Reusability of E-Training Course Templates among Different Disabled User Groups

eTraining Courses			Re-usability percentage
Developed for the two disabled user groups	Developed based on common eTraining Course Template(s)	Developed based on unique eTraining Course Template(s)	
210	148	62	70.47%

courses, as well as among the two disabled user groups ***(addressing objective 6)***. In order to measure that, we searched through the 210 e-training courses developed 1) for the same disabled user group and 2) for both disabled user groups, so as to identify the number of e-training courses which were designed based on common e-training course templates (that is, reused within two or more e-training courses), as well as based on unique e-training course templates (that is, used only in one e-training course). Tables 5 and 6 present the reusability results of the e-training courses according to the e-training course templates that they have been based upon.

As we can notice from Table 5, all e-training course templates were reused within the e-training courses developed for the same disabled user group. On the other hand, as shown in Table 6, 70.47 percent of the e-training courses developed for both disabled user groups were based on common e-training course templates, and only 29.53 percent of these courses required unique e-training course templates. This means that the majority of the e-training course templates were suitable for both disabled user groups and can be reused among them for the design and development of e-training courses.

5 Conclusion and Future Work

The issue of accessibility in web-based educational systems is important, so as to ensure that technology-supported training does not introduce more barriers to the inclusion of people with disabilities. However, early systems implementation suffered by the lack of interoperability considerations, which limits the sharing of resources, activities, and their underlying training practice.

Within this context, we presented the eAccess2Learn Framework, which adopts the current learning technology specifications and web accessibility standards, so as to support the main stages of the e-learning chain, namely, creation, publication, discovery, acquisition, access, use, and reuse of accessible digital training resources and courses, while retaining their interoperability between various e-training systems and platforms. In this framework, we identified the main stakeholders and we presented the key services and tools which empower them in the process of the design and development of accessible e-training resources and courses.

A case study of applying the eAccess2Learn Framework in two different disabled user groups, namely motor-disabled and low-vision people, provided us solid indications that

- Existing e-training resources can be transformed to accessible, so as to be understandable and navigable for the two disabled user groups.
- Existing e-training resources can be reused within different e-training courses, while retaining their interoperability between various e-training systems and platforms.
- Existing e-training course templates can be reused within different e-training courses, as well as, among different disabled user groups (in our case, the motor-disabled and the visually impaired people)

The framework reported in this paper can be further extended by facilitating the automatic recommendation of e-training resources and courses based on learner accessibility preferences. This could be implemented by adopting the relevant IMS AccessForAll specifications for modeling these preferences.

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