Adapting OpenCourseWare Based on the Needs and Preferences of Disabled Learners

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Abstract

OpenCourseWare (OCW) systems are becoming a significant source of learning that are widely used for various educational purposes. With the COVID-19 Pandemic situation, these resources showed the impact of having material and platforms to be reused and shared accessibly in the learning process. Learners have diverse backgrounds and needs, especially when it comes to learners with accessibility needs. It is essential to support these learners in their journey to increase their capabilities skill set. The question is, to what extent are these platforms and materials of good quality and accessible by diverse set of learners? On top of that, OCW platforms have complex requirements to convey information and knowledge to the learners in a collaborative environment. OCW platforms need to provide authoring tools to allow authors to develop content. In this research, we are concerned with answering the following research questions: 1) how to evaluate the quality and accessibility of these educational resources?, 2) how to define and represent the accessibility needs and preferences of learners?, 3) how to include these accessibility needs in the design and implementation of OCW platform and Open Educational Resource (OER).

In this thesis, we address these questions through five main steps: 1) designing quality evaluation metrics to evaluate the quality of OER through multiple dimensions on the platforms, 2) developing an approach for evaluating the accessibility of OER though analyzing metadata, 3) semantically representing the accessibility needs and preferences of learners, and the accessibility specifications of OER using ontologies, 4) using ontologies and knowledge graphs for filtering OER based on their accessibility features and predicted quality, and providing OER recommendations for learners according to their accessibility needs, and 5) providing guidelines and learnings of developing an accessible OCW (SlideWiki[1]) to address accessibility at the content level based on our development experience in an agile development environment.

The evaluation of our research was done by multiple questionnaires for learners and authors and through testing the OCW platform and OER with accessibility checking tools. The resultant proved to satisfy more accessibility needs for learners and authors.

[1] https://slidewiki.org/

Contents

Part I

Introduction and Preliminaries

CHAPTER 1

Introduction

Accessibility has gained significant attention over the past decades due to the equality laws enforced by governments to ensure the accessibility of systems and products. Also, the wide range of internet usage has urged web developers to be more inclusive and address the needs and preferences of a variety of users. By accessibility, we refer to designing systems, products, and services in a way that they are adaptable for people with disabilities [1], to help them interact with their environment equally as other users. As reported by the European Health and Social Integration Survey (EHSIS), there were more than 70 million people with disabilities aged 15 and older living in the European Union in 2012, which is equivalent to 17.6% of the EU population [2]. Approximately one out of four people with disabilities (25.6%) is reported to have accessibility problems in education and training contexts. Only 5% of public websites comply fully with web accessibility standards on average, while a larger number are partially accessible [3]. The European Act [4] proposed the directive of establishing the laws and regulations needed for products and services to be accessible, including requirements for computers, mobile, and web applications. Now, Accessibility has become a key requirement for developing web applications, especially in the e-learning contexts. One emerging type of e-learning systems are OCW systems, which provide means for distributing free educational content to a wide range of learners over the web. These learners include people with disabilities who have diverse needs and preferences, in terms of the type and severity of their disabilities, resulting in unique profiles. Such needs should be addressed by OCW systems to aid learners in improving their skill set. Two users with the same disability might have different needs and preferences; for example, one blind user might want to use a screen reader while another blind user might prefer a braille display, or both might want to use the same device but with different configurations (e.g., different text reading speeds). Defining and representing the needs and preferences of disabled learners with the help of accessibility and learner profiles in order to adapt the OCW system and educational contents accordingly is still an open area of research. We propose the use of ontologies to describe the accessibility knowledge required to represent learner profiles and foster the development of accessible OCW systems. Formally representing this knowledge by means of ontologies can ease sharing, integration, reuse, and reasoning as well as steer the adaptation of the OCW system and educational contents.

1.1 Motivation

As per the statistics of the World Health Organisation (WHO), one billion of the world population has some form of disability, and it is expected to double by 2050 [5]. At the European level, about *60%* of citizens with disabilities are employed (employment rate of persons without disabilities is *82%*), and *22.5%* of the youth with disabilities abandon education systems early (only *11%* of youth without disabilities) [6]. The lack of access to education, vocational rehabilitation, and training is among the most important reasons for low rates of employment [7]. Persons with disabilities have a high rate of abandoning education systems early and significantly lower employment rates partly due to the lack of access to education and vocational rehabilitation and training. It is not surprising, therefore, that providing high-quality OER that facilitate the self-development towards specific jobs and skills on the labour market in the light of special preferences of learners with disabilities is difficult.

Despite the large amount of OCW platforms and OER repositories (for example, the MERLOT collection hosts over 90,000 openly available resources from over 4,000 providers [8]), accessibility is still not widely addressed by OER [9]. There is a need to help learners define their preferences, and retrieve OER matching their needs (e.g., blind users might prefer textual over video resources). According to a systematic review, [10], focusing on recommender systems in e-learning, from 108 papers that were studied, only one has considered accessibility in its approach.

Furthermore, despite the high development potential in building OER recommender systems for addressing the growing need for education, based on the literature, we are confronted with a lack of studies in this area [11, 12]. According to the systematic literature review which analyzed web accessibility of educational websites from 2009 to October 2019 [13], the accessibility standards (e.g., Web Content Accessibility Guidelines (WCAG) 2.0) are not met on the educational websites among the 25 research work which they have analyzed.

1.2 Problem Statement and Main Challenges

Nowadays, web accessibility is part of evaluating the usability of a website. And it becomes a key requirement for creating OCW systems which should target a wider range of learners, including people with accessibility needs. Designing a single OCW that meets the needs of all types of learners is usually not possible, especially when we are addressing people with different types of disabilities at various levels of severity. For example, a blind person does not benefit from an image if it is not accompanied by a text description, whereas a person with dyslexia might instead prefer an image over a text description. We need to develop an approach for adapting educational resources of OCW systems to the learner's needs and preferences.

Challenge 1: Defining and evaluating the quality and accessibility of OpenCourseWare systems

Learners are now given a chance to perform free self-development using open educational resources, and teachers are reusing open materials that are prepared by well-known providers. However, it becomes hard to select good quality educational material due to the availability of a large number of repositories and resources. The challenge is how to recognize good quality open educational resources and how to evaluate the accessibility of these resources in order to recommend them to the learners based on their needs.

Challenge 2: Modelling accessibility needs and guiding learners to the most appropriate educational resources

Along with web accessibility acts, guidelines, and recommendations (i.e., WCAG, Section 504) that describe accessibility principles, best practices, guidelines and success criteria, there are also several researches that describe how users with disability use the web platforms. The challenge is how to represent these accessibility needs in a machine-readable format in order to understand these needs and address them in OCW and how to recommend these resources with respect to the learner preferences in terms of disability. We need to find a way to map the learner needs to the OER descriptions.

Challenge 3: Representing accessibility needs of learners in OpenCourseWare systems.

An OCW is composed of various components (e.g., the user interface of the platform, the educational resource representation, and collaborative tools). The challenge is how to collect and understand the accessibility needs of learners, and reflect them in each of these components. Furthermore, how to encourage authors of OCW to create accessible materials.

1.3 Research Questions

According to the challenges which we have defined, the following research questions will be addressed in this thesis,

> **RQ1**: How to evaluate the quality and accessibility of educational resources?

Many OER repositories are hosting and launching an enormous number of OER under Creative Common license[1] on a daily basis. However, the lack of high-quality services, such as OER search and recommendation systems, limit the use of OER. In order to address this question, we propose matrices to evaluate the quality of open educational resources. We analyze the accessibility descriptions of OER, and we propose a quality prediction approach for recommending OER, including accessibility features.

> **RQ2**: How can ontologies represent the accessibility needs and preferences of learners in OCW?

In order to answer this question, we created an ontology that represents the learners' needs together with the description of the educational resources from an accessibility perspective. The ontology was built on the basis of web accessibility and e-learning standards and guidelines. We developed a recommender prototype that uses this ontology to map the learner's needs to the most appropriate educational resources based on the features defined for these resources.

[1] https://creativecommons.org/

RQ3: How to include these accessibility needs in the design and implementation of OCW platform and OER?

In order to answer this question, we proposed the inclusion of accessibility guidelines and practices in the agile development methodology. We worked on a practical example of OER (i.e., slide presentation) to represent accessibility requirements in order to produce accessible slides.

1.4 Thesis Overview

The aim of this thesis is to highlight the accessibility need and requirement in OCW and guide the reader to the best practices that can be used to implement an accessible OCW. Furthermore, it shows how OCW can benefit from the usage ontology and knowledge graphs to enhance the accessibility presentation and help learner to get the most appropriate educational resources as per their preferences.

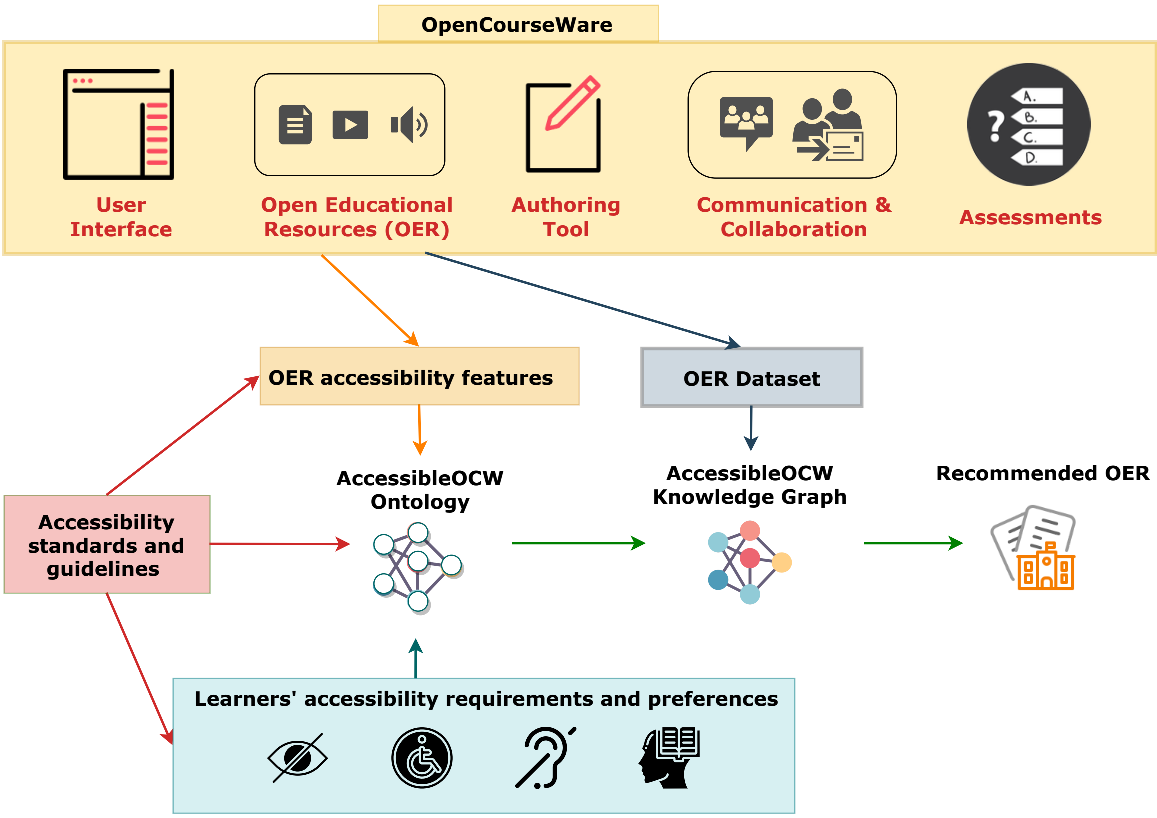


Figure 1.1: Thesis Overview: Addressing accessibility requirements of OCW using semantic web technologies

1.4.1 Contributions

1. **Contribution 1:** *OER Quality Evaluation Metrics*. We establish a set of evaluation metrics that assess OER quality in OER authoring tools. These metrics provide guidance to OER content authors to create high-quality content.

2. **Contribution 2:** *AccessibleOCW ontology*. We designed an ontology that describes the accessibility needs of learners and the accessibility features of OER with respect to the accessibility and e-learning guidelines and standards. The aim of this ontology is to provide a machine-readable representation of the domain knowledge of accessibility in OCW and allow other systems to reuse this knowledge.

3. **Contribution 3:** *AccessibleOER Recommendation Approach*. We created a knowledge graph and implemented a recommender prototype which uses the *AccessibleOCW ontology* to create learner profiles and help users to retrieve the most appropriate educational resources.

4. **Contribution 4:** *Accessibility Inclusive Development Approach*. We proposed the inclusion of accessibility in all the phases of agile development methodology. The aim is to consider accessibility in all the phases of OCW development in order to develop an accessible OCW. We also worked on the slide presentation as a real-world example to implement accessibility requirements of learners (e.g., visually impaired learners and cognitively impaired learners) and support authors by tools that encourage them to create accessible educational material.

1.4.2 List of Publications

1. Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Metadata Analysis of Open Educational Resources.* (Nominated for Best Short Paper Award) In 11th International Conference on Learning Analytics & Knowledge, 2021 Proceedings, ACM. https://doi.org/10.1145/3448139.3448208

2. **Mirette Elias**, Mohammadreza Tavakoli, Steffen Lohmann, Gábor Kismihók, and Sören Auer. *An OER Recommender System Supporting Accessibility Requirements.* In 22nd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) 2020, 57:1-57:4, ACM. https://doi.org/10.1145/3373625.3418021.

3. **Mirette Elias**, Allard Oelen, Mohammadreza Tavakoli, Gábor Kismihók, and Sören Auer. *Quality Evaluation of Open Educational Resources.* In 15th European Conference On Technology Enhanced Learning (EC-TEL) 2020 Proceedings, 410-415, Springer. https://doi.org/10.1007/978-3-030-57717-9_36

4. Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Quality prediction of open educational resources a metadata-based approach.* In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 29-31, IEEE. https://doi.org/10.1109/ICALT49669.2020.00007

5. **Mirette Elias**, Edna Ruckhaus, E.A. Draffan, Abi James, Mari Carmen Suarez-Figueroa, Steffen Lohmann, Abderrahmane Khiat, and Sören Auer. *Accessibility and Personalization in OpenCourseWare: An Inclusive Development Approach.* (Nominated for Best Full Paper

Award) In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 279-283, IEEE. https://doi.org/10.1109/ICALT49669.2020.00091

6. **Mirette Elias**, Steffen Lohmann und Sören Auer. *Ontology-Based Representation for Accessible OpenCourseWare Systems.* In *Information* 2018, 9(12), Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/info9120302

7. **Mirette Elias**, Abi James, Edna Ruckhaus, Mari Carmen Suárez-Figueroa, Klaas Andries de Graaf, Ali Khalili, Benjamin Wulff, Steffen Lohmann und Sören Auer. *SlideWiki - Towards a Collaborative and Accessible Platform for Slide Presentations.* In 13th European Conference On Technology Enhanced Learning (EC-TEL) 2018 Practitioner Proceedings, 1-13, CEUR Workshop Proceedings. http://ceur-ws.org/Vol-2193/paper6.pdf

8. **Mirette Elias**, Abi James, Steffen Lohmann, Sören Auer and Mike Wald. *Towards an Open Authoring Tool for Accessible Slide Presentations.* In 16th International Conference on Computers Helping People with Special Needs (ICCHP) 2018 Proceedings, 172-180, Springer. https://doi.org/10.1007/978-3-319-94277-3_29

9. **Mirette Elias**, Steffen Lohmann and Sören Auer. *Ontology-based Representation of Learner Profiles for Accessible OpenCourseWare Systems.* In 8th International Conference on Knowledge Engineering and Semantic Web (KESW) 2017 Proceedings, 279-294, Springer. https://doi.org/10.1007/978-3-319-69548-8_19

10. **Mirette Elias**, Steffen Lohmann, and Sören Auer. *Towards an Ontology-based Representation of Accessibility Profiles for Learners.* In 2nd International Workshop on Educational Knowledge Management (EKM) 2016 Proceedings. Co-located with 20th International Conference on Knowledge Engineering and Knowledge Management (EKAW), EKM@EKAW 51-59, CEUR Workshop Proceedings. http://ceur-ws.org/Vol-1780/paper5.pdf

11. **Mirette Elias**, Steffen Lohmann, and Sören Auer. *Fostering accessibility of OpenCourseWare with semantic technologies – a literature review.* In 7th International Conference on Knowledge Engineering and the Semantic Web (KESW) 2016 Proceedings, 241-256, Springer. https://doi.org/10.1007/978-3-319-45880-9_19

The complete list of publications completed during the PhD studies can be found in Appendix A.

1.5 Thesis Outline

The main goal of this thesis is to allow learners with accessibility needs to access open educational materials that match their needs and preferences. In order to achieve this goal, we split our research into three parts: 1) analyzing and evaluating the quality and accessibility of open educational resources, 2) representing accessibility definitions of learners and educational content with semantic technologies, and 3) reporting and recommending best practices for developing accessible OCW and OER.

1. *Chapter 2: Background.* This chapter provides an introduction to the domains which we are addressing in this thesis. More precisely, we are defining the acronyms of the three main domains: open education, web accessibility, and semantic web technologies.

Figure 1.2: The structure of the thesis and the related publications

2. *Chapter 3: Related Work*: This chapter discusses the state-of-the-art of web accessibility standards in open education and the related vocabularies (e.g., ontologies, data dictionaries, ..)

3. *Chapter 4: Accessibility and Quality Evaluation of OER*. This chapter focuses on evaluating the quality of open educational resources. In the chapter, we discuss the dimensions and measures used to evaluate the quality of OER.

4. *Chapter 5: Accessibility and OER Metadata*. This chapter explains how OER metadata can be used to evaluate the accessibility of OER. We analyzed the existing metadata that describes learning materials and evaluate the description of accessibility. We developed an evaluation model to assess the quality and accessibility of OER metadata.

5. *Chapter 6: Semantic Representation of Accessibility in OCW*. The chapter introduces our

solution to address accessibility in OCW. We explain how to describe accessibility preferences of learners and the accessibility features of educational materials using ontologies to provide semantic representation of the accessibility in open education domain and allow reuse for other functions (i.e., semantic search).

6. *Chapter 7: AccessibleOCW ontology for OER Recommendations*. We explain in this chapter the OER recommender system we developed to use our ontology in recommending accessible educational materials.

7. *Chapter 8: Best Practices for Accessible OCW*. This chapter discussed two main ideas. We discuss how to include web accessibility in all phases of the OCW development life cycle.

8. *Chapter 9: Developing Accessible Open Education Resources - Slide Presentations*. We examine the components within slide presentations that impact accessibility and evaluate six approaches to encourage authors to resolve accessibility issues.

9. *Chapter 10: Conclusions and Future Work*. Finally, we summarize our contributions, evaluate, and analyze our solution. We state the limitation of our work and future work and recommendations.

CHAPTER 2

Background

This chapter provides an overview of the domains covered in this thesis. We focus on three key domains: open education, web accessibility, and semantic web technologies. We introduce the main terms and concepts used in the following chapters for each domain. Section 2.1 defines OCW platforms which provide free open-licensed educational resources. Section 2.2 defines web accessibility and the available guidelines to develop accessible web content. Section 2.3 defines the semantic web technologies used in the thesis to semantically represent the accessibility requirements of OCW platforms.

2.1 Open Education and OpenCourseWare

Education is an enterprise of sharing; if educators are not sharing their knowledge with students, there is no learning process [14]. The Internet has empowered the sharing of resources in a way easier and more cost-effective than traditional ways of publishing and printing. This opened the chance for sharing and accessing learning material by various institutes. It started with e-Learning and distance learning platforms which were first developed to support the teachers and learners of a specific institute in their learning process. These platforms were mainly designed to provide materials for communication and collaboration between students and their teachers. Afterwards, these platforms started to broaden their sharing of material by providing free access to some courses; MIT OpenCourseWare[1] was among the first who started sharing their educational material openly in 2001.

The term OER was first introduced by UNESCO at the 1st Global OER conference in 2002. The aim of this initiative was to encourage learning institutes to provide their educational material online with an open-access licence, and also to allow the reuse and editing of this material. The concept of openness has provided many learners with access to high-quality learning materials; this has primarily benefited students in developed countries, allowing them to acquire novel knowledge at the lowest possible cost; all they need is an internet connection. This also helped teachers to easily reuse the educational content of well-reputed institutes. However, we should not neglect here that due to this openness, there is now a huge amount of educational material not of high quality. Thus, there is a need to evaluate quality before reusing such content. This part will be discussed in Chapter 4.

Massively Open Online Course (MOOCs) are defined as online courses which are free of charge,

[1] https://ocw.mit.edu/about/milestones/

with no formal entry requirement, no participation limit, and no earned credits [15]. Successful MOOCs are mostly guided by educational institutions [16], like edX[2] which is governed by Harvard and MIT, and FutureLearn[3] which is governed by The Open University. The main idea of MOOCs is to provide learners with real interactive courses through videos, textbooks, and exercises. Learners can communicate with each other and assess their progress through peer-reviewed tests or auto-graded quizzes. There are many types of MOOCs; for example, *syncMOOC* where the courses have duration, starting and ending date and material are provided in batches (e.g., weekly bases), and *asynchMOOC* courses which have no deadlines [16]. For example, openHPI[4] provides sync and async courses. MOOCs adhere different policies and some of them provides *open* courses and *paid* courses. Open courses can be freely used by learners while learners who want to get a certificate can pay for courses in order to prove their participation, get graded assignments, and exam evaluation (e.g., Coursera[5] one of the most popular MOOCs).

OCW are defined as ”free and open digital publication of high-quality college and university-level educational materials; these materials are organized as courses, and often include course planning materials and evaluation tools as well as thematic content” [17].

MOOCs and OCW terms are sometimes used interchangeably, although they have different representation concepts for educational materials. The courses provided by MOOCs are owned by the authors, while in an OCW, materials can be reused, edited and remixed as they have a creative commons license. Most of the time, the courses in an MOOCs are designed as part of a certificate or a learning objective. While a course in an OCW can be seen as a standalone course that can be easily reused as part of a syllabus or re-edited to fit various learning objectives. Courses at MOOCs are not always free; they might provide partial free material, while in order to join a verified track for certification, fees should be paid to enrol in the exams (e.g. edX). MOOCs can be interactive, teachers and learners can communicate together, and assessments can be peer-reviewed and discussed [18], while OCW are not designed for communication between teachers and learners, though there might be communication and feedback tools, but they are designed to be edited and reused openly by teachers and learners. OCW can have an assessment component for self-assessment, but they are not built for certifications.

In this Thesis, we focus on OCW platform, which provides open access to the educational material, and we discuss the state-of-the-art, challenges and limitations of building an accessible OCW platform.

2.1.1 OpenCourseWare Components

OCW platforms are often composed of the following components, as illustrated in Figure 2.1,

1. *User Interface* represents the design elements of the OCW website including browsing and navigation within the OCW pages and functions. The user interface also represents the structure design of the resource components (e.g., tree structure)

2. *Educational Resources* are educational materials that are openly available on OER repositories. These resources can be presented in various formats (e.g., slides, audio, video) so that learners

[2] https://www.edx.org
[3] https://www.futurelearn.com/
[4] https://open.hpi.de/courses
[5] https://www.coursera.org

can select their preferred style of learning. Authors are also allowed to reuse and customize these resources.

3. *Authoring tool* are tools used to edit/upload materials to the OCW. These tools might also include validation.

4. *Communication tools* are controls that allow social media sharing and facilitate communication channels with learners and authors if available.

5. *Assessments* are evaluation mechanisms used to assess the learning process. Assessments use various mechanisms to conduct checks (e.g., multiple choice questions) to help learners assess if they reached the intended goal of the learning materials.

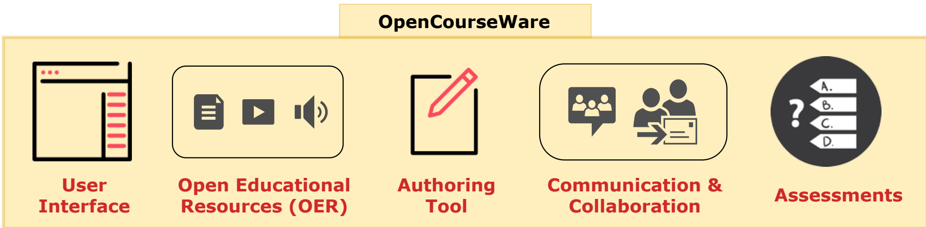


Figure 2.1: OCW components

2.1.2 Open Educational Resources

OER are openly licensed and freely available learning materials that can be used in learning contexts and beyond. These materials can be: assessments, assignments, books, case studies, courses, journals, primary sources, reference materials, simulations, tutorials, tests, and textbooks [19]. The openness of OER is defines by the permission of the five activities [20], also known as 5Rs of Openness [19],

1. *Reuse*: the right to reuse educational content in different ways.

2. *Retain*: the right to make, own, and control copies of the content.

3. *Revise*: the right to adapt, adjust, modify, or alter the content.

4. *Remix*: the right to combine the original or revised content with other material to create something new

5. *Redistribute*: the right to share copies of the original content, revisions, or remixes with others.

Often, OER is published on the web within an OCW platform, with resources organized into courses and complemented by tools for collaboration and evaluation. These materials are organized as courses and often include course planning materials and evaluation tools as well as thematic content [17].

There are hundreds of OCW platforms with thousands of open educational resources. Improving the availability and adoption of OER is an important step in the Education 2030 plan of UNESCO [21].

[6] https://nsufl.libguides.com/oer/5rs

Figure 2.2: The 5Rs of Using OER[6]

While OCW platforms and OER repositories already exist (for example, the MERLOT collection hosts over 90,000 openly available resources from over 4,000 providers [8]), their widespread adoption remains limited. For example, MIT OpenCourseWare is one of the well-known platforms that provide more than 2,500 resources (i.e., videos and supplementary resources) in various areas (e.g., Health and Medicine, Humanities, Mathematics) [22].

2.2 Web Accessibility

Web accessibility is simply defined as making the web usable by people with disabilities [23]. By accessibility, we refer to designing systems, products, and services in a way that they are adaptable for people with disabilities [1], to help them interact with their environment equally as other users. W3C defines Web Accessibility as "Web accessibility means that websites, tools, and technologies are designed and developed so that people with disabilities can use them" [24]. The aim is to allow people with disabilities to access, understand, navigate, interact, and contribute to the Web.

In the literature, the topic of web accessibility has also been addressed using other terms, such as Design-for-All, Universal Design, Access-for-All, etc. The majority of work done in these contexts has the goal of defining and describing issues, guidelines, standards, and methodologies for developing accessible systems, including hardware and software devices, mobile, and web applications. In general, disabilities can be grouped into four categories [25]:

1. *Visual impairments* (i.e., total blindness, low vision, and color blindness).
2. *Hearing impairments* (i.e., deafness and hard-of-hearing).
3. *Motor impairments* (i.e., inability to use a pointing device (e.g., a mouse) due to limited movement and control of arms, hands and fingers).
4. Cognitive impairments (i.e., language and learning disabilities, distractibility, inability to remember or focus on large amounts of information (e.g., dyslexia, dementia, etc.).

Each of these impairments has different variations and severity levels that require different types of adaptations for web accessibility. Even two users with the same disability might have different needs and preferences; for example, one blind user might want to use a screen reader while another blind user might prefer a braille display, or both might want to use the same device but with different configurations (e.g., different text reading speeds). These accessibility requirements are at best taken into account from the beginning of a new web project (e.g., by adding descriptive information about each image to support the user with screen readers). A number of standards and guidelines are available to support developers in designing accessible web applications. In this section, we review some of the available standards, guidelines, checklists, and techniques addressing the accessibility of web and e-learning contexts. Then, we present a number of tools that use the concepts of the semantic web (i.e., ontologies) to build accessible web pages and finally, we review some of the ontologies developed for addressing different purposes of accessibility.

2.2.1 Usability, Web Accessibility and Assistive Technologies

Usability refers to designing products that are easy to use, efficient, and satisfying to the user experience. Usability addresses general design aspects that affect any user. However, usability practices and research often do not sufficiently address the needs of people with disabilities [26]. Thus, web accessibility came to complement the usability requirements of these users.

Web accessibility is a facet of usability that aims to remove accessibility barriers for users with disabilities, by focusing on design and technical requirements that guide the development of accessible web applications. A number of guidelines and standards are used to help developers to create accessible user interfaces and functions. The most well-known technical guidelines are the web accessibility guidelines which are provided by W3C, starting with WCAG 1.0 until they reached WCAG 2.1 [27]. In general, WCAG is composed of a list of guidelines organized under 4 principles: perceivable, operable, understandable, and robust. For each guideline, there are success criteria evaluated by three levels: A, AA, and AAA. Each newer version of the WCAG technical standards and guidelines conforms to the older guidelines and adds more guidelines/success criteria that address newer design and functional challenges to implement accessibility. W3C has also published other guidelines: Authoring Tool Accessibility Guidelines (ATAG), and User Agent Accessibility Guidelines (UAAG). ATAG guidelines are created to help authors to create accessible web content. UAAG guidelines address the accessibility of user agents (e.g., browsers, browser extensions, media players, readers); this should handle accessibility on a higher level, which can directly communicate with the agent user interface (e.g., text customization) and the assistive technologies.

More accessibility act, standards, guidelines, and best practices will be discussed in Chapter 3 with more focus on accessibility guidelines which are useful for digital education (i.e., OCW, OER). The aim of these guidelines is to provide best practices for developers to create accessible content and provide a framework for evaluating accessibility in these platforms. A number of tools are available to evaluate the accessibility of website with respect to WCAG 2.0 like, Achecker[7], Taw[8]. Usability, web standards, and assistive technologies should all be considered when creating an accessible platform, as shown in Figure 2.3.

2.3 Semantic Web Technologies

The public release of the World Wide Web (WWW) in 1993 and the availability of browsers to search and view documents on the web have opened a new window for users to access data. Web 1.0 was the first form of using the web, which we call the web of documents. At this stage, the web was a read-only where people could use browsers to search and read documents; the documents were

[7] https://achecker.ca/checker/index.php
[8] https://www.tawdis.net/

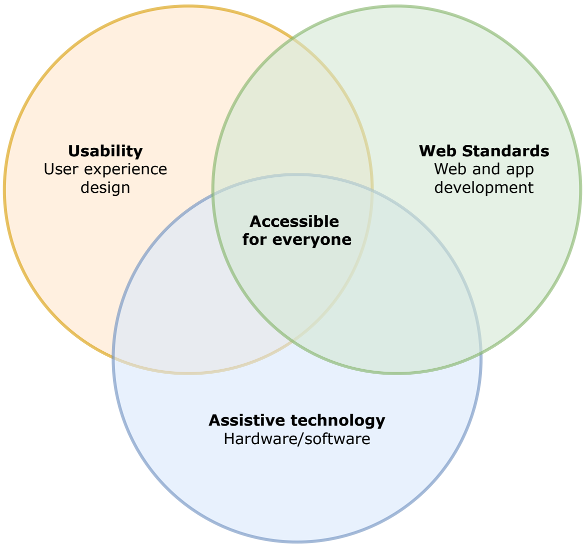


Figure 2.3: A Venn diagram showing how usability, web standards, and assistive technology make accessible experience[9]

connected through hyperlinking. With Web 2.0, the era of application started with a tedious amount of applications the users can interact with. Web 2.0 increased the emphasis on user-generated content and interoperability. However, applications are not related; a user might need to update the same information on various applications because there is no sharing of data. The vast amount of data sharing over the web elevated the importance of data and highlighted the usefulness of connecting the data and analyzing it. Tim Berners Lee stated that "The web of *human-readable* document is being merged with a web of *machine-understandable* data. The potential of the mixture of humans and machines working together and communicating through the web could be immense" [28].

Web 3.0, the third generation of the web, is also called the Web of Data. The goal of Web 3.0 is to add semantics to this data and make it machine-readable. Semantic abstracts data away from documents and application layer in order to represent data as facts and relationships connect facts together from different application Silos [29]. The semantic Web is defined as "an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation." [30]. Semantic Web is concerned with the meaning and not the structure of data.

The Semantic Web Stack, illustrated in Figure 2.4, shows the architecture of the Semantic web. This Stack was developed by Tim Berners-Lee with the aim of integrating technologies and languages used to create a semantic web. The diagram is composed of three layers [31]:

1. **Hypertext Web technologies**. The bottom layer provides the technologies that represent and identify semantic web resources. The layer is composed of: *Uniform Resource Identifier (URI)*, which uniquely defines the resource; *Unicode*, which defines the character schema that can be used to define many languages; and finally, semantic technologies use *Extensible*

[9] https://www.bbc.co.uk/gel/guidelines/how-to-design-for-accessibility
[10] https://en.wikipedia.org/wiki/Semantic_Web_Stack

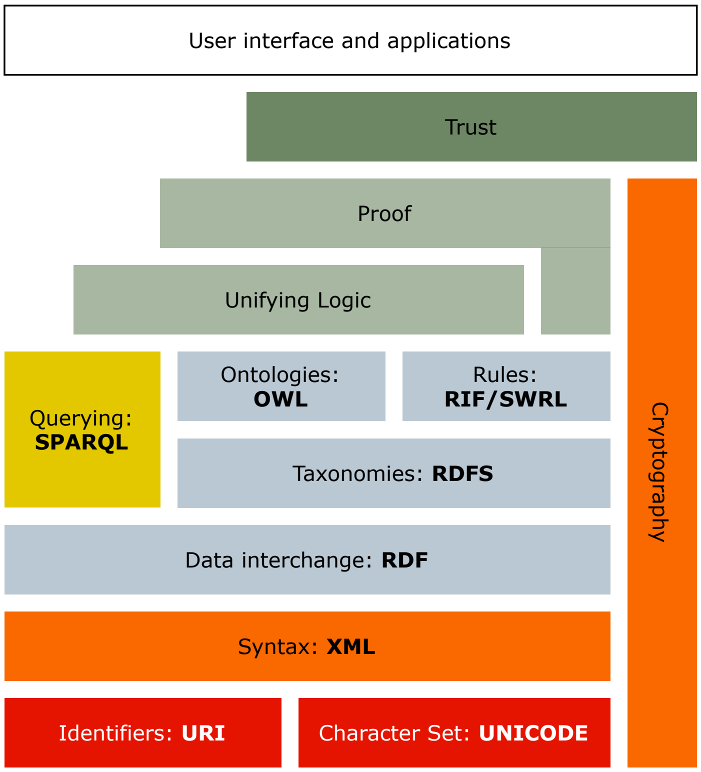


Figure 2.4: Semantic Web Stack[10]

Markup Language (XML) and XML Namespaces, the markup language that is used to represent semi-structured data, to add semantics to the data and connect namespaces from different sources.

2. **Standardized Semantic Web technologies**. The middle layer describes the standardized W3C technologies used to develop semantic web applications. This layer is composed of the languages that are used to represent the semantics of the data (*Resource Description Framework (RDF), Resource Description Framework Schema (RDFS), Web Ontology Language (OWL)*), the languages that are used to represent rules (*Rule Interchange Format (RIF)/Semantic Web Rule Language (SWRL)*), and languages that are used to query and retrieve data *Simple Protocol and RDF Query Language (SPARQL)*).

3. **Unrealized Semantic Web technologies**. The upper layer represents the technologies that support the realization of the semantic web; however, these technologies are not yet standardized. These technologies are used to verify the source and logic of the semantic web data (i.e., trusted sources) *Logic, Cryptography, Trust, Proof*. Finally, the *User Interface* allows the user to interact with the semantic web application.

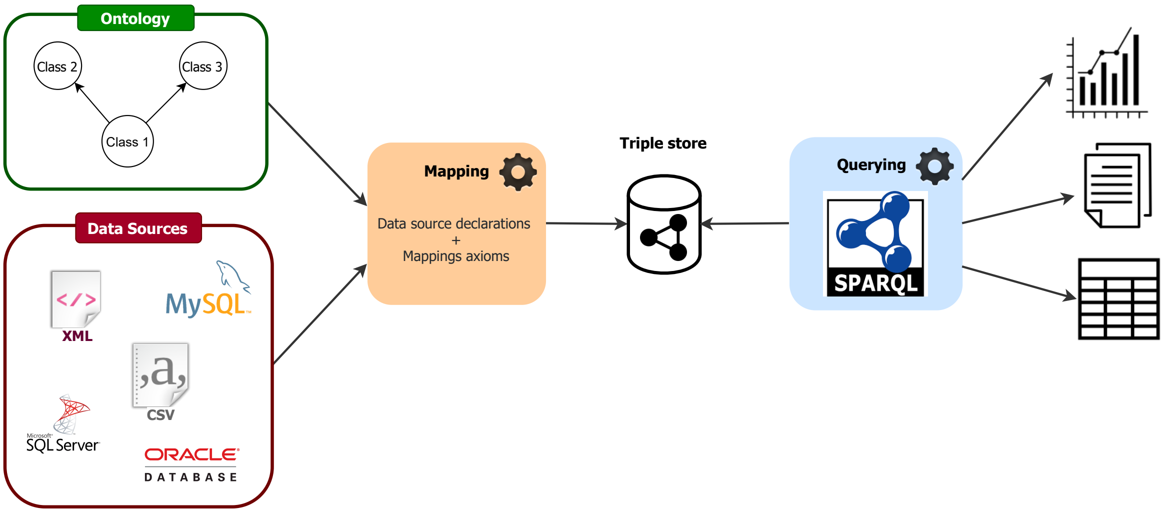


Figure 2.5: Knowledge Graph development process

The following semantic technologies are used in this thesis:

- **Resource Description Framework** is a framework used for expressing information about resources (e.g., people, places, events) in the form of a directed, labelled graph [32]. RDF represent information as a statement of triple (subject-predicate-object): subject (or resource), a predicate (or property) and a value (or object). Resources are uniquely identified using URI. RDF is serialized in different formats (e.g., RDF/XML[11], Turtle[12]).

- **Ontology** is defined as a "formal specification of a shared conceptualization" [33]. Ontologies are used to represent a domain of interest in a formal language to express the entities and relationships of this domain. Web Ontology Language (OWL) is the W3C standard ontology language that is used to formally define an ontology [34].

- **SPARQL Protocol and RDF Query Language** is the W3C standard language to query RDF [35]. SPARQL employs a Client-Server architecture to query an RDF, with a client user interface for input queries and a server SPARQL endpoint for processing the RDF and returning results (e.g., Apache Jena Fuseki[36]). The communication takes place over HTTP with a SPARQL protocol layer that defines the SPARQL query parameters.

- **Knowledge Graph** is a knowledge base that models data using graph representation for the purpose of data integration across domains. Using knowledge graphs aids in linking data from various domains, generating new knowledge, and inspecting recurring patterns that can be used in simulation and prediction models (i.e., using AI and deep learning algorithms) [37]. The knowledge graph is created by mapping datasets to the ontology concepts and relationship, as illustrated in Figure 2.5. The details of how we generated our knowledge graph will be described in Chapter 7.

[11] https://www.w3.org/TR/rdf-syntax-grammar/
[12] https://www.w3.org/TR/turtle/

CHAPTER 3

Related Work

This chapter summarizes the current state of research in the domains covered by this thesis. The existing acts, guidelines, and standards for web accessibility and digital education (i.e., e-learning, open education) are represented in Section 3.1. The related work of formalizing web accessibility in multiple domains is discussed and analyzed in Section 3.2, with a focus on open education. We look at the vocabularies and ontologies that specify how users, user interfaces, and educational resources should be made more accessible. The existing OCW systems that included web accessibility in their development process are shown in Section 3.3. Finally, Section 3.4 lists the gap found in the research, and Section 3.5 explains the findings and the thesis's directions.

Related publication

- **Mirette Elias**, Steffen Lohmann, and Sören Auer. *Fostering accessibility of OpenCourseWare with semantic technologies – a literature review.* In 7th International Conference on Knowledge Engineering and the Semantic Web (KESW) 2016 Proceedings, 241-256, Springer.

3.1 Open Education and Web Accessibility Acts, Guidelines, Standards, and Best Practices

Several standards and guidelines have been developed to address various accessibility requirements for software, hardware, and the web, among other systems with human interfaces. Web accessibility has got much significance recently due to the ubiquitous internet greatly facilitating information access. As a result, various policies and standards have been developed to ensure that the internet is accessible to a broader range of users, including persons with disabilities and the elderly. In our literature review, we focused on those standards and guidelines related to web accessibility and e-learning systems as per our concern with web accessibility in the OCW platform. Table 3.1 provides a collection of relevant standards, guidelines, checklists, and techniques we studied during our review. The list is organized into three categories: 1) standards and guidelines for making web applications more accessible, 2) standards for depicting disabilities, and 3) standards addressing accessibility needs of open education.

Table 3.1: Open education and web accessibility standards, guidelines, and checklist

Name	Type	Creator	Released (last updated)	Focus
Barrier Walkthrough	Checklist	Giorgio Brajnik	2009	Disabilities, incl. set of barriers and tips to address them
BBC Accessibility Standards and Guidelines	Organization standards and guidelines	BBC	2008 (2013)	Web and mobile accessibility
IBM Accessibility	Checklists and techniques	IBM	2008 (2011)	Web, software and hardware accessibility (based on Section 508 of the US Rehabilitation Act, W3C recommendations and IBM Research)
ICF	Standard	WHO	2001	Body functions and disabilities
IMS Access for All	Guidelines and metadata specifications	IMS Global Learning Consortium	2004 (2012)	Adaptation/personalization of learning resources and applications
ISO/IEC 24751	Standard	ISO	2008	E-learning, education and training accessibility
ISO/IEC TR 29138	Standard and guidelines	ISO	2009	User needs and their mappings to available standards
Section 508*	Standard and guidelines with checklist	US Government	2000	Electronic and information technology
WAI-ARIA	Technical specification	W3C	2014	Web accessibility guidelines
WCAG 1.0 WCAG 2.0 WCAG 2.1	Technical standard and guideline with checklist	W3C	1999 2008 2018	Web accessibility guidelines

*There are similar accessibility initiatives and standards in other countries (e.g., British Standard 8878 (BS 8878) [38]).

3.1.1 Web Accessibility Standards and Guidelines

Section 508 of the U.S. Rehabilitation Act [39] was the first accessibility initiative established in the context of the U.S. Standards for Electronic and Information Technology. Section 508 is a general-purpose standard developed by the U.S. Access Board for application to electronic and information technology resources developed and used by US federal agencies. A checklist of Section 508 guidelines is provided by the Center for Persons with Disabilities at WebAim [40]. Recently, it has been proposed to update the accessibility requirements of Section 508 and align them with WCAG 2.0.

W3C was among the first who developed web accessibility standards and guidelines with their WCAG. **WCAG 1.0** is a technical standard composed of a list of general guidelines and checkpoints for designing accessible web content together with technical recommendations and examples using the HyperText Markup Language (HTML), Cascading Style Sheets (CSS), Synchronized Multimedia Integration Language (SMIL), and Mathematical Markup Language (MathML) [41]. With **WCAG 2.0**, the W3C released a more comprehensive structured version of WCAG 1.0 [42], which is an approved ISO standard (ISO/IEC 40500:2012). It organized web accessibility into four design principles: perceivable, operable, understandable, and robust. Each principle is composed of a list of guidelines. Every guideline has testable success criteria that meet one of three conformance levels (A, AA, and AAA). At the time of writing this thesis, **WCAG 2.1** is the latest guidelines release which includes all the success criteria from 2.0. It adds 17 additional success criteria that address: mobile accessibility, people with low vision, and people with cognitive and learning disabilities [27]. W3C published another standard and set of guidelines called Web Accessibility Initiative – Accessible Rich Internet

Applications (WAI-ARIA) [43]. **WAI-ARIA** provides a technical specification for presenting dynamic content, and advanced user interface controls developed with client-side technologies, such as HTML, JavaScript, Ajax, and related technologies, to make web content more accessible to people with disabilities.

Some organizations came up with their own accessibility standards, such as IBM and BBC. **IBM** Accessibility [44] is a checklist with a number of guiding techniques for products, including web, software, hardware, etc. The checklist of IBM incorporates guidelines from Section 508 of the U.S. Rehabilitation Act, recommendations of the W3C, as well as experiences and findings from IBM Research. The **BBC** also created accessibility standards and guidelines for web and mobile applications [45] on behalf of their experiences in making digital products accessible to the broadest possible audience.

Other standards and guidelines describe typical needs for different types of disabilities. For example, a person with low vision may have problems with color, moving contents, long lines of text, etc. **ISO/IEC TR 29138-1:2009** provides a comprehensive summary of user needs to define accessibility barriers faced by people with disabilities when using information technology [46]. It defines relationships of these user needs with accessibility factors, particularly for the developers of standards and guidelines, such as the ISO/IEC Guide 71: "Guidelines to address the needs of older persons and people with disabilities".

The **Barrier Walkthrough** guideline is developed based on Section 508 and W3C [47]. The disabilities of users are categorized into groups, and for each group, a list of barriers is created. For example, using a cascading menu is considered a barrier for people with motor disabilities, as it can be difficult for them to navigate through multi-level menus. These barriers are then addressed with recommendations and guidelines from the available standards. A checklist is given for evaluating web accessibility with respect to each type of disability considered.

3.1.2 Classification and Description of Disabilities

Classification and Description of Disabilities International Classification of Functioning, Disability and Health (ICF) is used for defining and describing disabilities. It contains body functions and disabilities from a medical perspective, as illustrated in Figure 3.1. This classification can be used to describe different types of disabilities and to specify user capabilities and needs. The International Classification of Functioning, Disability and Health (ICF) Browser provides a detailed classification of body functions and disabilities with a qualifier that describes their severity, using a special coding system [48]. For example, "b2-sensory functions and pain" includes "b210-seeing functions" and "b230-hearing functions", where each category contains a more detailed list of the functions. ICF classification is widely used in literature to characterize and describe different types of disabilities; its ontology provides good means of reusability and adaptability for different usage purposes [49]. Much of the current literature uses the ICF classification to describe the characteristics of users with disabilities.

3.1.3 Web accessibility and Open Education

The **ISO/IEC 24751-1:2008** standard addresses accessibility in e-learning, education and training [51]. It provides a framework for describing and matching learner needs and preferences to digital learning interfaces and resources. The basic idea is that users specify their preferences, and learning objects

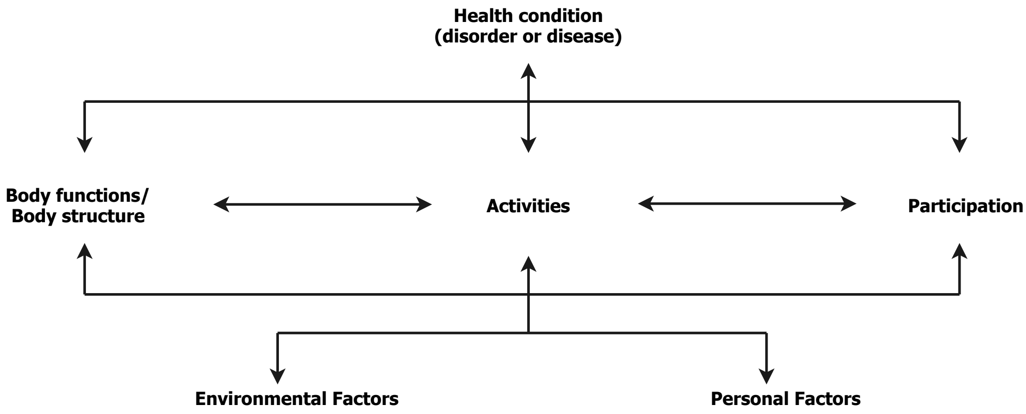


Figure 3.1: The International Classification of Functioning, Disability, and Health (ICF) [50]

display based on their needs. This requires the inclusion of different resources in the learning objects that cater to varied user types (i.e., subtitles can be used with videos to address hearing problems).

IMS Access for All (IMS AfA) specifications, developed by the IMS Global Learning Consortium[1], are guidelines and metadata for developing accessible learning applications and resources that take into account user's preferences and needs based on the ISO/IEC 24751-1:2008 standard [52]. It links accessibility metadata and learning objects; for example, it defines the sensory access mode of the education resource (e.g., auditory, tactile, or textual). The IMS AfA is composed of: IMS Global Access for All Personal Needs and Preferences (PNP) and IMS Global Access For All Digital Resource (DRD). AfA PNP specification is designed to suit the need of learners with disabilities with the goal of providing a machine-readable way (i.e., XML) to express learner needs and preferences for digitally based education and learning [53]. AfA DRD describes features of digital resources that can be modified to improve accessibility (e.g., resource format) [54].

3.2 Web accessibility and OpenCourseWare Ontologies

Several ontologies were developed to represent accessibility in different domains and perspectives. According to our literature review, some ontologies focused on describing user disabilities, accessibility guidelines, mappings users to assistive devices, and web content reformatting. Table 3.2 lists the accessibility ontologies we found, along with a brief description of their type of representation (e.g., OWL, metadata), focus (i.e., user characteristics, assistive devices, guidelines, etc.), reference of implementation (Ref.) if available, and the number of classes when the ontology file is available for computation. We included research papers that provide conceptual or meta-modelling representation; although they are not ontologies themselves, but they can provide classifications that can aid in the development of new ontologies or merging concepts with existing ones.

[1] https://www.imsglobal.org/

3.2.1 Anatomical Description of Disabilities

ICF and the Foundational Model of Anatomy (FMA) are two ontologies used for defining and describing disabilities. They contain body functions and disabilities from a medical perspective, as illustrated in Figure 3.1. These ontologies can be used to describe different types of disabilities and to specify user capabilities and needs. The **ICF ontology** [55], which is available in BioPortal [49], implements the corresponding standard of the World Health Organization (cf. Table 3.1) and provides a detailed classification of body functions and disabilities with a qualifier that describes their severity, using a special coding system [48].

The **Foundational Model of Anatomy (FMA)** is a reference ontology for the domain of anatomy founded by the University of Washington [56]. It represents the anatomical entities, spatial structure, and relations that characterize the physical organization of the body at all notable levels of granularity [56]. FMA is a large computer-based knowledge source, containing more than 100,000 classes, created for biomedical informatics. It can be used to represent disabilities, but it is rather complex and difficult to apply and browse in those contexts.

3.2.2 Web Accessibility Ontologies

A number of EU projects worked on accessibility and created ontologies for different purposes. We reviewed three of these ontologies: ASK-IT, ACCESSIBLE, and AEGIS. **ASK-IT** project focused on trip organization needs for individuals with special needs, such as accessibility of transportation, paths, and remote access to household appliances. The ontology expresses the information demands of users with mobility impairments in a standard way, making search and retrieval easier [57]. The ASK-IT ontology consists of user groups, supported services, transportation, and tourism-related content. It mainly focused on mobility-impaired users, but it also included vocabularies for cognitive and sensory impairments. **ACCESSIBLE**[2] project worked on developing an overall European Assessment Simulation Environment for aiding designers and developers to create accessible software applications and evaluate them [58]. The project had two main results: a number of accessibility assessment tools (i.e., for mobile apps, web pages, etc.) and an ontology describing different domains of accessibility and interaction between them. The ACCESSIBLE ontology includes ICF-based characteristics for users with disability, definitions of assistive devices and software applications, WAI-ARIA and WCAG 2.0 online accessibility standards and guidelines, and evaluation rules for mapping user requirements and limitations [59]. The description of the user characteristics makes use of the ICF standard, by integrating the information required for illustrating the disabilities while neglecting medical and other biological details. The ACCESSIBLE ontology can be considered as a general-purpose ontology for the accessibility domain, as well as, a useful reference to adapt and extend upon. The **AEGIS**[3] project develops the Open Accessibility Framework (OAF), which outlines the steps required to consider a computing platform accessible [60]. The AEGIS ontology adopted parts of the ACCESSIBLE ontology and extended it with the Persona concept, which is intended to relate accessibility concepts to accessibility scenarios.

INREDIS (INterfaces for RElations between Environment and people with DISabilities)[4] is a research and development project supported by the Spanish government in the context of the INGENIO

[2] http://www.accessible-eu.org
[3] http://www.aegis-project.eu
[4] http://www.inredis.es

2010 initiative. They developed an interoperable architecture that enables people with disabilities to interact with their environment via multiple devices (smartphones, tablets, etc.) in order to communicate with and control other devices (television, door locks, etc.). Three ontologies were developed and evaluated within the project: i) The INREDIS ontology provides formal descriptions of disabilities and to check if a user can interact with a specific device. If a problem occurs, assistive software is meant to provide alternative interaction means with respect to the user needs [61]. ii) The Egonto ontology, an updated version of INREDIS ontology, which was developed for the EGOKI system. EGOKI is a model-based generator for adaptive user interfaces developed in the INREDIS project. Egonto ontology was used to support the automatic generation of user interfaces for ubiquitous services accessible by people with disabilities [62]. iii) The Affinto ontology was designed as an extension for the EGOKI system, to provide information about the sensory and perceptual capabilities of users in order to support the development of multimodal affective resources [63]. In addition, the Affinto ontology takes into account emotional and modality issues to provide knowledge about affective interactions, including the environment as well as social, task, and spatial-temporal perspectives [64].

SUS-IT (Sustaining IT use by older people to promote autonomy and independence)[5] project is funded by the New Dynamics of Ageing (NDA) initiative in the UK. The ontology assists a capability reasoning system in mapping users to appropriate assistive technologies [65]. It defines vocabularies for describing capabilities, their properties, and structural links between these capabilities. The user characteristics have been derived from a subset of the ICF standards.

Some ontologies have been developed for annotating and adapting user interface contents and components according to the preferences and accessibility needs of specific users. The *Impairment User Interface* ontology [66] describes both user impairments and user interface components. The taxonomy of user impairments was created with the help of a domain expert [67]. Rules were added to connect impairments with corresponding user interface components and to generate a list of suggestions. These suggestions were used afterwards to adapt the CSS styles of websites. Valencia et al. developed an adaptation system using a set of techniques based on the WAI-ARIA recommendations [68]. Their ontology models the user characteristics, adaptation techniques, annotation model, and the relations between them. The adaptation techniques are categorized into content, presentation, and navigation. Reasoning rules are used to infer the techniques that match the user's needs. Obrenovic et al. created formalized vocabularies to describe human functionalities, and anatomical structures needed for developing multimodal user interfaces [69]. The vocabularies are a combination of the ICF standards [48], FMA ontology [56], and additional concepts of interaction defined by the authors.

AccessOnto provides a framework for integrating accessibility guidelines into requirement specification documents [70]. The ontology is modelled in UML to describe existing guidelines (e.g., accessibility guidelines of WAI, IBM, Microsoft, Apple, and other companies and institutions), user characteristics, and objects in the interaction environment [71]. In another project, a classification supporting the modelling of human-computer interaction based on ICF was proposed to facilitate the matching of user capabilities (abilities/disabilities) to interaction capabilities of existing devices [72]. Strictly speaking, it is not an ontology but a categorization of the most frequently occurring disabilities and related assistive technologies.

Other ontologies focus specifically on the personalization of web pages for visually-impaired users. Xiong et al. presented an ontology-based approach for developing web user interfaces based on a structured representation of accessibility guidelines [73]. The **WAFA** ontology is used as a

[5] http://sus-it.lboro.ac.uk

controlled vocabulary to drive page transformations. It describes the structure, structural abstraction, meta-knowledge, spatial knowledge, and functionality of a web page [74]. WAFA is built upon the Travel Ontology of the Dante tool and contains structural and navigational knowledge about web pages [75]. **OntoSAW** represents the structural elements, attributes, and relationships between web page components, taking into account accessibility properties of the WAI guidelines [76]. It has been developed for the SAW tool, which uses ontology to edit web page code in order to make it more accessible. SADIe [77] is a transcoding tool which generates semantic annotations for web documents. The contents of the web documents were structured in an ontology used in the transformation process.

3.2.3 Web Accessibility and Open Education Ontologies

ADOLENA (Abilities and Disabilities OntoLogy for ENhancing Accessibility) ontology was developed for the South African National Accessibility Portal (NAP) [78]. It encompasses abilities, disabilities, devices, and functionalities. ADOLENA is an experimental ontology that has been created as a proof-of-concept for enhancing search capabilities by Ontology-Based Data Access (OBDA). **ADOOLES** (Ability and Disability Ontology for Online LEarning and Services) ontology was developed on the basis of ADOLENA to annotate learning resources. It represents knowledge in the domains of e-learning and disabilities [79].

The **Accessibility Metadata Project**[6] has been initiated to make educational resources more accessible by enriching their metadata. The developed metadata categories have partly been added to Schema.org [80]. The project is based on the Access for All (AfA) specification [52] and conforms to ISO/IEC 24751-1:2008: “Information technology - Individualized adaptability and accessibility in e-learning, education and training” [51].

3.3 Accessible OpenCourseWare Initiatives

Accessibility and Design for All refer to the creation of products, environments, programs and services that can be used by all people, to the greatest extent possible, without the need for adaptation or specialized design [91]. In general, accessibility requirements are defined by the web accessibility guidelines, such as W3C Web Content Accessibility Guidelines (WCAG) 2.1 [42] or the W3C Cognitive and Learning Disabilities Accessibility Task Force (Cognitive A11Y TF) [92] and Easy-to-Read [93] guidelines, to guide the development of accessible systems. Some guidelines have been specifically designed for the development of accessible e-learning systems, for example, IMS AfA [52]. Inclusive OCW, therefore, should address these accessibility requirements. For example, users with visual impairments receiving information through audio require a reduced presentation interface that allows them to reach the main functionalities in a less confusing manner and avoid information overload. These users use the keyboard as input, and to have a flexible interaction, they require headings and descriptive texts [23].

Improving the availability and adoption of OER is marked as an important step in the Education 2030 plan of UNESCO [21]. Despite the large amount of OCW platforms and OER repositories, accessibility is still not widely addressed by OER [9]. There is a need to help learners define their preferences, and retrieve OER matching their needs (e.g., blind users might prefer textual over video resources). According to a systematic review, [10] focusing on recommender systems in e-learning,

[6] http://www.a11ymetadata.org/resources/

Table 3.2: List of accessibility ontologies

Reference Name	Year	Representation	Focus				Ref.	No. of Classes
			User Model	ATs	Guidelines	Others		
Accessibility Metadata [81]	2012	Metadata tags	Sensory	-	WAI-ARIA WCAG	-	[80]	-
Accessibility Vocabularies in Multimodal UI [69]	2007	OWL	ICF, FMA, interaction effects	-	-	-	[82]	114
ACCESSIBLE [58]	2009	OWL	Based on ICF	Assistive devices	WAI-ARIA WCAG2	-	[59]	166
AccessOnto [70]	2008	UML	User profile	Interface objects	WAI, IBM, etc.	-	[71]	-
ADOLENA [78]	2008	OWL	Based on ICF	Device functionality	-	-	[83]	141
ADOOLES [79]	2012	OWL	Based on ADOLENA	Assistive mechanism	-	-	n/a	-
AEGIS [57]	2010	OWL	ACCESSIBLE ontology	Assistive devices	WAI-ARIA WCAG2	Personas	[84]	15
Affinto [63]	2010	OWL	Physical Cognitive Emotional	Software devices	-	Context model	[85]	86
ASK-IT [57]	2008	OWL	Mobility-impaired	Assistive devices	-	Agents and services	[86]	1,400
Classification for HCI [72]	2006	Structure	Extends ICF	Devices	-	-	-	-
Egonto [62]	2015	OWL	Cognitive Physical Sensory Affective	Hardware Software	-	Adaptation model	[87]	54
FMA [56]	2012	OWL	Body anatomy	-	-	-	[56]	145
ICF [48]	2012	OWL	Built for ICF standards	-	-	-	[49]	1,595
Impairment User Interface [66]	2007	OWL	Taxonomy [88]	-	-	Interface adaptation	[67]	114
INREDIS [61]	2010	OWL	Communication and modality	Software devices	-	Context model	n/a	-
Layered capability [65]	2012	OWL	ICF sample	-	-	-	n/a	-
OntoSAW [76]	2007	-	Visually-impaired	-	WAI	Web page components	n/a	-
SADIe [77]	2006	OWL	Visually-impaired	-	-	Web page components	n/a	-
WAFA [74]	2007	OWL	Visually-impaired	-	-	Web page components	[89]	152
WAI-ARIA Annotations and Ontologies [68]	2013	Conceptual model	Cognitive Physical Sensory	-	WAI-ARIA	Annotation, adaptation models	-	-

*n/a: not available, ATs: Assistive Technologies from 108 publications that were studied, only one has considered accessibility in its approach. Despite the high development potential in building OER recommender systems for addressing the growing need for education, based on the literature, we are confronted with a lack of studies in this area [11, 94].

According to the systematic review [9], which focused on the research that evaluate the accessibility of the OCW interface, features and functions (e.g. search), content representation and authoring tool. They reviewed the evaluation approach conducted manually, automatically or by the simulator to evaluate the accessibility of existing OCW (e.g. MARLOT, OCW UPM, OER Commons). According to their review, none of the existing OCW satisfies all the accessibility principles: perceivable, operable, understandable and robust. The results highlighted that accessibility is still in its infancy within OER and that researchers should focus more on considering the four accessibility principles when providing OER. Additionally, while several researchers have focused on several issues related to accessibility within OER, the limited focus has been given to assistive technologies using OER.

Navarrete and Luján-Mora used IMS AfA specifications to describe the learner profile and OER to allow personalization and accessibility of OER [95]. They developed the OER4ALL website, which customizes the user interface and provides alternative OER representations to address different disability profiles. They used self-identification of disability and provided sample OER to evaluate their approach. They evaluate the accessibility features (e.g., disability profile, adaptive interface, accessibility option for search, delivering accessible resources as per the disability profile) of OCW (i.e., MERLOT, OER Commons, MIT, OLI, ARIADNE, OpenStax, OERfAll). Iniesto and Covadonga proposed a recommender system (YourMOOC4all), which collects feedback from learners regarding existing MOOCs to help improving accessibility of MOOCs [96].

3.4 Gap in Research

Overall, the reviewed standards and guidelines have several similarities in how they address accessibility issues. However, each standard addresses accessibility issues at a different level of granularity and from a different perspective. For example, Section 508 states on a general level that alternative descriptions for pictures are required, while WCAG is more precise by prescribing the use of the HTML “alt” attribute for images in websites. Further issues, checkpoints, tips, and technical aids are given in the other standards (e.g., IBM Web Accessibility Checklist, Section 508 standards, and WCAG 2.0 [97]). The W3C standards, i.e., the WCAG 2.0 and WAI-ARIA standards and guidelines for web accessibility, are most widely used and accepted. In particular, several governments, such as the Canadian and Australian ones, require conformance of all government-related websites to the WCAG 2.0 guidelines [98].

According to our review of the literature, there is still work to be done in the area of open education accessibility. There is a lack of authoring tools supporting the creation of accessible resources, a lack of study of the effectiveness of OER with respect to accessibility, and a lack of assessment and evaluation methods of accessibility. From our review and findings, we derived three main aspects that should be addressed to develop an accessible OCW platform. The aspects are described from a learner-centric perspective in the following:

3.4.1 Accessibility of the OCW Platform

From the definition of OCW, we identified the main functional components as: user interface, educational resources, authoring tool, communication and collaboration tools, and assessment tools. Each component should address the accessibility needs of its main stakeholders, given the intended functional purpose of the component. For example, the accessibility of the platform's user interface is addressed by the design decisions, HTML and CSS, and language used for implementation. All of these should be following accessibility guidelines in order to be accessible by assistive technologies.

Accessibility is not a feature that can simply be implemented into the platform; it is a requirement that should be considered when designing and implementing each module and interface of the platform. Therefore, it is essential to include accessibility in each phase of the platform's development life cycle. Following only the accessibility guidelines (e.g. WCAG 2.1), in our experience developing the SlideWiki platform, is not enough to establish an accessible OCW platform. The inclusion of users with accessibility needs, on the other hand, emphasizes the platform's accessibility criteria and ease of use. As a result, it is necessary to include the users in the platform's requirement analysis, development, and testing in order to assess the platform's accessibility. This will be explained in more detail in Chapter 8.

3.4.2 Accessibility Representation of Learners Preferences

During our investigation, we noticed that the majority of web accessibility standards and guidelines are oriented toward sensory-impaired users (i.e., visual and hearing impairments). The capabilities and needs of these users are defined and addressed by various web accessibility guidelines and assistive technologies. The needs of mobility impairments are also addressed with some guidelines, in particular by describing the requirements of corresponding assistive technologies (e.g., creating web page content so that it can be accessed with the keyboard and assistive devices instead of requiring the use of a mouse).

Except for a few research studies and recommendations [99], we found little about standards and guidelines for cognitive impairments. Although some existing recommendations can be regarded as appropriate for representing specific forms of cognitive impairments, the needs of corresponding users have yet to be adequately addressed. The task force "Cognitive A11Y TF" has been initiated by the W3C to focus on the web accessibility needs of cognitive-impaired users and people with learning disabilities [92]. Since our research focuses on OCW, cognitive impairments form an important category, as they encompass people with learning disabilities. There are multiple types and variations of learning disabilities; describing and structuring them in a formal ontology would make the knowledge available and reusable in OCW contexts.

3.4.3 Accessibility of the Open Educational Resources

OER is the fundamental component of an OCW platform. Accessibility of OER should be considered during content representation, creation, validation, and management.

Content representation. ISO 24751 specifies that a single educational content be available in several formats (e.g., slides, audio, video) so that learners can choose their preferred learning style [51]. This notion would be useful if different forms of educational resources could be generated for a learning object that could target specific types of disabled learners (e.g., a video would not be helpful for blind people). It is also possible to develop specialized educational resources for people with disabilities (e.g., a plain document with notes for learners with learning disabilities). This would necessitate developing course materials in accordance with a set of accepted guidelines, which would include learning difficulties.

Content creation. Authoring tools are used to create and edit the resource content. The accessibility of the authoring tool is a prerequisite for creating accessible material. Although OCW platforms can reuse a variety of HTML editor plugins, not all of them comply with the accessibility guidelines. Even if they fulfil the WCAG guidelines, there are still improvements that need to be made to ensure that accessible content is generated. Validation of alternative text for images, for example, may not be included in the HTML editor. Another example is determining the level of text difficulty.

Content validation. The validation of educational content from the targeted impairments group should be stated initially, together with the user requirements. In the second step, a set of criteria with a checklist should be prepared for the resource materials to follow. Finally, resources are validated against the set of rules and accessibility flaws should be highlighted.

Content annotation and management. Semantically annotating educational resources facilitates the retrieval of educational resources based on the preferences of learners. When numerous representations of the same learning resource exist, annotation and management of these resources are critical. This, for example, allows for the addition of a recommendation system that suggests appropriate materials to different groups of learners with accessibility needs.

3.5 Findings and Research Directions

After analyzing the related work, we can summarize the main elements required for a comprehensive ontology supporting OCW accessibility as follows: disability types, assistive technologies, standards and guidelines, and learning objects. Disability types should be considered with details about their classification, specification, the level of severity, together with a definition of their functional limitation. The functional limitation might differ from one person to another, even if they have the same disability. That is why some ontologies proposed using the term *capabilities* in order to specify what a user *can* do. Defining capabilities would make it easier to direct users to the most appropriate solution with respect to their abilities [65]. Assistive technologies should be clearly defined by their specification and capabilities in order to adapt content with their usage. Specifying the standards and guidelines (i.e. web and e-learning) with which the system should comply, either a specific country accessibility act and regulation or accepted standards and guidelines. Finally, representing the learning objects and annotating them to facilitate their retrieval with respect to the user's needs.

Among the reviewed ontologies, we find several available ones that satisfy these requirements. The ACCESSIBLE ontology [59], as explained above, is composed of a number of widely accepted standards and guidelines (ICF, WAI, etc.), which can be extended and reused for other purposes. Likewise, the AEGIS ontology [84] defines various personas with reference to the ACCESSIBLE ontology, which provides more insight into the needs and capabilities of people with specific disabilities. The Affinto ontology [85] focuses on extra elements, environmental factors (noise, light, etc.), and personal properties (emotion, mood, etc), which may also be useful information affecting human behaviour. From the perspective of learning objects, the Accessibility Metadata Project can be incorporated as it provides descriptive metadata for educational resources, which can help to map resources to user needs.

3.6 Summary

In this chapter, we surveyed the state-of-the-art and outlined requirements and challenges for developing accessible OCW platforms using the semantic web, particularly ontologies. We have reviewed existing standards and guidelines addressing web and e-learning accessibility, and we have summarized and categorized available ontologies with regard to different types of impairments. We also discussed and suggested some ontologies that can be reused and adapted for creating accessible OCW, as discussed in Section 3.5.

In summary, we have reviewed 20 research on ontologies and related models designed to address accessibility. 17 of these research are ontologies, and nearly all of them have been developed by the Web Ontology Language (OWL), but only 11 of those OWL ontologies are still available online. We examined those 11 ontologies in more detail and counted the number of classes they comprise of. As seen in Table 3.2, FMA is the largest ontology among them, with more than 100,000 classes. However, it does not purely focus on accessibility but is a domain ontology representing detailed knowledge about human anatomy. Much smaller compared to FMA but still a large ontology is ICF, which comprises nearly 1,600 classes. ASK-IT is also a large ontology, as it contains many classes describing tourism, transportation, and travel services. Most of the other ontologies have between 50 and 170 classes, except for AEGIS, which features only 15 classes as an extension of the ACCESSIBLE ontology.

We highlighted the need for additional accessibility standards, guidelines, and ontologies for special types of disabilities, such as cognitive impairments, and their importance for OCW. Finally, we defined a number of aspects that should be considered in the development of accessible OCW.

Part II

OpenCourseWare Quality Evaluation

CHAPTER 4

Accessibility and Quality Evaluation of OER

OER are free and open-licensed educational materials that are widely used for learning. Section 4.1 explains how OER quality assessment has become essential to support learners and teachers in finding high-quality OER and to enable online learning repositories to improve their OER. Section 4.2 analyzes the literature to identify the dimension of evaluating the quality of OER. Section 4.3 establishes a set of evaluation metrics that assess OER quality in OCW authoring tools. These metrics provide guidance to OER content authors to create good quality content. Section 4.4 implements the metrics and evaluates them within SlideWiki, a collaborative OCW platform that provides educational materials in slide presentation format. Finally, Section 4.5 evaluates the relevance of the metrics through a questionnaire conducted among OER experts and users.

Related publication

- **Mirette Elias**, Allard Oelen, Mohammadreza Tavakoli, Gábor Kismihók, and Sören Auer. *Quality Evaluation of Open Educational Resources.* In 15th European Conference On Technology Enhanced Learning (EC-TEL) 2020 Proceedings, 410-415, Springer.

4.1 Quality Evaluation of OER

OCW platforms organize education materials, known as OER, in the form of online courses. These courses generally provide a learning plan and evaluation tools. Many OCW platforms exist with various OER representations, such as videos, audio and slides. Finding high-quality OER becomes increasingly cumbersome due to the growing amount of published resources [100]. However, selecting high-quality resources is crucial to ensure the quality of an online course. In this chapter, we propose evaluation metrics to assess the quality of OER. The proposed metrics are designed to be implemented within OER authoring tools. This means that the metrics have clear definitions and can be measured objectively. The metrics have their foundation in existing research and similar approaches found in the literature. Although the presented metrics are evaluated on presentation slides, they can be applied to other OER representations as well.

We address two research question: 1) *how to evaluate the quality of OER material?* and 2) *how to use this evaluation to guide OER authors and learners?* In order to define the quality metrics and to develop the implementation, we investigate related work to OER quality assessment. Accordingly, we select and extend the dimensions that are related to content representation, and we define a set of metrics for each dimension. Finally, we evaluate our work by conducting a questionnaire with OER expert users (i.e., instructors and PhD students) and by implementing a set of metrics in an authoring tool.

4.2 Quality Evaluation Dimensions of OER

From the state-of-the-art, we focused on approaches that address quality aspects related to the OER content and representation. We analyzed dimensions found in the literature and categorized them based on the quality aspects: 1) feature quality (i.e., quality related to functionalities provided by the OER repository), 2) technological quality (i.e., quality related to the technology and implementation of the OER repository), and 3) content quality (i.e., quality related to the OER material and content representation). Table 4.1 shows the dimensions that were extracted and categorized as per our analysis.

The **feature aspect** is defined by the following dimensions: *Availability* refers to the presence of material and availability to access and download. *Multilinguality* refers to the availability of the platform and resources in multiple languages. *Reusability* refers to the open access license and reusing of materials (e.g., creative commons licensing). It also refers to the representation format of the OER whether it supports reusability or not. *Provenance* refers to the availability of revision history of material and authorship. *Recency* refers to the ability to check if a material is up-to-date. *Openness* refers to the ability to share material over social media, peer review, adding comments, rating resources for evaluation needs.

The **technological aspect** of OER repositories is summarized into the following dimensions: *Accessibility* refers to the ability of people with special needs to access educational materials. *Alignment to standards* refers to the alignment to the available standards and guidelines (e.g., metadata, multimedia representation). *Usability* refers to the implementation and design decisions for supporting easiness of use, intuitiveness, and easiness of navigation. *Compatibility* refers to the compatibility for types of devices (e.g., mobile).

The **content aspect** of OER material is summarized into the following dimensions: *Structure* refers to the organization, decomposition and navigation of the OER content. *Accuracy* refers to the correctness of the content. *Comprehensiveness* refers to the clarity and readability of text. *Discoverability* related to the ability to retrieve resources by searching. *Multimodality* refers to the components used to represents the content like, strong visual structure (animations, images, and videos). *Self-assessment* refers to the availability of self-assessment to support learnability.

From the analysis, we found that most of the evaluation approaches that were studied in Table 4.1, evaluate the dimensions and metrics either conceptually or by providing a checklist to experts or users. These checklists are either filled out manually or in the form of online surveys [111]. Automatic OER quality assessment and author quality guidance were not addressed. Since this study focuses on evaluating the quality of *OER materials*, we focus on the dimensions defined in the content quality part from Table 4.1 and extended them in Table 4.2. We also use accessibility and compatibility from the technological aspect because they affect OER content as well. The accessibility dimension, for example, ensures that the technology used for implementing an OER repository complies to WCAG 2.1 [27]. Furthermore, accessibility should be considered in material creation; for example, to enhance the readability for visually impaired users by including textual descriptions to images and charts.

Table 4.1: Summary of quality evaluation dimensions

Dimensions	References	[101]	[102]	[103]	[104]	[105]	[106]	[107]	[108]	[109]	[110]
Features quality	Availability	✓	✓	✓							✓
	Multiliguality	✓	✓	✓		✓					
	Reusability	✓		✓		✓		✓	✓		
	Provenance	✓						✓			✓
	Recency	✓						✓			✓
	Openness	✓	✓	✓	✓		✓	✓		✓	
Technological quality	Accessibility		✓		✓	✓	✓	✓	✓	✓	
	Alignment to standards		✓	✓	✓		✓		✓		✓
	Usability		✓		✓	✓		✓	✓	✓	
	Compatability		✓			✓		✓	✓		
Content quality	Structure		✓					✓	✓	✓	
	Accuracy		✓		✓			✓	✓	✓	
	Comprehensive-ness		✓		✓		✓	✓			✓
	Discoverability	✓	✓	✓							
	Multimodality				✓	✓	✓	✓	✓	✓	✓
	Self-assessment	✓	✓		✓		✓				

4.3 OER Quality Evaluation Metrics

The Open Education Consortium (OEC) defines OER as materials that are composed of course planning, thematic content, and assessment tools [17]. Accordingly, we divided our evaluation approach of OER into three dimensions: content structure, learning content, and self-assessment. Content structure defines the organization and navigation of the educational resource. Learning content refers to the representation of the learning material. Self-assessment is related to the availability of questions to evaluate the learning process. Based on the dimensions analyzed in Table 4.1, we selected the dimensions that are related to the quality of the learning content and addressed in these components. Table 4.2 lists the dimensions and metrics to assess the quality of OER materials.

4.3.1 Content Structure

The **Content Structure (CS)** determines how a course's materials are organized. The quality of the course structure is important because it is the primary interface for accessing educational resources. Content Structure refers to the organization of a course's educational resources (e.g., modules, lessons), as well as the navigation between them and the metadata that describes the educational resource (i.e., level, subjects).

The design of the content structure should provide a clear overview of the course, simple and predictable navigation structure. The content structure can be represented using hierarchical branching, indexes, custom learning paths utilizing conditional branching, or complex objective hierarchies [113].

According to our study of the related standards and guidelines for open education in Chapter 3, we use the IMS Content Packaging (IMS CP) specification. The default approach of content structure in

Table 4.2: OER quality metrics

Dimension	Metrics	Description
Content Structure (CS)	CS1. Clearness of the taxonomies	CS1.1 Short and descriptive name (i.e., characters limit) CS1.2 Coherence with content title (i.e., consistent file name with the content title) CS1.3 Progress inference from title (i.e., consistent coding scheme)
	CS2. Easiness of navigation	CS2.1 Hierarchical design (i.e., well-organized structure) CS2.2 Depth of the taxonomy (i.e., less scrolling)
	CS3. Adaptability of the structure	CS3.1 Availability of adaptability mechanism (e.g. smaller chunks design)
	CS4. Discoverability of the content [112]	CS4.1 Availability of Standardized Metadata (i.e., sum of the normalized importance scores of metadata) CS4.2 Adherence to Standardized Metadata (i.e., including a Rating function)
Learning Content (LC)	LC1. Quality of text	LC1.1 Correctness of text spelling and grammar LC1.2 Comprehensiveness of text (i.e., using readability meters)
	LC2. Adaptability of content	LC2.1 Availability of various content formats (e.g., based content, web media, interactive media, video, audio) LC2.2 Availability of multiple content representation (e.g., multiple themes for learning slides) LC2.3 Consistency between the content types (i.e., synchronized maintenance and versioning management)
	LC3. Compatibility of content on multiple devices	LC3.1 The number of supported devices (e.g., mobile phone, tablet, laptop, assistive technologies) LC3.2 Availability of compatibility checking mechanisms (e.g., validating responsiveness of web pages)
	LC4. Accessibility of content representation	LC4.1 Compliance to guidelines of content representation (e.g., WCAG 2.1 guidelines) LC4.2 Availability of validation approach of content representation (e.g., validating that an image contains alternative description to support accessibility)
	LC5. Multilinguality of content	LC5.1 Availability of resources in more than one language (i.e., other than English) LC5.2 Existence of translation approach (i.e., automatic translation, expert-revised) LC5.3 Availability of synchronization of material translation
Self-assessment (SA)	SA1 Availability of self-assessment	SA1.1 Existence of self-assessment content SA1.2 Availability of answers SA1.3 Average number of questions covering the content (i.e., number of questions per each learning object) SA1.4 Existence of question generation approach (e.g., automatic generation or author entry)
	SA2. Variety of self-assessment questions	SA2.1 Available type of questions (e.g., multiple choice, close text, sorting). SA2.2 Average number of question per assessment type

IMS CP specification is a tree view or hierarchical representation, that is encompassed in an XML format [113]. We adopt the hierarchical structure as it provides an organized and sequential form for accessing the elements of educational resources (i.e., module, sub-modules) and it is recommended by the IMS CP specification [113]. It is assessed by the four metrics: 1) clearness of the taxonomies, 2) easiness of navigation, 3) adaptability of the structure, and 4) discoverability of the content.

CS1. Clearness of the taxonomies

Definition: The naming given to OER components should be self-explanatory and consistent with the content title of the OER. *Example:* The resources with the name “Slide 1” or “Module 1” are not considered clear naming. *Metrics:*

- *CS1.1 Short and descriptive name*. To improve the readability of an OER name, it should be short and concise. The name of the content should be represented in one line; a number or characters limit can be provided with respect to the design of the OER hierarchical menu and also taking into consideration the compatibility with other devices. Some guidance can also be provided to authors, such as, avoiding the use of abbreviations and special characters.

$$title\_length\,(o) = \frac{number\_of\_words\,(o)}{max\_number\_of\_words} X \frac{length\_of\_name\,(o)}{maximum\_length} < 1 \tag{4.1}$$

- *CS1.2 Coherence with content title*. The name of the file should be consistent with the content title. The OER file name can be automatically generated from the title. The title can still be changed by the author, but a validation mechanism ensures adherence to this rule. This can be accomplished using the Jaccard similarity between name and title [114].

$$title\_coherence(name\,(o)\,, title\,(o)) = \frac{|name\,(o) \cap title\,(o)\,|}{|name\,(o) \cup title\,(o)\,|} > 0.8 \tag{4.2}$$

- *CS1.3 Progress inference from title.* Following a consistent coding scheme and displaying the material position in relation to the course. The name of the content can follow a systematic naming approach (e.g., code + title), where code can be an incremental module number. This metric can be automatically validated with a regular expression check.

CS2. Easiness of navigation

Definition: The navigation structure of the OER components should be simple and predictable.

- *CS2.1 Hierarchical design.* A hierarchical structure is adopted to ensure content is well-organized. This could be in the form of modules and sub-modules as recommended by the IMS CP specifications [113]. The validation approach checks for the availability of a hierarchical structure.

- *CS2.2 Depth of the taxonomy.* This is related to the depth of the hierarchical structure and the number of elements in each hierarchical level. The IMS CP specification implements the OER structure into two levels (i.e., level 0 describes the modules of an OER, and level 1 describes the content). The specification does not recommend or limit the number of hierarchical levels or depth. However, according to the empirical studies on hierarchical menus design in websites and mobile platforms [115, 116, 117], the deeper the hierarchical structure gets, the more cumbersome navigation becomes. Moreover, a simpler (i.e., shallower) hierarchical structure improves screen reader accessibility, as they require less scrolling and less memorization [118].

$$1 \leq hierarchical\_depth \leq 3 \tag{4.3}$$

CS3. Adaptability of the structure

Definition: The extent to which an OER structure can be personalized to the learner competencies. The design, distribution, and sequence of the modules (and objects within the modules) should be designed with the aim of personalization (e.g., backward design or goal-oriented design [119], adaptive learning design [120]). The IMS CP is used together with IMS Simple Sequencing (IMS SS) [121] to allow adaptability and conditional branching of the OER organization according to the learners profile, where the IMS SS specification provides the sequence of the content and resources defined in IMS CP according to the activity behavior of learners.

- *CS3.1 Availability of adaptability mechanism*. This metric is defined by a Boolean value which indicates the availability of an adaptive navigation support [122]. In order to create an adaptable learning sequence, the OER learning material is designed and distributed into smaller chunks to allow easier restructuring of its components [123]. The IMS SS is used to design the default learning path and adapt it as per the learner profile.

CS4. Discoverability of the content

Definition: Discoverability shows how an educational resource can be found and used through educational services (such as search and recommender systems), which is realized by metadata. There are two main standards for describing educational materials: 1) IEEE Standard for Learning Object Metadata (LOM) [124], which specifies the aspects, vocabularies, and representation methods (e.g. XML and RDF) for describing learning objects [125, 126], and 2) Learning Resource Metadata Initiative (LRMI) [127] that describes educational materials in order to facilitate the process of finding learning resources via search engines, such as Google and Bing [128]. To find criteria for metadata, we evaluated the aforementioned standards and extracted the most important properties for describing OER. This is done based on analyzing more than 8,000 quality-controlled open educational resources. We will explain this approach in Chapter 5. Accordingly, we define two measures to check the quality of an OER with respect to their metadata:

- *CO4.1 Availability of Standardized Metadata*. For calculating the availability score of an OER o, we calculate the sum of the normalized importance scores of its available metadata fields:

$$availability\_score\,(o) = \sum_{k=available\_fields} norm\_importance\_rate\,(k) \tag{4.4}$$

- *CO4.2 Adherence to Standardized Metadata*. To calculate the adherence score of each OER o, we multiply the normalized importance score of k by the rate of o in the field k (according to the

Rating Function):

$$adherence\_score\,(o) = \sum_{k=fields} norm\_importance\_rate\,(k) * rate\,(o,k) \tag{4.5}$$

4.3.2 Learning Content

The **Learning Content (LC)** refers to the learning material and its representation. In this part, we define dimensions related to learning content which refers to the learning material and its representation.

LC1. Quality of text

Definition: The correctness and comprehensiveness of the content text. *Example:* The text should be clear and free of spelling, grammar, and typographical errors.

- *LC1.1 Correctness of text spelling and grammar.* The existence of a validation approach to ensure the correctness of the text. Although spelling and grammar checks are included as add-ons to many browsers, an authoring tool should also make sure that the title does not include spelling mistakes and provides a warning of such errors in case these add-ons are not presented or their highlights are not effective.

- *LC1.2 Comprehensiveness of text.* An OER is expected to address different types of learners; some contents should support easy-reading if they are targeting learners of different languages or learners with cognitive impairments. Validation of the text complexity can be added in the authoring tool to ensure that the text is readable by different types of learners (e.g., non-native English speakers, learners with cognitive disabilities). One example would be to use readability meters, like Flesch-Kincaid Ease [129], to check the complexity of the text and provide a warning if the complexity of the text exceeds some number. There are also approaches that can be used to provide alternative synonyms of complex words [130] or suggest an easier structure for sentences [131].

LC2. Adaptability of content

Definition: The availability of multiple content formats and representations to address different preferences and needs of learners. In order to address personalization and individual learning styles, various content types should be available. *Example:* Providing video representation as well as textual content that can be better accessed by visually impaired users.

- *LC2.1 Availability of various content formats.* The number of formats representing an OER content addressing different learning styles. The content can be described by document-based content, web media, interactive media, video, and audio.

- *LC2.2 Availability of multiple content representation.* The extent to which content can be adapted per the learner's preferences. For example, providing multiple themes for learning slides to address different preferences of learners (e.g., coloring contrast and text style and text size).

- *LC2.3 Consistency between the content types.* The extent to which these contents are consistent with each other and the existence of synchronized maintenance and versioning management.

LC3. Compatibility of content on multiple devices

Definition: The extent of interoperability on different types of devices. Accessibility of OER material on multiple devices is highly recommended by learners to access and continue their progress from any type of device [132].

- *LC3.1 The number of supported devices (e.g., mobile phone, tablet, laptop, assistive technologies).* The OER repositories conduct compatibility by following responsive design approach [132] and following the design guidelines of these devices [133].
- *LC3.2 Availability of compatibility checking mechanisms.* Compatibility checking can be executed manually by quality control engineers or automatically (e.g., validating responsiveness of web pages [134], validating compatibility to assistive technologies [135]).

LC4. Accessibility of content representation

Definition: The accessibility of content to learners with accessibility needs (e.g., visually impaired users).

- *LC4.1 Compliance to guidelines of content representation.* There are many standards and guidelines available for each type of content format [136]. An OCW system should specify the guidelines they are following and ensure accessibility of these content types, like following WCAG 2.1 guidelines [27].
- *LC4.2 Availability of validation approach for accessibility of content representation.* Specifying the standards and guidelines for accessibility is not sufficient. An approach for validating the content in terms of these guidelines in the authoring tool itself is also required (i.e., validating that an image contains an alternative description to support accessibility)

LC5. Multilinguality of content

Definition: Availability of material in multiple languages. Multilinguality has been a common requirement as the majority of courses are provided in English; there is a need to have courses defined in other languages either by authors creating them or by using automatic translation or crowdsourcing approaches. The quality of multiple languages has been defined by three measures [101].

- *LC5.1 Availability of resources in more than one language.* The number of languages an OER is presented with (i.e., other than English).
- *LC5.2 The approaches used for translation.* It defines the approach used for translation (i.e., automatic translation, expert-revised) and how the translation is evaluated.
- *LC5.3 Availability of synchronization of material translation.* It specifies how edits are synchronized in all versions.

4.3.3 Self-assessment

Self-assessment (SA) is designed to help learners track their learning progress, and understandability of the material [137].

SA1. Availability of self-assessment

Definition: The availability of questions and answers designed for evaluating the learning process.

- *SA1.1 Existence of self-assessment content*. The availability of questions for self-assessment can be measured by a Boolean value for content existence [101].
- *SA1.2 Availability of answers*. The availability of answers to the questions can be measured by Boolean value.
- *SA1.3 Average number of questions covering the content.* The coverage of the self-assessment is calculated by the number of questions per learning object (i.e., module) to the total number of modules of an OER [101].
- *SA1.4 Existence of question generation approach.* The type of approach used to create the self-assessment question (e.g., automatic generation or author entry). Recently, the availability of a question generation approach has become more relevant [138].

SA2. Variety of self-assessment questions

Definition: Providing various types of self-assessment material to address different skills of learners. Since learners have different learning competencies, it is helpful to provide different styles of questions to address their different learning skills (e.g., comprehensiveness, problem solving).

- *SA2.1 Available type of questions*. This is measured by a numeric value that indicates the total number of different types of self-assessment questions (e.g., multiple choice, close text, sorting).
- *SA2.2 Average number of questions per assessment type.* This metric measures the balance between different types of self-assessment questions. The average number of questions per assessment type.

4.4 Implementation

For the implementation, a set of eight metrics (i.e., CS1.1, CS2.1, CS4.1, CS4.2, LC4.1, LC5.1, SA1.1, SA1.2) has been selected from Table 4.2. The set of quality metrics was selected based on relevance, appropriateness and technical viability within the SlideWiki platform. Figure 4.1 shows a quality report within the SlideWiki user interface. The figure displays a quality report from a deck available via SlideWiki[1]. The quality report is displayed on deck-level, and is visible to all users. There are several reasons for making the quality report public. Firstly, there is an extra incentive for OER creators to ensure that their presentation meets a certain quality standard. Secondly, learners can decide to use an OER based on its quality. And finally, due to the collaborative nature of SlideWiki, learners can help improve the slide deck based on the report. For each metric, the number of detected issues is listed. In case no issues are found, the text “All good” is displayed. For metrics CS4.1 and CS4.2, a quality score is shown. Listed metrics can be expanded to view more details about a particular metric, including why adhering to this metric is important. In case an issue is detected, more information about this issue is displayed.

[1] `http://slidewiki.org/deck/90789/02-rdf-data-model/deck/90789`

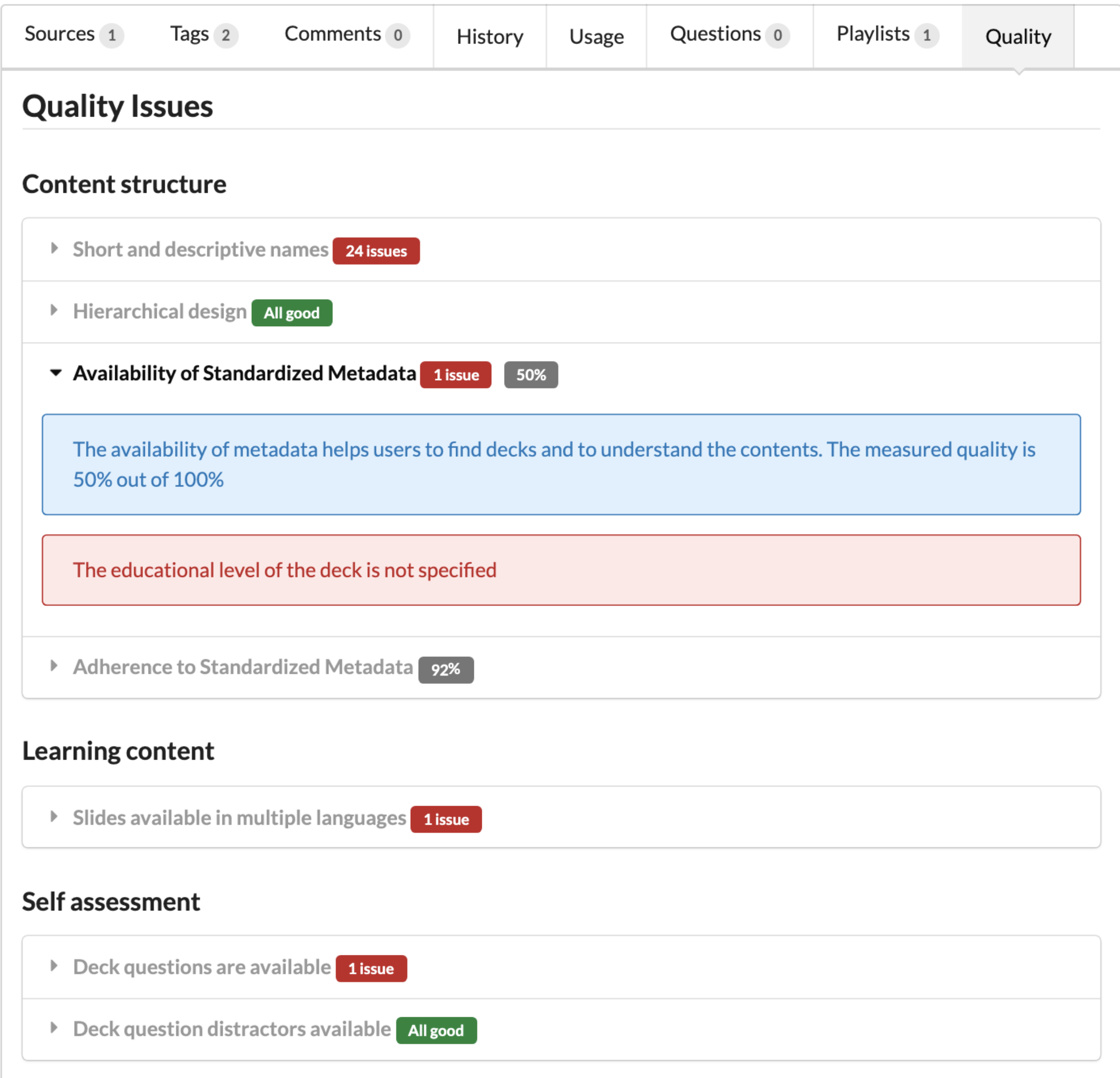


Figure 4.1: Quality scoring report within SlideWiki

The quality checks are performed when the quality report is requested. This means that the results of the check are not stored. An advantage is that in case a deck is updated, the quality report is also automatically updated. However, performing a quality check takes more time because checking a deck is resource intensive. Since only eight metrics are implemented, this is currently not an issue. However, when more metrics are implemented, storing the results will become necessary.

4.5 Evaluation and Discussion

To evaluate our quality dimensions and metrics, we invited OER expert users (either university instructors or PhD students) and asked them about the importance (1: less important, 5: very important) of our metrics in each dimension with the help of a qualitative questionnaire in (Appendix C). Moreover, the participants provided opinions about the overall quality of existing OER (as *Current Quality* column, 1: lowest quality, 5: highest quality), and overall usefulness (1: not useful, 5: very useful) of our metrics in each dimension. We collected the feedback of ten participants who had experience with OER as author (2 participants), learner (5 participants), and teacher (5 participants). The results of this survey with respect to each dimension and the overall evaluation are summarised in Table 4.3.

For the *Content Structure*, most of the metrics in this dimension received an average importance rate between 3 and 5. The evaluation results of each dimension and metric are: 1) *Content Structure* is considered useful by 100% of the participants, 2) for the *Learning Content*, the comprehensiveness of text, availability of multiple content format, and compatibility to various devices received the highest importance rates. The accessibility dimension had an evaluation rate between 3 and 4. Multilinguality received the least importance rate. The overall dimensions and metrics of the *Learning Content* is considered useful by 60% of the participants, and For the *Self-assessment*, the availability of

Table 4.3: Summary results of the questionnaire

Dimensions and Metrics	Importance Rate (%)					Current Quality	Usefulness
	1	2	3	4	5		
Content Structure							
CS1.1 Short and descriptive name	0	0	20	60	20		
CS1.2 Coherence with content title	0	0	40	40	20		
CS1.3 Progress inference from title	0	10	40	30	20		
CS2.1 Hierarchical design title	0	0	20	80	0	Not satisfied: 30%	
CS2.2 Depth of the taxonomy	40	20	20	0	20	Neutral: 40%	Agree: 100%
CS3.1 Availability of adaptability mechanism	10	0	20	40	30	Satisfied: 30%	
CS4.1 Availability of Standardized Metadata	0	0	10	70	20		
CS4.2 Adherence to Standardized Metadata	0	10	20	50	20		
Learning Content							
LC1.1 Correctness of text spelling and grammar	10	20	30	30	10		
LC1.2 Comprehensiveness of text	0	20	10	60	10		
LC2.1 Availability of various content formats	0	10	10	50	30		
LC2.2 Availability of multiple content representation	10	40	40	10	0		
LC2.3 Consistency between the content types	0	20	40	20	20		
LC3.1 The number of supported devices	0	20	0	40	40	Not satisfied: 10%	Disagree: 10%
LC3.2 Availability of compatibility checking mechanisms	0	10	50	40	0	Neutral: 40%	Neutral: 30%
LC4.1 Compliance to guidelines of content representation	0	10	50	40	0	Satisfied: 50%	Agree: 60%
LC4.2 Availability of validation approach of content representation	10	10	40	40	0		
LC5.1 Availability of resources in more than one language	20	20	40	10	10		
LC5.2 Existence of translation approach	10	30	20	30	10		
LC5.3 Availability of synchronization of material translation	20	30	30	10	10		
Self-assessment							
SA1.1 Existence of self-assessment content	0	0	20	60	20		
SA1.2 Availability of answers	0	10	20	10	60		
SA1.3 Average number of question covering the content	0	30	40	30	0	Not satisfied: 30%	Disagree: 10%
SA1.4 Existence of question generation approach	0	20	30	40	10	Neutral: 30%	Neutral: 10%
SA2.1 Available type of questions	0	20	30	30	20	Satisfied: 40%	Agree: 80%
SA2.2 Average number of question per assessment type	0	20	40	30	10		

questions and answers received the highest importance rates. The overall dimensions and metrics of the 3) *Self-assessment* is considered useful by 80% of the participants.

At the end of the questionnaire, we asked the participants to rate (between 1 and 5) the usefulness and coverage of the proposed dimensions and metrics. Regarding the usefulness and coverage of the proposed dimensions and metrics, 70% of the participants find our dimensions and metrics useful, and 50% of the participants agreed that the proposed dimensions and metrics cover the important metrics needed for evaluating the quality of OER materials, while 30% of the participants provided a neutral response.

4.6 Summary

This chapter defines quality evaluation metrics for OER to help learners and teachers to find high-quality OER and guide OER repositories to improve their content. Two research questions are addressed in this chapter. To answer the first question, "how to evaluate the quality of OER", we established and distributed quality evaluation metrics covering three aspects of OER quality assessment: content structure, learning content, and self-assessment. For the second question, "how to use the evaluation metrics to guide authors and learners of OER", we selected eight of these metrics and implemented them in SlideWiki. Quality reports are publicly visible for all users in order to help learners find high-quality content, and encourage authors to improve their materials. We evaluated our metrics by collecting feedback from OER users and creators via a questionnaire.

CHAPTER 5

Accessibility and OER Metadata

OER metadata is important not only to aid learners in finding relevant content among a large number of educational resources but also to indicate OER quality [139], as shown in Chapter 4. In this chapter, we focus on OER metadata for describing accessibility features and evaluating the quality of open educational material to enhance the search results of recommender systems. This chapter is arranged into two parts. The first part explores the state-of-the-art describing accessibility features of OER metadata in Section 5.1. The aim of this part is to assess how accessibility metadata can be used to recommend educational resources to learners. The second part explains how OER metadata is used to evaluate the quality of OER in Section 5.2. Section 5.3, we analyze the accessibility metadata and study how to use them for OER recommendation. This part is a collaborative work with Mohammadreza Tavakoli (PhD student at Joint Lab of TIB[1]). Section 5.4 explains the inclusion of accessibility metadata to enrich the OER recommendations with the accessibility needs of learners.

Related publications

- Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Metadata Analysis of Open Educational Resources* (Nominated for Best Short Paper Award). In 11th International Conference on Learning Analytics & Knowledge, 2021 Proceedings, ACM.
- **Mirette Elias**, Mohammadreza Tavakoli, Steffen Lohmann, Gábor Kismihók, and Sören Auer. *An OER Recommender System Supporting Accessibility Requirements.* In 22nd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) 2020, 57:1-57:4, ACM.
- Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Quality prediction of open educational resources a metadata-based approach.* In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 29-31, IEEE.

5.1 OER Accessibility Metadata

Metadata is descriptive data linked with OER that aids in discovering relevant resources when searching for materials. As a result, OER metadata should make it easier to find and share educational resources.

[1] https://www.tib.eu/de/forschung-entwicklung/joint-lab

There are two main standards for describing educational materials: 1) IEEE Standard for Learning Object Metadata (LOM) [124] which specifies the aspects, vocabularies, and representation methods (e.g. XML and RDF) for describing learning objects [125, 126], and 2) Learning Resource Metadata Initiative (LRMI) [127] that describes educational materials in order to facilitate the process of finding learning resources via search engines, such as Google and Bing [128]. However, these standards do not explicitly describe the accessibility features of OER. As per our review of the state-of-the-art in Chapter 3, the AfA DRD is the most comprehensive guideline for describing the accessibility properties of learning objects. Accordingly, we propose a categorisation to analyze the availability of accessibility parameters in: 1) OER metadata standards and guidelines, 2) several specifications that describe accessibility properties of learning objects, and 3) OER repositories that include accessibility in their metadata parameters. The aim of this analysis is to identify how accessibility is recognized in different metadata guidelines and repositories and evaluate the accessibility coverage.

Table 5.1 summarizes the accessibility metadata of these OER metadata standards and repositories. We propose the following categorization of accessibility metadata parameters to simplify the comparison between these references into: *Visual* if it provides description about visual representations (e.g., color, contrast), *Auditory* if it provides description about audio representations (e.g., sound, caption), *Textual* if it contains description about the text display (e.g., reading order, text adjustment compatibility), *Type* if it provides the format type of the learning resource (e.g., PDF, slides), *Control* if it provides information about the flexibility of access (e.g., keyboard accessible) and with assistive technology, *Platform* if it provides information about the platform, software, or API which the content is accessible with (e.g., iOS accessible), *Level* if it provides information about the educational level or the age of learners and finally, *others* if it provides other information that can be useful for accessibility, for example, MERLOT provides metadata about the accessibility standards which the educational material conforms to.

5.1.1 Accessibility Metadata in OER Standards and Guidelines

In this section, we analyze the existing OER metadata and define the parameters that can be used for describing the accessibility of content, as summarized in Table 5.1. Almost all of the studied OER metadata guidelines and repository include the metadata parameters: *Subject, Description, Date, language, Size, Duration*, which are also useful to consider when searching and recommending for educational material but in this study, we focus on parameters that are more related to accessibility.

IEEE Standard for Learning Object Metadata (LOM) defines the metadata structure of a learning object by describing its characteristics in groups (e.g., life cycle, meta-metadata, educational, technical, educational, rights, relation, annotation) [124]. LOM contains metadata parameters that describe: content type (LearningResourceType, Format, Control (InteractivityType, Interactivity-Level), platform requirements (InstallationRemarks, OtherPlatformRequirments), Level of education (Difficulty, TypicalAgeRange). However, there are no parameters for visual, textual, or auditory descriptions.

Table 5.1: Summary of the state-of-the-art OER accessibility metadata

References/ Accessibility Description	Visual	Auditory	Textual	Content Type	Control	Media/Platform	Level/Audience	Others
A11ymetadata	accessibilityFeature, accessibilityHazard	accessibilityFeature	accessibilityFeature	accessMode, accessModeSufficient	accessibilityControl	accessibilityAPI	-	accessibilitySummary
DCMI	StillImage, Image, MovingImage	Sound	Text	DCMIType, FileFormat, MediaType, MediaTypeOrExtent	InteractiveResource	Software	educationLevel, Audience	Standard
IMS AfA DRD	AccessMode, DisplayTransformability, AccessModeOrnamental	AccessMode	AccessMode, DisplayTransformability	AccessMode, AdaptationMediaType	ControlFlexibility, AtInteroperable	ApiInteroperable, AtInteroperable	EducationalLevelOfAdaptation	-
LOM	-	-	-	LearningResourceType, Format	InteractivityType, InteractivityLevel	InstallationRemarks, OtherPlatformRequirments	Difficulty, TypicalAgeRange	-
LRMI	-	-	-	learningResourceType	interactivityType		educationalLevel, complexityLevel, readingLevel, EducationalAudience, typicalAgeRange	-
MERLOT SkillsCommons	color, contrast, imageAltText, noFlickering, decorativeImages, complextImageText	multimediaTranscript	textAccess, textAdjustmentCompatible, textAdjustable, readingLayoutCompatible, readingLayoutPageNumbers, readingLayoutPageNumbersAlt, tableMarkup readingOrder	type	keyboardInteractive, interactivityType	multimediaAccessiblePlayer	level	stemMarkup, formalPolicy, statement, organization
OerCommons	Accessibility	Accessibility	Accessibility	-	MediaFormat	-	EducationLevel	-

Dublin Core provides two specifications for describing educational resources: Learning Resource Metadata Initiative (LRMI), Dublin Core Metadata Initiative (DCMI)

1. DCMI is a general descriptive metadata for describing resources. The terms are developed by RDF [140]. DCMI describe 15 elements with their properties: identifier creator, contributor, publisher, title, description, language, subject, coverage, format, type, date, relation, source and rights. The metadata parameters of DCMI include description: DCMIType describes the content type of resource (i.e., Collection, Dataset, Event, Image, InteractiveResource, MovingImage, PhysicalObject, Service, Software, Sound, StillImage, Text), and highlights information about the accessibility type of resource: visual, auditory, and textual. The content type is defined by format (FileFormat, MediaType, MediaTypeOrExten), Control (InteractiveResource), Platform (Software), and level (educationLevel, Audience), and others (Standard) a resource can conform to a specific standard.

2. LRMI is a collection of classes and properties to describe educational resources. This specification is adopted by schema.org to describe learning objects. The schema is developed in RDF. It includes the metadata parameters that describe the type of content: learningResourceType (e.g., presentation, handout), Text: alignmentType (e.g., requires, textComplexity, readingLevel), and Level: educationalLevel which specifies the required level of education (e.g., beginner, intermediate, advanced).

IMS AfA DRD [54] is an IMS specification that describes the accessibility properties of educational resources. The metadata is represented in XML format. AfA DRD specification is descried in detail in Chapter 6 when we explain our ontology. In a quick summary, the content type is described by AccessMode, and it also includes information about visual, auditory and text. For visual, auditory and text, it includes details about their representation (i.e., DisplayTransformability., Hazard). Platform is described by ApiInteroperable and compatibility with assistive technologies, AtInteroperable. Control is described by ControlFlexibility. Level is defined by EducationalComplexityOfAdaptation, EducationalLevelOfAdaptation. This specification contains metadata about adaptations that aim to provide various types of learning objects in order to address a wider range of learners (i.e., HasAdaptation, IsAdaptationOf , IsFullAdaptationOf, LanguageOfAdaptation).

Accessibility Metadata Project (A11ymetadata) [81] aims to make accessible content discoverable so that quality educational resources on the web can be found and the most appropriate content made available to a learner's needs. The project defines seven accessibility metadata, and their assigned values [141]. The metadata accessMode and accessibilityFeature describes the content representation of the visual (i.e., alternativeText), auditory (i.e., audioDescription, highContrastAudio), and text (i.e., readingOrder). Platform compatibility is described by accessibilityAPI (e.g., iOSAccessibility, JavaAccessibility, MacOSXAccessibility). Control is described by accessibilityControl (fullKeyboardControl, fullMouseControl, fullSwitchControl, fullTouchControl, fullVideoControl, fullVoiceControl). The accessibilityHazard indicates the existance/nonexistance of hazards like flashing, noFlashingHazard, motionSimulation, noMotionSimulationHazard, sound, noSoundHazard, accessibilitySummary,

5.1.2 Accessibility Metadata in OCW platforms

Some OCW platforms present accessibility metadata like, **MERLOT** OCW. Including accessibility metadata takes place by authors/providers by filling a form [142] with 30 different categories (e.g., URL to Formal Accessibility Policy, URL to Accessibility Statement, URL to Accessibility Evaluation Report, Text Access, Text Adjust). **SkillsCommons** OER Repository build their accessibility metadata after MERLOT [143], as listed in Table 5.2. An XML version is provided for authors/providers to guide them in adding accessibility metadata to their educational resources.

OER Commons is an OCW that includes accessibility metadata [144]. Two metadata parameters are included: AccessMode describes the content type (visual, Auditory, Textual, Audio Description), and AccessibilityFeatures describes more detail about the resource representation (Caption, Verbatim Captions, Long Description, Transcript). They provide an advanced search that takes into account these accessibility metadata.

Table 5.2: Accessibility metadata from SkillsCommons dataset

Accessibility metadata	Description
formalPolicy	URL to Formal Accessibility Policy
statement	URL to Accessibility Statement
organization	URL to Accessibility Evaluation Report
textAccess	Text Access - Text to Speech
textAdjustmentCompatible	Text Adjust - Compatible
textAdjustable	Text Adjustment - Adjust Font and Colors
readingLayoutCompatible	Reading Layout - Reflow the Text
readingLayoutPageNumbers	Reading Layout - Page numbers match printed material
readingLayoutPageNumbersAlt	Reading Layout - Reflow the Text
readingOrder	Reading Order - Digital resource layout
structuralMarkupText	Structural Markup - Navigation Text
structuralMarkupLists	Structural Markup - Lists
structuralMarkupReaders	Structural Markup - eReader application
tableMarkup	Table Markup
hyperlinkActive	Hyperlinks Rendered As Active
color	Colors Compatible With Assistive Technology
contrast	Contrast Ratio of at Least 4.5:1
imageAltText	Non-Decorative Images Have Alt Text
decorativeImages	Decorative Images Marked With Null Alt Text
complextImageText	Complex Images, Charts, and Graphs Have Text Descriptions
multimediaTextTrack	Multimedia - Text track
multimediaTranscript	Multimedia - Transcript
multimediaAccessiblePlayer	Audio/Video Delivered Via Media Player
noFlickering	Non Flickering Content
stemMarkup	STEM Content (e.g. Mathematics, Chemistry) Markup
stemNotationMarkup	STEM - Notation markup
keyboardInteractive	Interactive - Keyboard
interactiveMarkup	Interactive - Markup
interactivePromptText	Interactive - Text prompts

5.2 Quality Evaluation of OER Metadata

Many OER repositories (e.g., MIT[2], Khan Academy[3]) are hosting and launching millions of OER under Creative Common license[4] on a daily basis. However, the lack of high-quality services, such as OER search and recommendation systems, limit the discovery and use of OER [11, 145, 94]. In order to provide such services, high-quality metadata that describe OER thoroughly and reliably are essential [112]. Although most of the OER repositories are using standardized metadata definitions (e.g., LOM [124] and LRMI [127]) to improve open educational services, the lack or low-quality of metadata still limit the performance of these initiatives [146, 147].

Most of the literature about OER metadata quality focused on metadata records and their data values [148]; they can be categorised into: 1) research defining dimensions and metrics for metadata, and 2) approaches that improve the quality of metadata. Currently, the following dimensions have been proposed to determine the quality of OER metadata: *completeness, accuracy, provenance, consistency, coherence, timeliness*, and *accessibility* [149]. Ochoa and Duval [150] have defined a set of calculated metrics based on the dimensions, which have been widely reused by researchers addressing OER metadata quality [151]. Moreover, they evaluated the metrics regarding *completeness and accuracy* on *425* OER from the ARIADNE Learning Object Repository [147]. Palaez and Alarcon have evaluated the completeness and consistency of OER metadata based on Ochoa and Duval's metrics [150] and the standardized domain values (e.g., language should be according to *ISO 639-111* language standard) [152].

To have high-quality metadata, some methods have been developed in order to help authors and experts in providing metadata for OER. A process for improving the metadata quality of OER was developed to support domain experts with metadata creation; the process introduces qualitative methods (e.g., online peer review of metadata) and tools (e.g., metadata quality assessment grid) in the various phases when it comes to populating metadata in OER repositories [153]. Furthermore, a higher level of metadata quality analysis was applied to help metadata creators to assess and improve the quality of metadata [148]. They exploit linked open data to discover and analyze connectivity between metadata records. Accordingly, they used network statistics (e.g., density of graph) to calculate the relationship between the metadata records in terms of their attributes (e.g. subject) and values. Their study was applied on six large digital library collections and they discussed several improvements that can help users find related resources.

5.2.1 Metadata Analysis of Open Educational Resources

This section summarizes the collaborative work done with our colleagues at German National Library of Science and Technology (TIB).

We built an OER metadata dataset after retrieving all search results for the terms ”Information Technology” and ”Health Care” via the *SkillsCommons API* [154] resulting in a metadata pool of 8,887 open educational resources[5]. Each OER contains the following metadata: url, title, description, educational type, date of availability, date of issuing, subject list, target audience-level, time required to finish, accessibilities, language list, and quality control (a categorical value that shows if a particular

[2] https://ocw.mit.edu/
[3] https://www.khanacademy.org/
[4] https://creativecommons.org/
[5] Our dataset can be downloaded from: https://github.com/rezatavakoli/ICALT2020_metadata

OER went through manual quality control or not). We used our dataset to explore the availability of metadata values, which are related to the category quality control (”with control” or ”without control”). Table 5.3 shows an example of OER metadata describing educational resources in the dataset. Our analysis showed a clear increase in OER metadata quality (in terms of *availability* of metadata) in the quality controlled OER, which can be interpreted as a result of OER quality control.

Table 5.3: Example of OER metadata extracted from SkillsCommons API

Metadata	Value
id	2933
title	CGS1061 Introduction to Computers
description	This course is designed to provide complete coverage of computer basics, including computer hardware and components, operating system software, application software, networks, and the Internet. The course is organized into three modules, with each module matching the three tests of the IC3 certification. The module lessons are introduced in a logical progression to build on previously learned concepts and features. Students will be prepared to take each module exam working toward the IC3 certification.
url	https://www.skillscommons.org//handle/taaccct/2933
type	Online Course
availability_date	2013
issued_date	
subjects	['Online College Course', 'Information Technology']
level_availability	available
time_required_availability	available
accessibilities	['textAccess', 'textAdjustmentCompatible', 'textAdjustable', 'readingLayoutCompatible', 'readingLayoutPageNumbers', 'readingLayoutPageNumbersAlt', 'readingOrder', 'structuralMarkupText', 'structuralMarkupLists', 'structuralMarkupReaders', 'tableMarkup', 'hyperlinkActive', 'color', 'contrast', 'languageMarkup', 'languageMarkupAlt', 'imageAltText', 'decorativeImages', 'complextImageText', 'multimediaTextTrack', 'multimediaTranscript', 'multimediaAccessiblePlayer', 'noFlickering', 'stemMarkup', 'stemNotationMarkup', 'keyboardInteractive', 'interactiveMarkup', 'interactivePromptText']
languages	['en_US']
quality_checking	With Checking

5.2.2 OER Metadata Scoring Model

As the first step when building our scoring model, we defined the importance of each metadata field based on those open educational resources, which went through quality control. We set the importance rate of each metadata field according to its availability rate among quality controlled OER (between 0 and 1). For instance, all quality controlled OER have a *title* and therefore, we set the importance rate of *title* to 1, and for *Time Required*, we set it to 0.58 since 58% of the controlled OER have *Time Required* metadata. Moreover, we normalised the calculated importance rates as normalized importance rate. Afterwards, for each field, we created a rating function in order to rate metadata values. We fit a normal distribution on values (lengths) of the following metadata fields: *title, description, and subjects*, as they have distributions similar to normal and used the reverse of *Z-score* concept (as $\frac{1}{\lceil |x-\bar{x}|/s \rceil}$ where $\bar{x}$ and s is the mean and standard deviation respectively of the field in the dataset) to rate the metadata values based on the properties of the quality controlled OER. Thus, the closer an

OER *title/description/subjects* length is to the mean of distributions, the higher is the rate. It should be mentioned that when a value is equal to the mean, the rate will be 1, and when it is empty, the rate will be 0. Moreover, we used a boolean function for the four fields: *level, length, language, and accessibility*, which assigns 1 when they have a value and assigns 0 otherwise.

Finally, we defined the following two scoring models in order to cover the availability and adherence of the defined benchmarks:

Availability Model. We calculate the availability score of an OER o as Equation (5.1) where $norm\_import\_rate(k)$ is *Normalized Importance Rate* of metadata field k. This score shows how complete that metadata is in a weighted summation, in which the normalized important rates are the weights. Therefore, the more an OER contains important fields, the higher the availability score is. For instance, an OER with metadata about *title*, *description* and *level* (metadata fields with the highest importance rates), achieves a higher availability score than another one which has metadata for *subjects*, *time required*, and *accessibilities*.

$$avail\_score(o) = \sum_{k=available fields} norm\_import\_rate(k) \tag{5.1}$$

Normal Model. We calculate the normal score of an OER o as Equation (5.2), where $norm\_import\_rate(k)$ is the *Normalized Importance Rate* of metadata field k, and *rating(o, k)* is the assigned rating to OER o based on the rating function of k. This score shows how close metadata to the defined benchmark is (based on metadata of the OER with quality control). With this scoring model, an OER with the most similar metadata properties to the metadata of quality controlled OERs achieves the highest normal score.

$$norm\_score(o) = \sum_{k=fields} norm\_import\_rate(k) * rating(o, k) \tag{5.2}$$

5.2.3 Predicting the quality of OER based on their metadata

We used 80% of our data as a training set and trained a machine learning model to predict the quality of OER based on their metadata and our scoring model. Therefore, we got the OER "with control" as higher quality class (containing 4,651 OERs), and set the remaining as lower quality class (containing 4,236 OERs). As a classifier, a Random Forest model was trained to make a binary decision (i.e., high-quality or low-quality) based on the fields: *Importance score, Availability Score, Level Metadata Availability, Description Length, Title Length, and Subjects Length*. We built a test set using the remaining 20% of data. The classifier achieved an accuracy of **94.6%**, where 95% of F1-score for "with control" class, and 94% of F1-score for "without control" class[6]. Moreover, we extracted the importance value of each feature for the classification task. The importance values reveal the effect of each feature in our prediction model. The model assigns the highest value to the *Availability Score* and *Normal Score* features, which are the indicators we proposed. Thus, we can infer that these two indicators can illustrate the quality of OER metadata.

[6] The implementation steps and results in Python can be downloaded from: https://github.com/rezatavakoli/ICALT2020_metadata

5.3 OER Accessibility Quality Analysis and Recommendation

We used the SkillsCommons dataset to analyze the accessibility metadata. Figure 5.1 summarized the availability of accessibility metadata with respect to the availability of quality control checks for an OER. We analyzed 8,887 resources; 52% of these resources have been checked for quality, while 48% of them did not pass a quality control test as per the information collected from the metadata. Among the 52% resources, 31% of them contain accessibility metadata. Among the 48%, only 3% of them contain metadata. As concluded from our analysis of data, if the resources are quality controlled, the probability that they provide accessibility metadata is higher than the others that are not quality controlled. Figure 5.2 summarizes the metadata of the resources that contained accessibility metadata. For instance, the most commonly used metadata is *textAdjustmentCompatability* 84.2%, and *stemMarkup* is the least used parameter 23.8%. In Chapter 7, we will explain in more detail the use of these parameters and how we used them to evaluate the accessibility of OER and recommend material to learners.

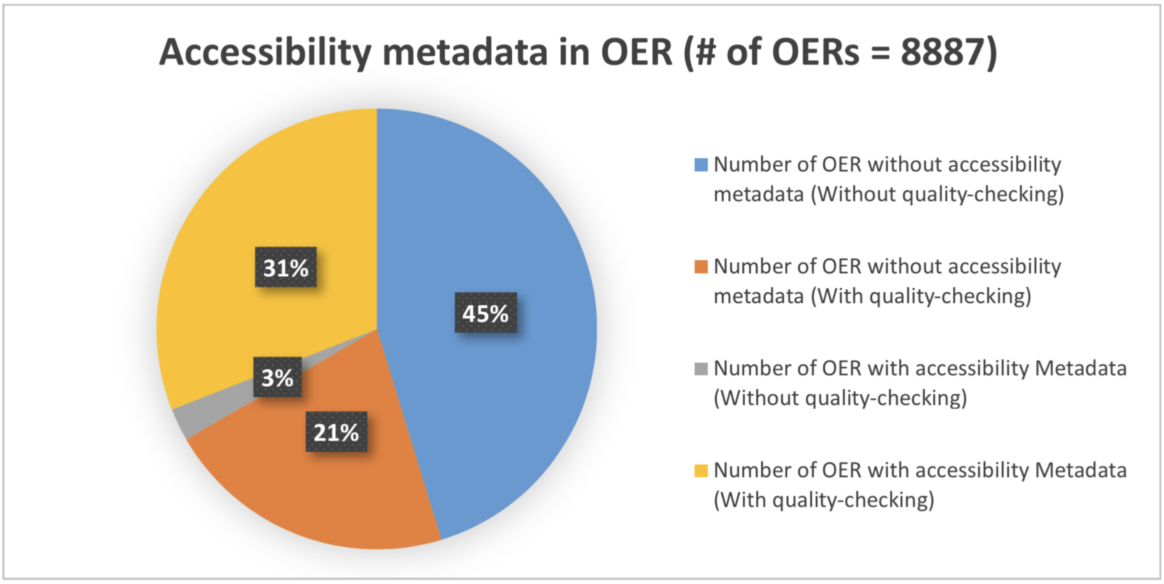


Figure 5.1: Analysing the availability of accessibility metadata in SkillsCommons dataset

5.4 Recommendation Engine

This part took place in eDoer[7] Educational portal, which focuses on recommending OER to learners based on their job and targeted skills. To predict the quality of OER, we used the above approach that creates a scoring model for OER metadata, and a prediction model of OER quality based on their metadata. The study showed that there is a tight relationship between OER metadata quality and OER quality control processes, in such a way that the more an OER passes quality control processes, the higher is the probability of containing high-quality metadata. Accordingly, the model predicts whether

[7] https://labs.tib.eu/edoer/

an OER passed the quality control process or not based on its metadata. Therefore, we applied this prediction model to the collected educational resources and removed the ones indicated as *Without Quality Control*.

In order to include accessibility in our OER recommender engine, we create a 28-dimensional vector of X (according to the available accessibility list, as shown in Table 5.2) for each OER regarding their accessibilities. For this, when an OER has specific accessibility, we set its corresponding value in the list to 1, otherwise set the value to 0. Respectively, for each learner, we define a 28-dimensional vector P as a preference vector based on his/her accessibilities preferences that contain a float weight (between 0 and 1) for each parameter in X. The goal is to find the best weights (P vector) for each learner based on their rating satisfaction. Therefore, we use *Gradient Descend* to optimize the preference vector (P) based on users' ratings by minimizing the following loss function:

$$LossFunction = \sum_{o=recommended\_OERs} |(P \cdot X_o) - Y_o| \tag{5.3}$$

where X_o is the 28-dimensional vector of an OER o and Y_o is the satisfaction rating (between 0 and 1) of the learner for that particular OER o. Finally, to recommend an OER to a learner u for a particular skill s, our system checks the available OER according to the learner's occupation and the level that learner u has in skill s, and calculates cosine similarity for them to recommend the OER with the closest X vector to the user preference vector (P).

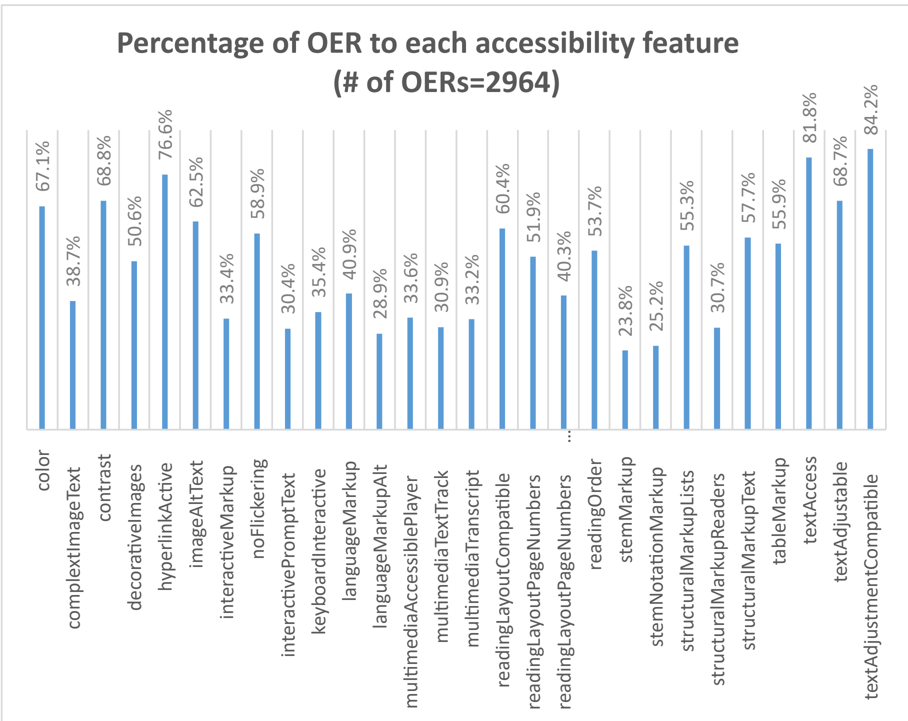


Figure 5.2: Analysing accessibility metadata parameters in SkillsCommons dataset

5.5 Summary

This chapter studied and analyzed the quality and accessibility of the metadata of OER. First, we analyzed the metadata of OER and focused on the metadata parameters that various metadata standards and guidelines use to express accessible features of OER. Second, we discussed how the quality of the metadata of OER and the quality of its content could be related to one another.

We described the approach used for analyzing metadata and predicting the quality of OER accordingly. This approach was built on a large OER dataset collected and analyzed to provide deeper insights into OER metadata quality. A scoring and a prediction model were proposed to evaluate the quality of OER metadata and, as a consequence, OER content quality. Applying the model to the Skillscommons dataset indicated that it can detect OER with quality control with the accuracy of **94.6%**. We analysed the accessibility metadata (i.e., 28 parameters) of the Skillscommons dataset of the OER with quality control. We tested and evaluated the accessibility of the content of these OER and found a relation between the accessibility of the OER and the quality of describing its accessibility metadata. The evaluation and results are discussed in detail in Chapter 7.

Part III

Semantic Representation of Accessibility in OCWs

CHAPTER 6

Semantic Representation of Accessibility in OCW

This chapter demonstrates how the accessibility requirements of OCW are semantically represented. Semantic web technologies (i.e., ontology) aim to represent domain knowledge in a machine-readable way to allow sharing, querying and inference of data, and integration with open linked data; as introduced in Section 6.1. Section 6.2 explains how we developed the AccessibleOCW ontology and Section 6.3 describes in the detail the concepts and properties that define the accessibility needs of learners, and accessibility features of OER. The AccessibileOCW ontology is openly accessible and queryable at VoCol[1]. Section 6.4 describes how the learner class is defined in triples using Turtle. Section 6.5 describes OER examples using the ontology definitions. Section 6.6 proposes learner profiles with recommended OER features. Finally, Section 6.7 evaluates the profiles by personas and SPARQL query.

Related publications

- **Mirette Elias**, Steffen Lohmann and Sören Auer. *Ontology-based Representation of Learner Profiles for Accessible OpenCourseWare Systems.* In 8th International Conference on Knowledge Engineering and Semantic Web (KESW) 2017 Proceedings, 279-294, Springer.

- **Mirette Elias**, Steffen Lohmann, and Sören Auer. *Towards an Ontology-based Representation of Accessibility Profiles for Learners.* In 2nd International Workshop on Educational Knowledge Management (EKM) 2016 Proceedings. Co-located with 20th International Conference on Knowledge Engineering and Knowledge Management (EKAW), EKM@EKAW 51-59, CEUR Workshop Proceedings.

- **Mirette Elias**, Steffen Lohmann, and Sören Auer.*Fostering accessibility of OpenCourseWare with semantic technologies – a literature review.* In 7th International Conference on Knowledge Engineering and the Semantic Web (KESW) 2016 Proceedings, 241-256, Springer.

[1] https://vocol.iais.fraunhofer.de/accessibilityOnto/

6.1 Semantically Describing Accessibility in OCW using Ontologies

The goal of adopting ontologies is to express domain-specific knowledge in a machine-understandable language that can be used for further research and analysis purposes (e.g., data simulation, deep learning, question-answering). RDF standards represent the domain concepts, relationships, and instances into web resources URI, that can be globally accessed and linked with other ontologies, known as Open Linked Data. Thus, we've decided to use ontologies to semantically represent the accessibility requirements of OCW. The main advantage is that it enables OCW platforms to use our ontology to explain accessibility in their platforms, as well as other researchers to extend and reuse our ontology in other domains. The ontological representation of accessibility needs in OCW is still not widely addressed, according to our review of the state-of-the-art in Chapter 3, as well as representing accessibility needs as capabilities to address the inherent complexity on the unique effects of various types of disabilities on people.

In the following sections, we explain 1) how we analyzed the accessibility needs and preferences of OCW, 2) how we developed the ontology, and 3) how we queried the ontology to retrieve accessible educational resources based on learner profiles.

6.2 Ontology Development Methodology

In order to develop the AccessibleOCW ontology, we followed the ontology development life cycle of METHONTOLOGY [155], as illustrated in Figure 6.1. We followed and adapted the stages and activities to build our ontology as follows:

OCW and reuse it for resource recommendation. Researchers and OCW software engineers are the intended users of this ontology, with the purpose of reusing it to reflect learners' accessibility unique demands and accessibility features of educational resources OER to aid in semantic search and resource recommendation.

2. Conceptualization. Design a conceptual model that represents the domain of ontology. We analysed the state-of-the-art in terms of accessibility guidelines and standards, as well as ontologies

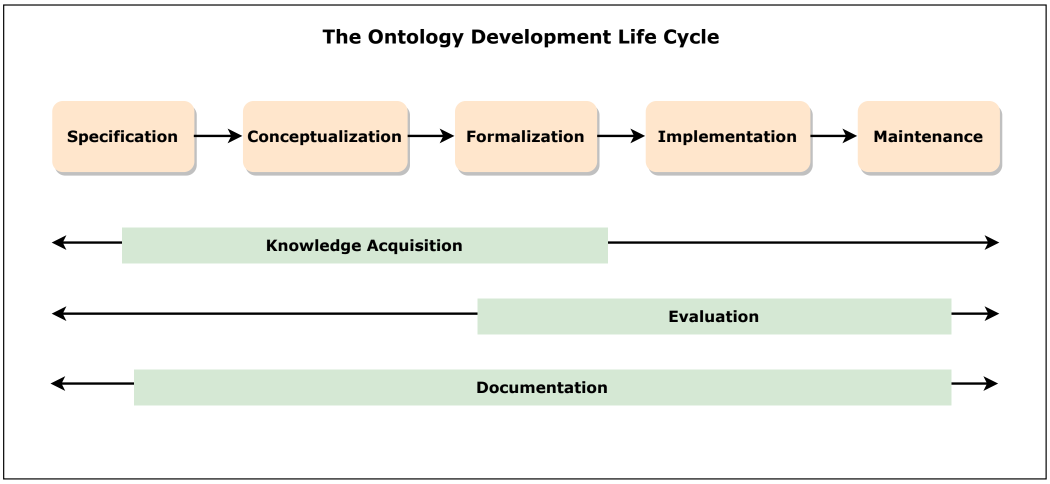


Figure 6.1: The ontology development life cycle stages and activities of METHONTOLOGY

that represent accessibility in e-learning and other domains (as mentioned in Chapter 3). As a result, we decided to reuse the concepts of ACCESSIBLE ontology [59] to describe the accessibility needs of learners. The ACCESSIBLE ontology uses the ICF categorization to represent various forms of disabilities and associated accessibility requirements when utilizing websites and mobile applications. On the other hand, we decided to describe the accessibility aspects of learners, and educational resources using the IMS AfA specifications [52]. We started by sketching the main concepts and relationships and iteratively developing the AccessibleOCW ontology.

3. Formalization. Describe the ontology in more detail. We defined the main concepts of the previous stage more precisely, hierarchies and restriction axioms, to emphasise the meaning and relationships of the ontology. We developed the ontology by parsing the IMS AfA specifications and schema documents to create the classes, properties, relationships, and individuals. We focused on two specifications: IMS Global Access for All Personal Needs and Preferences (AfA PNP) [53] and IMS Global Access For All Digital Resource (AfA DRD) [54]. AfA PNP specification is designed to suit the need of learners with disabilities with the goal of providing a machine-readable way (i.e., XML) to express learner needs and preferences for digitally based education and learning [53]. AfA DRD describes features of digital resources that can be modified to improve accessibility [54]. AfA PNP can be used in conjunction with AfA DRD to provide digital resources that match learners' needs and preferences.

4. Implementation. Implement the ontology in a formal representation (e.g., OWL, RDF). We used Protégé[2] software application to create the ontology as defined in the previous stage. We added instances of learners using personas defined at WAI [156] and educational resources examples from SkillsCommons[3] platform as it provides accessibility metadata to the educational resources. We used SWRL to emphasise rules and conditions, and SPARQL to query and evaluate the results.

5. Maintenance. Edit and update the ontology. We maintained the ontology after reviewing and getting feedback from accessibility, OCW and ontology experts. The ontology is maintained to the latest available versions of AfA specifications. The learner profile follows the AfA PNP (Public Candidate Final 2.0, 18th January, 2021)[4]. The education resource description follows the AfA DRD (Version 3.0 Specification Public Draft 1.0, 13th September, 2012)[5]

During the development of AccessibleOCW ontology, three activities were working throughout the development life cycle:

1. Knowledge Acquisition. This stage takes part along all the previous stages, where domain knowledge is collected, and interviews with experts were conducted. We began by reviewing the current state-of-the-art and identifying relevant standards and ontologies. Following that, we worked on the ontology in batches, beginning with 1) identifying learner accessibility preferences, 2) describing OER accessibility features, and 3) specifying the relationships between them. We reviewed the ontology with domain experts to collect requirements and feedback along its development. This was accomplished by analyzing the documentation and parsing the XML files for the AfA PNP and AfA DRD specifications, as well as the best practices to construct a match between learner preferences and education resources features.

[2] https://protege.stanford.edu/

[3] http://www.skillscommons.org/

[4] https://www.imsglobal.org/sites/default/files/spec/afa/3p0/information_model/imsafa3p0pnp_v1p0_InfoModel.html#Ref_AfADRD21

[5] https://www.imsglobal.org/accessibility/afav3p0pd//AfA3p0_DRDinfoModel_v1p0pd.html

2. Evaluation. Evaluating the technical quality of the ontology. The ontology was evaluated by collecting feedback from the domain (i.e., accessibility and open education experts) and ontology experts. The ontology was evaluated when we created the knowledge graph and included OER datasets and ran SPARQL queries to retrieve data; this will be discussed in Chapter 7.

3. Documentation. The documentation was done within the ontology definition to make it understandable and reusable by others. The documentation of AccessibleOCW ontology[6] is publicly available to help others to understand the ontology and reuse its concepts.

6.3 AccessibleOCW Ontology

AccessibleOCW ontology formalizes the needs and preferences of learners, together with the properties of the educational resources, in order to provide a standard representation and allow the reuse of these concepts. The ontology provides a structured schema for defining the metadata of the learner's profile and educational resources. One of the advantages of employing an ontology is that its concepts can be reused and extended in other applications, in our instance, in the context of e-learning and OCW in particular. Because we built our AccessibleOCW ontology using the IMS AfA specification, it may be utilized as a schema for representing the fundamental concepts of OCW in other systems.

AccessibleOCW ontology is currently composed of 16 classes. It is openly available and deployed on VoCol[7] [157] and GitHub[8]. The ontology contains two main classes: `Learners` and `Digital Resources` with their relevant properties, and other classes that are used to describe the different representations of the educational resources and preferences of the learners. We are reusing the ACCESSIBLE ontology to represent domain knowledge of disability types, characteristics, and functional limitations, as well as the WCAG accessibility guidelines and checkpoints.

ACCESSIBLE ontology is a result of ACCESSIBLE Project (Accessibility Assessment Simulation Environment for New Applications Design and Development), which is part of the EU's 7th Framework Program for Research and Technological Development (FP7) and aims to define a comprehensive European Assessment Simulation Environment [158]. ACCESSIBLE ontology is composed of three main ontologies: 1) Generic ontology, the core ontology that expresses impairments, disabilities, and functional limitations of persons as per the definition of ICF [48], and it imports the other ontologies, 2) Domain-specific ontologies that include ontology for WCAG 2.0 guidelines and checkpoints and device ontology (e.g., braille, speech devices), and 3) Rules ontology contains a set of rules based on SWRL to connect between the generic and domain-specific ontologies, for example, in the case of a color-blind user, success criterion 1.4.6 of WCAG 2.0 requires to check if the foreground and background color (or image) has a contrast ratio of at least 7:1 [159].

In the following sections, we explain in more detail the concepts and properties of our AccessibleOCW ontology, as illustrated in Figure 6.2. It is divided into three sub-sections: Section 6.3.1 explains all data and object properties related to learners, Section 6.3.2 explains all the data and object properties related to educational resources, and Section 6.3.3 explains all other related classes created to support the IMS AfA specifications and link the learner and educational resources together. The AccessibleOCW's classes and attributes are defined by the prefix `aocw`, additional prefixes are used to refer to other ontologies as well.

[6] http://accessibility.semantic-interoperability.org/
[7] http://vocol.iais.fraunhofer.de/accessibilityOnto/
[8] https://github.com/EIS-Bonn/Accessibility

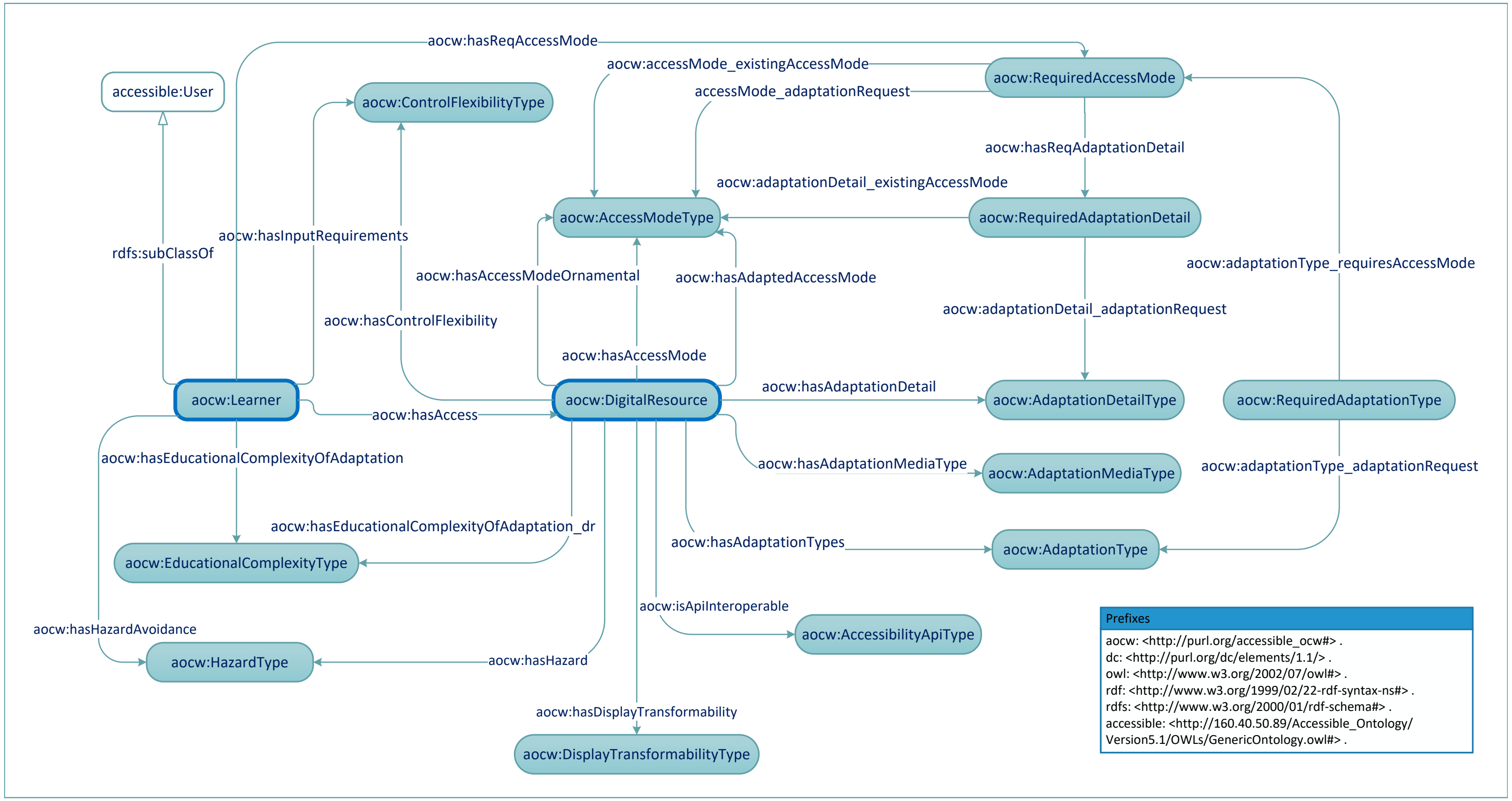


Figure 6.2: AccessibleOCW ontology

6.3.1 Learner Class Representation

The `aocw:Learner` class describes the properties of learners together with their needs and preferences. It is a subclass of the `accessible:User` class of the ACCESSIBLE ontology [59], which contains the characteristics of users with accessibility needs. The `aocw:Learner` class has various properties: 1) properties that are inherited from the `accessible:User` class [160], and 2) properties that are created to incorporate accessibility concerns in e-learning in compliance with the AfA PNP specifications. The properties are defined as follows:

1. `accessible:hasName` data property of type string and refers to the user's name.

2. `accessible:hasAge` data property of type integer and sets the age of the user. We have overwritten this property with the data property `aocw:hasBirthDate` of type timedate in order to provide updated data of the users.

3. `accessible:hasEducation` data property of type string to set the education of the user. We replaced this property with the data type property `aocw:hasEducationalLevelOfAdaptation`, which indicates the educational level of the learners; at best, it should refer to a specific educational system definition (e.g., ASN Educational Level Vocabulary[9]). The property helps in guiding learners to the most appropriate educational resources with respect to their educational level.

4. `accessible:hasJob` data property of type string identifies the job title of the user.

5. `accessible:hasLocation` data property of type string to specify the location of the user (e.g., city, country).

6. `accessible:hasMaritalStatus` data property of type string indicates the marital status of the user.

7. `accessible:TechnologyUsage` data property of type string that describes the user's usage of technology in a narrative and detailed way (e.g., the devices, configurations and preferences defined by a user).

8. `aocw:isAtInteroperable` data property of type boolean indicates that a user uses assistive technologies; when true, the user should be guided to educational resources that are compatible with assistive technologies. The value of `aocw:isAtInteroperable` can be inferred from the properties of ACCESSIBLE using SWRL rules. We created the Rule 6.1 to deduce the *true* value of `aocw:isAtInteroperable` property if the user has a disability `User_has_Disability` and this disability type is using an assistive technology device `accessible:Disability_has_Device`.

9. `aocw:hasLanguageOfAdaptation` data property of type language expresses the language used by the learner and the expected language of the educational resources. The IMS specification requires using RFC 4646 (Tags for identifying Languages); this can be defined by Dublin Core `dcterms:RFC4646`. However, we use `xsd:language` because RFC 4646 is obsoleted by RFC

[9] http://purl.org/ASN/scheme/ASNEducationLevel/

5646 as per DCMI Metadata Terms[10]. Thus, we decided to use `xsd:language` that sets the language codes defined by RFC 1766, which is till valid (e.g., en, en-US, fr, or fr-FR).

10. `aocw:hasLanguageOfInterface` data property of type language represents the preferred language of the website interface.

11. `aocw:hasEducationalComplexityOfAdaptation` object property connects `aocw:Learner` and `aocw:EducationalComplexityType` classes. It represents the level of difficulty that a learner can handle (i.e., simplified material, enriched material).

12. `aocw:hasReqAccessMode` object property links between `aocw:Learner` and `aocw:RequiredAccessMode` classes. It is the learner's preferred means of access. Thus, the resource content is represented in the way that the learner wants. For example, if the resource is visual, a learner might prefer a textual representation (e.g., If a resource's existing access mode is auditory, `aow:auditory_textual` instance indicates that the required adaptation representation is textual).

13. `aocw:hasReqAdaptationDetail` object property connects the classes `aocw:Learner` and `aocw:RequiredAdaptationDetail`. It defines the fine detail of the required adaptation types, such as verbatim. For example, if an educational resource is auditory, the learner may request a text format; the text can be verbatim, which extracts an audio transcript word by word.

14. `aocw:hasHazardAvoidance` object property connects the classes `aocw:Learner` and `aocw:HazardType`. It denotes the user's desire to avoid specific material that contains potentially hazardous aspects such as motion or flashing.

15. `aocw:hasInputRequirements` object property relates the classes `aocw:Learner` and `aocw:ControlFlexibilityType`. For example, a learner can select either to fully use a keyboard or a mouse for input control.

16. `aocw:hasAccess` object property links the `aocw:Learner` class with the `aocw:DigitalResource` class that is used to filter the accessible educational resources according to the user requests and preferences.

```
User_has_Disability(?user, ?disability) ^ Disability_has_Device(?disability, ?
    device) -> isAtInteroperable(?user, true)
```

Listing 6.1: **SWRL Syntax.** A rule that infer the value of `aocw:isAtInteroperable` based of the user disability and device usage.

6.3.2 OER Class Representation

The `aocw:DigitalResource` class defines the properties of an individual educational resource (i.e., OER). We defined the educational resources classes and properties based IMS AfA Digital Resource Description (DRD) specification. The AfA DRD specifications implement the main guidelines of WCAG 2.0. It defines properties of educational resources such as, the complexity of content, language

[10] https://dublincore.org/specifications/dublin-core/dcmi-terms/#RFC4646

of content, and compatibility with assistive technologies. We developed the following data properties to describe educational resources (we call it digital resource as it is called in the AfA DRD specification).

1. `aocw:hasURI` data property of URI type; it specifies the URL of the digital resource.
2. `aocw:hasAccessMode` object property connects the classes `aocw:DigitalResource` and `aocw:AccessModeType`. It establishes the format in which educational resources are represented (e.g., text, visual, auditory).
3. `aocw:hasAccessModeOrnamental` object property connects the classes `aocw:DigitalResource` and `aocw:AccessModeType`. It describes the access mode (i.e., representation) of the decorative content of resource or adaptation.
4. `aocw:hasAdaptation` data property of URI type. It specifies an adaptation's resource identifier for this resource. An educational material, for example, could have both original visual access modes and an alternative text representation.
5. `aocw:hasAdaptedAccessMode` object property connects the classes `aocw:DigitalResource` and `aocw:AccessModeType`. It represents a resource's adaptation access mode (e.g., visual); the type of adaptation is confined to the instances of `aocw:AccessModeType` class.
6. `aocw:hasAdaptationType` object property connects the classes `aocw:DigitalResource` and `aocw:AdaptationType`. This property describes the type of resource adaptation (e.g., captions, transcript) if the resource has one. The type of adaptation is confined to the instances of `aocw:AdaptationType` class.
7. `aocw:hasAdaptationDetail` object property connects the classes `aocw:DigitalResource` and `aocw:AdaptationDetailType`. It specifies the fine detail of one or more adaptation type values (e.g., verbatim). The type of adaptation is confined to the instances of `aocw:AdaptationDetailType` class.
8. `aocw:hasAdaptationMediaType` object property connects the classes `aocw:DigitalResource` and `aocw:AdaptationMediaType`. It identifies the media type that is typically used to group accessibility features or functions (e.g., Braille). The media type of adaptation is confined to the instances of `aocw:AdaptationMediaType` class.
9. `aocw:hasControlFlexibility` object property connects the classes `aocw:DigitalResource` and `aocw:ControlFlexibilityType`. It specifies a single input technique that is adequate for controlling the resource (i.e., fullKeyboardControl, fullKeyboardControl).
10. `aocw:hasDisplayTransformability` connects the classes `aocw:DigitalResource` and `aocw:DisplayTransformabilityType`. It identifies a display feature of the provided resource that can be changed programmatically (e.g., font size, background color); defined by the instances of `aocw:DisplayTransformabilityType` class.
11. `aocw:hasEducationalComplexityOfAdaptation_dr` object property connects the classes `aocw:DigitalResource` and `aocw:EducationalComplexityType`. It defines the level of difficulty of the resource content(i.e., simplified material, enriched material).

12. `aocw:hasHazard` object property connects the classes `aocw:DigitalResource` and `aocw:-HazardType`. It denotes the presence of hazard elements in the resource (e.g, flashing).

13. `aocw:hasLanguageOfAdaptation_dr` object property connects the classes `aocw:Digital-Resource` and `aocw:LanguageModeDType`. It defines the language of the resource content.

14. `aocw:isAdaptationOf` data property of URI type. If this resource in an adaptation of another resource, this property specifies the original resource URI.

15. `aocw:isApiInteroperable` object property connects the classes `aocw:DigitalResource` and `aocw:AccessibilityApiType`. It indicates that the resource is compatible with the referenced accessibility API (e.g., Android accessibility).

16. `aocw:isAtInteroperable_dr` data property of type boolean indicates that a resource is compatible with assistive technologies.

17. `aocw:isFullAdaptationOf` data property of URI type. It specifies the resource URI that has been fully adapted by the stated resource.

18. `aocw:isPartialAdaptationOf` data property of URI type. It specifies the resource URI that has been partially adapted by the stated resource.

6.3.3 Related Accessibility Classes

In this section, we explain more classes and instances that were developed based on the specifications of AfA PNP and AfA DRD. These classes are linked to `aocw:Learner` and `aocw:DigitalResource` classes via object properties as stated in the previous sections.

1. `aocw:AccessModeType` class defines the representation value, either for the resource or the requirements of the learner. The instances of this class include: `auditory`, `colour`, `itemSize`, `textual`, `visual`, `position`, `tactile`, and `textOnImage`.

2. `aocw:RequiredAdaptationType` class describes the type of the adaptation required for special types of representations (e.g., if `auditory_caption` is set for an auditory format, an adapted caption is required).

3. `aocw:AdaptationType` class represents the available types of adaptations. The instances of this class include: `alternativeText`, `audioDescription`, `captions`, `e-book`, `haptic`, `highContrast`, `longDescription`, `signLanguage`, and `transcript`.

4. `aocw:ControlFlexibilityType` class describes the input requirements of the learners and resources, i.e., whether `fullKeyboardControl` or `fullMouseControl`.

5. `aocw:EducationalComplexityType` class defines the level of complexity required by the learners and provided by the resources (e.g., `simplified`, `enriched`).

6. `aocw:HazardType` class describes modes that should be avoided for some users, such as flashing, motionSimulation, olfactoryHazard, and sound.

7. `aocw:RequiredAccessMode` the recommendation resulting from querying the ontology and the preference selected by the user.

8. `aocw:DisplayTransformabilityType` class defines those components of a resource that can be programmerly adapted. The instances of this class include `backgroundColour`, `cursorPresentation`, `fontFace`, `fontSize`, `fontWeight`, `foregroundColour`, `highlightPresentation`, `layout`, `letterSpacing`, `lineHeight`, `structurePresentation`, `wordSpacing`.

9. `aocw:ReplacesAccessMode` class is a newly defined class in AfA PNP (Public Candidate Final 2.0, 18th January, 2021). Since the most recent release of AfA DRD was 2012, this class and its sub classes have yet to be specified in terms of educational resources. However, we added it to the ontology to ensure that it follows the most recent definition of the IMS Specifications, and that future improvements can be made after the new versions are released. The class has the following sub classes `AdditionalTestingTime`, `Braille`, `Environment`, `InvertDisplayPolarity`, `LanguageMode`, `LineReader`,`LongDescription`, `Magnification`, `Spoken`, and `TextAppearance`.

6.4 Learner Profiles Definition

We created five learner profile examples to describe the different needs and preferences of learners based on the AccessibleOCW ontology. Each profile represents a type of disability with its recommended preferences. These profiles were created by analyzing the features and properties of users defined in the following two resources: (i) GPII [161], an infrastructure proposed by an international consortium to provide auto-personalization for different types of device interfaces, and (ii) the accessibility needs of learners in massive open online courses (MOOCs) [162]. Both resources use WCAG2.0 guidelines to categorize and define the types of user needs and preferences. The five profiles are categorized as follows:

1. *Blindness*. This category includes totally blind users, where text cannot be read by any means of magnification. In this category, learners require full-control keyboards as input devices. Content with flashing sound and motion simulation should be avoided. Assistive technologies are used, such as screen and Braille readers. In terms of the digital resource recommendations, learners would always require an alternative textual or auditory description for any visual or audio representation (alternative text for an image, transcript for audio files, etc.).

2. *Low Vision*. This category includes users with low sight and color-blind users. Learners with low vision share several preferences with blind learners, but they also require zooming for text and visual objects, which means that a digital resource should allow zooming while preserving the content structure.

3. *Deaf and Hard of Hearing*. This category includes users with no or too little hearing. A learner might require sign language instead of textual materials.

4. *Cognitive, Language, and Learning Disabilities*. This category includes users with low literacy. Learners with cognitive impairments often prefer simplified versions of educational material and might also require special formatting of text (i.e., specific CSS styling).

5. *Physical Disabilities*. This category includes users with physical function limitations, such as general mobility or the moving of hands and arms. Some learners with physical impairments might require full mouse control.

Listing 6.2 provides a representative example of the blind learner profile. The properties of the learner are defined using the classes and properties of the ACCESSIBLE ontology. The properties and classes of the ACCESSIBLE ontology start with the prefix `acc`. We use the property `User_has_Disability` from the ACCESSIBLE ontology to define the user's disability. This property has a well-defined list of disabilities with respect to the ICF standard classification, as mentioned before. When this property is defined, other properties can be concluded from the ACCESSIBLE ontology, such as the devices that can be used by this type of disability, and the limitations resulting from this disability.

```
@PREFIX : <http://purl.org/accessible_ocw#> .
@PREFIX owl: <http://www.w3.org/2002/07/owl#> .
@PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> .
@PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#> .

:Learner_blindness  rdf:type owl:Class ;
                    rdfs:subClassOf :Learner ;
                    acc:User_has_Disability "Blindness";
                    :hasReqAccessMode :auditory_textual , :auditory_auditory ,
                                  :colour_textual , :orientation_textual ,
                                  :position_textual ,
                                  :textOnImage_textual , :textual_textual ,
                                  :visual_textual , :visual_auditory ;
                     :hasHazardAvoidance :flashing , :sound ,
                                         :motionSimulation ;
                     :isAtInteroperable "true"^^xsd:boolean .
```

Listing 6.2: **Turtle Syntax**. A Learner subclass with total blindness.

6.5 OER Features Definition

For evaluating our digital resources representation, we used examples from the Accessibility Metadata Project [80]. It provides several examples to represent various properties of digital resources based on the IMS AfA properties that are included in *schema.org*. In Listing 6.3, we give an example of a digital resource representation using our ontology. It shows one digital resource with three different representations: video, text, and audio. The source file `digitalResource1` is a video with a visual access mode property. This digital resource is available in two alternative forms for better accessibility: `digitalResource2` is a textual resource that can be tactually accessed, and `digitalResource3` is an auditory resource with full keyboard control.

The main idea is to store the accessibility features of the educational resource (e.g., keyboard access), together with all alternative resources and their properties within the structure described in the ontology. The accessibility features of the educational resource are collected from the OER metadata as explained in Chapter 5. The mapping of these metadata parameters to the AccessibleOCW ontology concepts and properties is explained in Chapter 7 when we generate the knowledge graph. With this structure, we can use rules and queries to filter the resources based on the accessibility needs of learners.

```
@PREFIX : <http://purl.org/accessible_ocw#> .
@PREFIX dc: <http://purl.org/dc/elements/1.1/> .
@PREFIX owl: <http://www.w3.org/2002/07/owl#> .
@PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> .
@PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

:digitalResource1 rdf:type owl:NamedIndividual , :DigitalResource ;
                  :hasAccessMode :visual ;
                  :hasControlFlexibility :fullKeyboardControl ;
                  :hasDisplayTransformability :backgroundColour ;
                  :hasEducationalComplexityOfAdaptation_dr :enriched ;
                  :hashazard :flashing ;
                  :isAtInteroperable_dr "true"^^xsd:boolean ;
                  :hasAdaptation "digitalResource2_URI"^^xsd:anyURI ,
              "digitalResource3_URI"^^xsd:anyURI .

:digitalResource2 rdf:type owl:NamedIndividual , :DigitalResource ;
                  :hasAccessMode :textual ;
                  :hasAdaptedAccessMode :tactile ;
                  :hasAdaptationMediaType :braille ;
                  :hasControlFlexibility :fullKeyboardControl ;
                  :hasEducationalComplexityOfAdaptation_dr :enriched ;
                  :isAtInteroperable_dr "true"^^xsd:boolean ;

:digitalResource3 rdf:type owl:NamedIndividual , :DigitalResource ;
                  :hasAccessMode :auditory ;
                  :hasControlFlexibility :fullKeyboardControl ;
                  :hasEducationalComplexityOfAdaptation_dr :enriched ;
                  :isAtInteroperable_dr "true"^^xsd:boolean ;
                  :isAdaptationOf "digitalResource1_URI"^^xsd:anyURI .
```

Listing 6.3: **Turtle Syntax**. Example of digital resource instances.

6.6 Learner Profiles and Accessible OER

We defined five general learner profiles for five different types of disabilities. Each profile is defined as sub-classes of the *Learner* class with some recommended properties as per the profile of learners. The list of all profiles with their properties and recommended digital resource adaptations is defined in Tables 6.1, 6.2, 6.3, 6.4, and 6.5. The terms used in both tables are the classes and properties defined in AccessibleOCW ontology, which have been adopted from the data element specification of IMS AfA. The properties of the learner include the input requirements (e.g., keyboard, mouse controls), the hazard interface that should be avoided (e.g., flashing, sound, motion simulation), assistive technology usage, educational level of adaptation (e.g., simplified, enriched or complex material), the language and level of education are string values which are left to the learner selection. The recommended digital resources adaptation, as defined in the table, includes the original type of resources and the adaptation requirement for each type of user; for example, a blind user would prefer a text alternative to a visual resource.

We evaluated these learner profiles by a questionnaire to collect the preferences and needs of different types of learners. The main idea of the questionnaire is to validate the preferences which were created for each type of disability and make sure that the digital resource recommended matches the learner's needs. The questionnaire is composed of five questions with a list of answers to select from; participants were also allowed to add their comments and feedback; the questionnaire is attached in Appendix C. We collected the feedback of seven experts; four of them are working with blind and low-vision learners, one of them working with learners with cognitive impairments (in particular, intellectual and neurodevelopmental disabilities), and two experts in the usability and web accessibility field. We got sufficient feedback for the blind and low-vision profiles but not enough feedback for the other profiles, especially for the deaf and physical impairment profiles, in terms of validating them and aligning our ontology. However, the feedback and comments we got are valuable and help in shaping our future work.

Table 6.1: Profile representation of users with total blindness

Learner Profiles (GPII)	Blindness		
General preferences			
Input Requirements	fullKeyboardControl		
Hazard Type Avoidance	flashing, sound, motionSimulation		
Interoperability to AT	true		
Educational Complexity	simplified or enriched		
Digital resource preferences			
Original Access Mode	Required Access Mode	Required Adaptation Type	Required Adaptation Detail
auditory	textual, auditory	transcript, LongDescription	verbatim
colour	textual, auditory	alternativeText	no recommendations
itemSize	no change	no recommendations	no recommendations
orientation	textual, auditory	alternativeText, longDescription	recorded, enhanced, synthesized
position	textual, auditory	alternativeText, longDescription	recorded, enhanced, synthesized
textOnImage	textual, auditory	alternativeText, longDescription	recorded, enhanced, synthesized
textual	textual	no recommendations	no recommendations
visual	textual, auditory	alternativeText, transcript, e-book, audioDescription	enhanced, synthesized, realtime, recorded

Table 6.2: Profile representation of users with low vision

Learner Profiles (GPII)	Low Vision		
General preferences			
Input Requirements	fullKeyboardControl		
Hazard Type Avoidance	flashing, sound, motionSimulation		
Interoperability to AT	true		
Educational Complexity	simplified or enriched		
Digital resource preferences			
Original Access Mode	Required Access Mode	Required Adaptation Type	Required Adaptation Detail
auditory	textual, auditory	LongDescription, transcript	verbatim
colour	visual, textual	highContrast, alternativeText	enhanced
itemSize	visual	[Zooming]	enhanced
orientation	visual, textual, auditory	alternativeText, longDescription	recorded, enhanced, synthesized
position	visual, textual, auditory	alternativeText, longDescription	recorded, enhanced, synthesized
textOnImage	visual, textual, auditory	highContrast, alternativeText or longDescription	recorded, enhanced, synthesized
textual	visual	[Zooming], [CSS]	no change
visual	visual, textual, auditory	highContrast, alternativeText, transcript, e-book, audioDescription	enhanced, synthesized, realtime, recorded

Table 6.3: Profile representation of users with deaf and hard hearing

Learner Profiles (GPII)	Deaf and Hard of Hearing		
General preferences			
Input Requirements	no recommendation		
Hazard Type Avoidance	sound		
Interoperability to AT	true		
Educational Complexity	simplified or enriched		
Digital resource preferences			
Original Access Mode	Required Access Mode	Required Adaptation Type	Required Adaptation Detail
auditory	textual, visual	signLanguage, transcript, caption	enhanced, verbatim
colour	no change	no recommendations	no recommendations
itemSize	no change	no recommendations	no recommendations
orientation	no change	no recommendations	no recommendations
position	no change	no recommendations	no recommendations
textOnImage	visual	signLanguage	enhanced
textual	textual, visual	signLanguage	no recommendations
visual	visual, textual	captions, signLanguage, alternativeText, longDescription	enhanced, verbatim, realTime

Table 6.4: Profile representation of users with cognitive impairments

Learner Profiles (GPII)	Cognitive, Language, and Learning Disabilities		
General preferences			
Input Requirements	fullKeyboardControl		
Hazard Type Avoidance	flashing, sound, motionSimulation		
Interoperability to AT	true		
Educational Complexity	simplified		
Digital resource preferences			
Original Access Mode	Required Access Mode	Required Adaptation Type	Required Adaptation Detail
auditory	auditory, visual, textual	transcript	enhanced, synthesized, symbolic
colour	visual	highContrast, alternativeText	enhanced
itemSize	visual	[Zooming]	enhanced
orientation	visual, auditory, textual	alternativeText	recorded, enhanced, synthesized
position	visual, auditory, textual	alternativeText	recorded, enhanced, synthesized
textOnImage	visual, auditory, textual	highContrast, alternativeText	recorded, enhanced, synthesized
textual	visual, auditory, textual	highContrast, alternativeText	recorded, enhanced, synthesized
visual	visual, textual, auditory	alternativeText, audioDescription, highContrast, transcript	enhanced, synthesized, realtime, recorded, symbolic

Table 6.5: Profile representation of users with physical impairments

Learner Profiles (GPII)	Physical Disabilities		
General preferences			
Input Requirements	fullKeyboardControl, fullMouseControl		
Hazard Type Avoidance	motionSimulation		
Interoperability to AT	true		
Educational Complexity	simplified or enriched		
Digital resource preferences			
Original Access Mode	Required Access Mode	Required Adaptation Type	Required Adaptation Detail
auditory	auditory, visual, textual	transcript	enhanced, symbolic, synthesized
colour	no change	no recommendations	no recommendations
itemSize	no change	no recommendations	no recommendations
orientation	visual	no recommendations	enhanced, symbolic
position	visual	no recommendations	enhanced, symbolic
textOnImage	visual, textual	no recommendations	symbolic
textual	visual, textual	no recommendations	recorded, enhanced, symbolic
visual	visual, textual	no recommendations	recorded, enhanced, symbolic

6.7 Evaluation

There are various methods for evaluating ontologies depending on the type of ontology and the purpose of the evaluation. Brank et al. defined six levels of ontology evaluation: 1) lexical, vocabulary, or data layer, 2) hierarchy or taxonomy, 3) semantic relations, 4) context or application level, 5) syntactic level, 6) structure, architecture, design [163]. Evaluation approaches are classified into: evaluation against a gold standard, application-based evaluation, criteria-based evaluation, and Data-driven evaluation [164]. Each of these approaches addresses one or several evaluation levels. The aim of our ontology is to represent the domain knowledge of accessibility with OCW with the purpose of assisting learners in finding educational material that matches their accessibility profiles. Accordingly, we evaluate the ontology on the context level using application-based approaches (task-based evaluation). The application-based evaluation measures the feasibility of performing tasks within an application. We followed this evaluation by using: 1) personas methodology to evaluate the applicability of representing learner profiles in the ontology, 2) competency questions to evaluate the completeness of expected answers.

We evaluated the ontology using the *personas* methodology. In particular, we used the personas that were created by W3C to test different types of user-centered systems [165]. We selected two personas for the evaluation: a totally blind user and a hard hearing. We used the descriptions to create corresponding instances in our ontology. The classes and properties used are a combination of the ACCESSIBLE ontology, representing the disability types and their characteristics, and the AccessibleOCW concepts representing the accessibility needs in an OCW.

Persona 1 – Ms. Ilya is a blind person. She uses a screen reader and only uses web browsers that can be fully controlled with a keyboard. She did not learn how to use a Braille device. Listing 6.2 shows the user profile of Persona 1. The needs of a blind person are defined by the ontology concepts, where `hasReqAccessMode` states that a textual representation is required for visual resources, and `hasReqAdaptationType` states to use this textual representation instead of the visual one.

Persona 2 – Ms. Martinez is an old woman with hard hearing problems since her birth. She is trained in using sign language next to written language. She has problems with audio material; she requires audio content to have a transcript and videos to have subtitles. Listing 6.5 depicts the representation of Ms. Martinez (Persona 1) in our ontology. The `hasReqAccessMode` of this persona requires textual representations for resources that are of auditory type. For instance, *Persona 1* requires a textual alternative for any visual resource; hence, only `digitalResource2` is an appropriate content format for this learner. Listing 6.8 defines a SPARQL query that retrieves the resources that have the access mode required by a `Learner_blindness` class.

```
@PREFIX : <http://purl.org/accessible_ocw#> .
@PREFIX dc: <http://purl.org/dc/elements/1.1/> .
@PREFIX owl: <http://www.w3.org/2002/07/owl#> .
@PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> .
@PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#> .

:Learner2 a owl:NamedIndividual , :Learner_blindness ;
            acc:hasName "Ms. Ilya"^^xsd:string;
            acc:hasAge "20"^^xsd:int;
            acc:hasJob "Chief accountant"^^xsd:string;
            :hasReqAccessMode :visual_textual;
            :hasReqAdaptationType :visual_alternativeText ,:visual_audioDiscription;
            :isAtInteroperable "true"^^xsd:boolean;
            :hasInputRequirements :fullKeyboardControl.
```

Listing 6.4: **Turtle Syntax**. A Learner class with total blindness and an instance example.

```
@PREFIX : <http://purl.org/accessible_ocw#> .
@PREFIX dc: <http://purl.org/dc/elements/1.1/> .
@PREFIX owl: <http://www.w3.org/2002/07/owl#> .
@PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> .
@PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#> .

:Learner1 a owl:NamedIndividual , :Learner_deaf;
            acc:hasName "Ms. Martinez"^^xsd:string;
            acc:hasAge "62"^^xsd:int;
            :hasLanguageOfAdaptation "English"^^xsd:string;
            :hasLanguageOfInterface "English"^^xsd:string;
            :hasReqAccessMode :auditory_textual;
            :hasReqAdaptationDetail :auditory_verbatim;
            :hasReqAdaptationType :auditory_caption.
```

Listing 6.5: **Turtle Syntax**. An example of learner instance with hearing impairments.

We created the following competency questions to evaluate the ontology:

- Q1: How to retrieve the functional limitations and assistive technology needs for learners with total blindness?
- Q2: How to retrieve educational resources represented in text only (no visual)?
- Q3: How to retrieve educational resources that match the learner's needs?

We use SPARQL to query the ontology to answer these competency questions. Listing 6.6 retrieves the functional limitations and device used by learners with total blindness to answer Q1. It also retrieves the `isAtInteroperable`, which indicates the usage assistive technology; this property was set by the SWRL at listing 6.1. Listing 6.7 answers Q2 by retrieving educational resources represented in the text. Listing 6.8 retrieves educational resources that match the access mode required by learners (i.e., visual, textual)

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#>
PREFIX acc_ocw: <http://purl.org/accessible_ocw/>

select ?learner ?function ?device ?ATrequired
where {

?learner rdfs:subClassOf* acc_ocw:Learner.
?disability a acc:Disability. FILTER ( ?disability = acc:Blindness).
?function acc:FunctionalLimitation_belongsTo_Disability ?disability.
OPTIONAL {?disability acc:Disability_has_Device ?device}.
OPTIONAL {?learner acc_ocw:isAtInteroperable ?ATrequired}.
}
```

Listing 6.6: **SPARQL query**. Q1: Retrieving the disability functional limitation and assistive technologies for learner.

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#>
PREFIX acc_ocw: <http://purl.org/accessible_ocw/>

select ?resource ?type
where {
    ?resource a acc_ocw:DigitalResource.
    ?resource acc_ocw:hasAccessMode ?type.
    FILTER (?type = "textual").
}
```

Listing 6.7: **SPARQL query**. Q2: Retrieving educational resources with text representation.

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#>
PREFIX acc_ocw: <http://purl.org/accessible_ocw/>

select ?resource ?reqMode
where {
    acc_ocw:Learner_blindness acc_ocw:hasReqAccessMode ?reqMode.
    ?adap acc_ocw:adaptationType_requiredAccessMode ?reqMode.
    ?adap acc_ocw:adaptationType_adaptationRequest ?type.
    ?resource a acc_ocw:DigitalResource.
    ?resource acc_ocw:hasAdaptedAccessMode ?type.
}
```

Listing 6.8: **SPARQL query**. Q3: Retrieving educational resources that are relevant to the learner access mode requirement.

6.8 Discussion

We designed a web form collecting the learner profiles in a way that it addresses these preference variations. At first, the form was designed for the learners to input their disabilities. Feedback from the questionnaire was with regard to the privacy and discrimination of learners. The idea of asking learners to select their disability type was not considered a suitable way to create a learner profile. One alternative would be to detect their needs from the usage of their browser (i.e., detecting their screen reader usage) and adapt the system with respect to it and, at the same time, allow them to select their preferences from a general list of properties which are not related to a special group of users. Accordingly, we developed a user interface for learners to select/create profiles. The learners can select a profile from the list of five profiles, as illustrated in Figure 6.3. The profile is retrieved by querying the ontology; for example, the properties of the learner with total blindness are retrieved by the SPARQL query at Listing 6.9. The learners can create their personal profiles, as illustrated in Figure 6.4, by editing their preferences and saving their profiles.

```
PREFIX acc: <http://purl.org/accessible_ocw#>
SELECT distinct ?property ?value
WHERE {
  acc:Learner_blindness ?property ?value .
}
```

Listing 6.9: **SPARQL query**. SPARQL query of blind learner profile

We developed a prototype using Python[11] and Django web framework[12]. We used Owlready2[13] package to access and query the AccessibleOCW ontology. We decided for Python and Django as it supports accessibility concepts (e.g., packages that check web accessibility like PA11Y[14] and ontology-oriented programming. We used SPARQL [166] to query the ontology, using Apache Jena

[11] https://www.python.org/
[12] https://www.djangoproject.com/
[13] https://owlready2.readthedocs.io/en/v0.37/
[14] https://pa11y.org/

Fuseki[15] as the SPARQL server. The user input is saved in an RDF file.

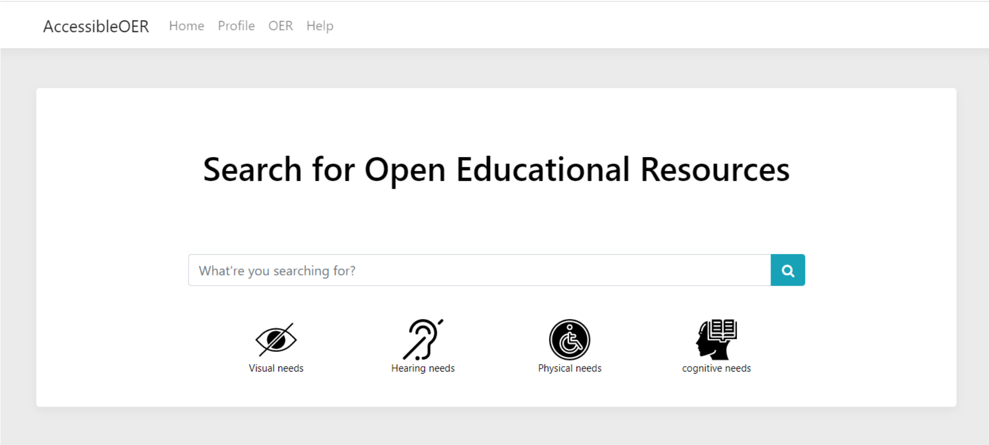


Figure 6.3: OER Search with learner profile

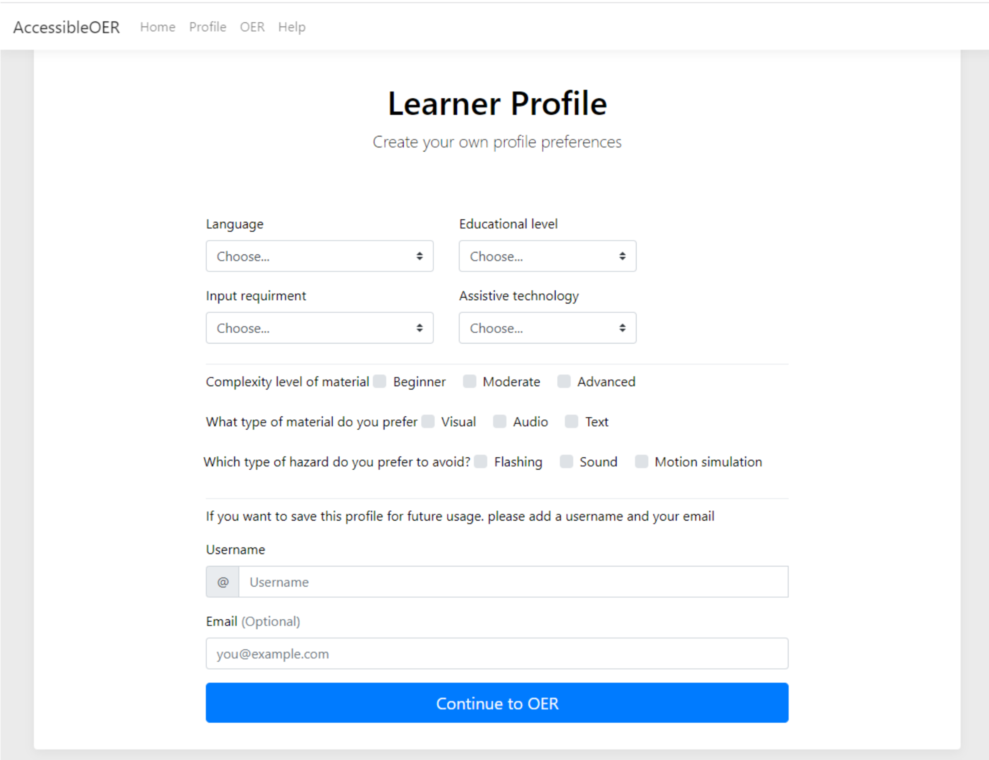


Figure 6.4: Learner input profile

15 https://jena.apache.org/documentation/fuseki2/

6.9 Summary

In this chapter, we presented AccessibleOCW ontology that addresses accessibility in OCW. We reused and extended the ACCESSIBLE ontology to represent learner needs and preferences with respect to the accessibility requirements of the IMS AfA specifications. IMS AfA is concerned with annotating digital resources and learner preferences to achieve better accessibility. Combining it with the ACCESSIBLE ontology makes it more extendable and does not limit it to special types of disabilities. The combination of IMS AfA and the ACCESSIBLE ontology provides more detailed descriptions of disabilities, assistive technologies, and user preferences. Furthermore, it allows the addition of concepts of other disabilities, such as cognitive impairments, which are relevant in learning contexts and suggests mappings to educational resources. We illustrated how to use the AccessibleOCW ontology to represent disabled learners on two example personas defined by W3C. We utilized the descriptions of disabilities from the ACCESSIBLE ontology to infer IMS AfA properties using basic reasoning, whereas other properties are based on direct user input.

CHAPTER 7

AccessibleOCW ontology for OER Recommendations

This chapter explains how AccessibleOCW ontology is used for recommending OER based on the learner's profile. We build a knowledge graph using the AccessibleOCW ontology and an OER metadata dataset. Section 7.1 explains the structure of the OER metadata and the data mapping process to generate the knowledge graph. To provide OER recommendations to learners, we use SPARQL queries to retrieve the educational resources based on their accessibility metadata. Section 7.2 proposes a technical architecture for using ontology to recommend educational resources. Section 7.3 evaluates the knowledge graph by discussing two use cases and testing the accessibility of the resultant educational resources.

Related publication

- **Mirette Elias**, Mohammadreza Tavakoli, Steffen Lohmann, Gábor Kismihók, and Sören Auer. *An OER Recommender System Supporting Accessibility Requirements.* In 22nd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) 2020, 57:1-57:4, ACM.

7.1 AccessibleOCW Knowledge Graph

A knowledge graph models real-world data using graph representation across various topical domains [167]; they are built on the RDF standards and often used for data integration. A knowledge graph comprises a semantic model (i.e, ontology) and data connected to the entities of this model. Knowledge graphs aid in linking data from various domains, in exploring domain-specific and interrelated knowledge, and in inspecting recurring patterns that can be used in simulation and prediction models (i.e., using artificial intelligence and deep learning algorithms) [37].

The aim of building this knowledge graph is to evaluate the use of AccessibleOCW ontology in recommending OER that matches the learner's profile. We study in this chapter how existing OER metadata are mapped to the AccessibleOCW ontology and queried to retrieve a set of recommended OER as defined by the learner's classes and properties. Our approach is arranged into two processes, as illustrated in Figure 7.1: 1) *Processing OER metadata* extracts OER metadata from OER repositories, analyzes accessibility metadata and prepares the data for mapping, and 2) *Building AccessibleOCW* *knowledge graph* uses the AccessibleOCW ontology and the OER metadata (e.g., CSV) and generate the knowledge graph.

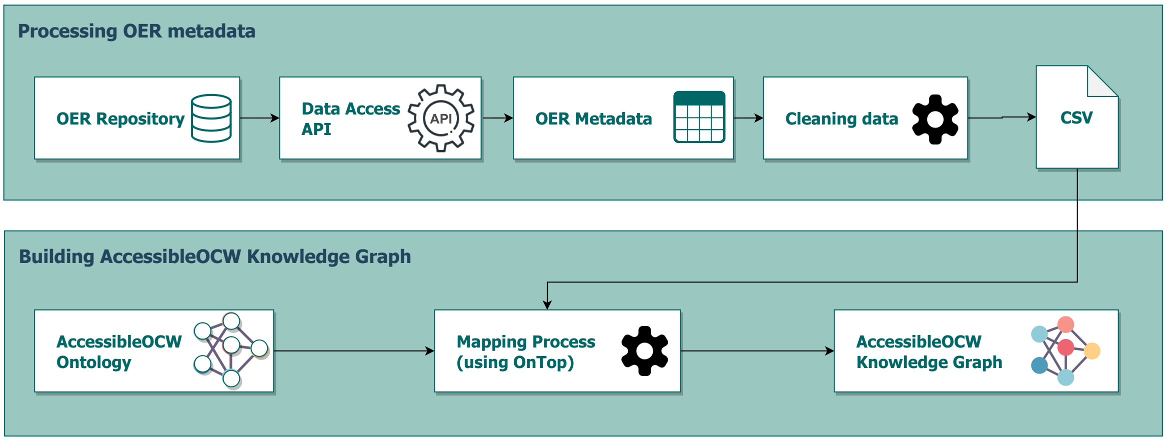


Figure 7.1: AccessibleOCW knowledge graph generation

7.1.1 Processing OER metadata.

OER metadata are described differently from one platform to another according to the metadata standards adopted. To analyze the accessibility of OER, we need to represent them within the concepts and relationship of the AccessibleOCW ontology. *Data Mappings* are used to connect the data sources, in our case, the OER metadata dataset, to the ontology classes and properties.

We use the OER metadata from the SkillsCommons dataset which was collected in Chapter 5. An example of the OER metadata describing an educational resource in the dataset is shown in Table 5.3. It should be noted that we did not collect all OER metadata from the SkillsCommons API; instead, we focused on metadata parameters that are related to accessibility descriptions. The SkillsCommons dataset is generated in CSV format; the *accessibility* column list all the supported accessibility metadata parameters in a string list (i.e., ['textAccess', 'decorativeImages']). When an accessibility metadata parameter exists this means the resource supports this parameter; if the parameter does not exist, then the resource does not support this parameter.

First, we go through the files and make sure to fix any inconsistent data (e.g., character encoding, data format) that might cause errors when generating the knowledge graph. Second, we analyze the OER metadata parameters and prepare the mappings table; to connect these parameters to the `DigitalResource` class and all other related classes and properties. This step is done prior to the preparation of the mapping axioms to make sure all the fields of the datasets are mapped and described by the ontology. The mappings of the SkillsCommons metadata dataset to AccessibleOCW ontology are shown in Table 7.1.

Table 7.1: SkillsCommons accessibility metadata and AccessibleOCW properties

AccessibleOCW properties	SkillsCommons OER accessibility metadata	Comment
DigitalResource.hasURI	url	URL field is mapped to `hasURI` data property
DigitalResource.title	title	Title field is mapped to `title` annotation
hasAccessMode	type	Type field is mapped to the `AccessModeType` class type property. This metadata needs processing to extract the type (e.g., text, visual) from the string value
AccessModeType.Value	textAccess, tableMarkup, readingOrder	These metadata fields are related the *Text* resources, they are mapped to multiple `AccessModeType.Value`
AccessModeType.Visual	multimediaTextTrack, multimediaTranscript, imageAltText, decorativeImages, complextImageText, color, contrast	These metadata fields are related the *Visual* resources, they are mapped to multiple `AccessModeType.Value`
AccessModeType.Auditory	multimediaTextTrack, multimediaTranscript	These metadata fields are related the *Auditory* resources, they are mapped to multiple `AccessModeType.Value`
atInteroperable	textAccess, readingOrder, hyperlinkActive, color, imageAltText, interactivePromptText, tableMarkup, decorativeImages, interactivePromptText	When these metadata fields exist, the `atInteroperable` is assigned *true*
hasControlFlexibilityType	keyboardInteractive	keyboardInteractive is assigned the *fullKeyboardControl* from `ControlFlexibilityType`
hasHazard	noFlickering	noFlickering is assigned to the negation of *flashing* from `HazardType`
hasDisplayTransformability	textAdjustmentCompatible, textAdjustable, readingLayoutCompatible, educationalComplexityOfAdaptation	These fields are mapped to the properties of `DisplayTranformability` (e.g., DisplayTranformability.fontSize)
Media	stemMarkup, stemNotationMarkup	These fields indicate the existence media like ChemML or MathML. They are mapped to the properties of `AdaptationMediaType`

7.1.2 Building AccessibleOCW Knowledge Graph

Knowledge graphs are built on RDF standards. RDB to RDF Mapping Language (R2RML) in the W3C language used to express the mappings between relational data sources and RDF datasets (i.e., ontologies) [168]. We use the *Ontop* framework for Ontology Based Data Access (OBDA) to generate the knowledge graph [169]. OBDA architecture allows querying data sources through a higher conceptual representation (i.e., ontologies) [170]. The *Ontop* is an open-source[1] virtual approach to OBDA which expose relational databases as virtual RDF graphs. Ontop translates the SPARQL queries into SQL queries to query these data sources [171]. We use the Ontop-Protégé[2] plugin to design the R2RML axioms and query the knowledge graph. Figure 7.2 illustrates our mapping approach.

1. *Importing the SkillsCommons dataset (CSV file) in H2 database*[3]. We use H2 database engine to import the CSV file. The H2 database engine converts the CSV data to a relational data table. We can query and validate this table in the H2 database browser interface using SQL queries.

[1] https://ontop-vkg.org/
[2] https://sourceforge.net/projects/ontop4obda/files/
[3] https://www.h2database.com/html/main.html

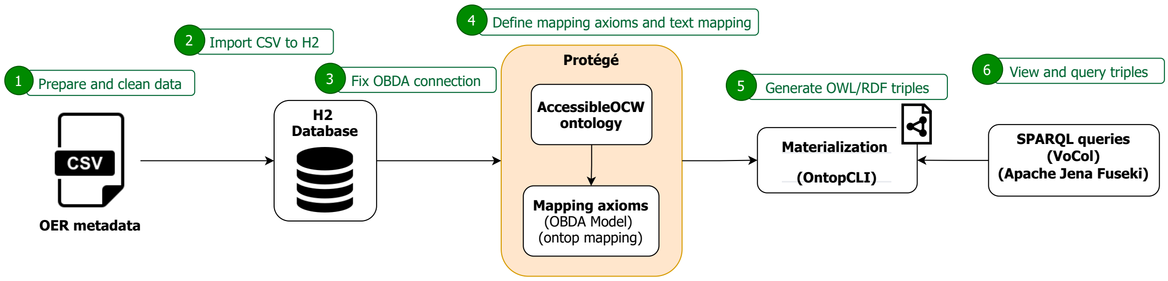


Figure 7.2: Knowledge Graph Development Steps

```
CREATE TABLE OER AS SELECT * FROM CSVREAD('filepath/oers\_dataset.csv')
```

2. *Connecting Ontop-Protégé to H2 database.* To establish the OBDA connection, Ontop-Protégé uses the JDBC driver (org.h2.Driver) to connect to the H2 database.

3. *Define the mapping rules*. Ontop-Protégé provides a mapping interface to create the mapping axioms, as illustrated in Figure 7.3. These axioms are then translated to R2RML language to represent the mapping rules. Listing 7.1 demonstrates a sample of the R2RML mappings used to map the metadata parameters to the AccessibleOCW ontology.

4. *Materializing the knowledge graph.* Ontop provides a virtual knowledge graph that can be queried in Ontop-Protégé and it also provides a materialization function. Materialization is used to convert data and produce output in RDF triples file (e.g., Turtle). Ontop Command Line Interface[4] is used for data materialization[5].

```
 ontop materialize -m aocw_oer.obda -f turtle -o aocw_oer.ttl -p
aocw_oer.properties -t aocw_oer.ttl
```

In this section, we validated the mapping of OER metadata from SkillsCommons dataset to the AccessibleOCW concepts and relationships. In order to map metadata from other OER repositories, we need to create another mapping file with respect to the mapping parameters associated to the OER.

7.2 OER Recommender: A Proposed Technical Architecture

The overall system architecture is thus composed of: AccessibleOCW ontology, learner profile OER metadata, and a recommender model which is composed of an OER quality prediction and the recommendation engine, as illustrated in Figure 7.4. *AccessibleOCW ontology*, as described in Chapter 6 contains the relevant accessibility knowledge required in OCW contexts. *Learner profile* is a representation of learners, including information about their accessibility needs. A web form is used to either select from existing profiles or create a new profile. *OER metadata* is extracted from open

[4] https://ontop-vkg.org/guide/cli.html
[5] https://sourceforge.net/projects/ontop4obda/files/ontop-1.17.0/

```
@PREFIX : <http://purl.org/accessible_ocw/> .
@PREFIX dc: <http://purl.org/dc/elements/1.1/> .
@PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@PREFIX rr: <http://www.w3.org/ns/r2rml#> .
@PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> .

<urn:MAPID-c4fc66ec6ad44fb0bc7ceb7205b1dc5c> a rr:TriplesMap;
  rr:logicalTable [ a rr:R2RMLView;
      rr:sqlQuery """SELECT id, title, url, type, CASE WHEN CHARINDEX('noFlickering',
    accessibilities) >0 THEN 'flashing' ELSE '' END AS hazard, CASE WHEN CHARINDEX('
    keyboardInteractive', accessibilities) >0 THEN 'fullKeyboardControl' ELSE '' END AS
    controlFlexibility, CASE WHEN CHARINDEX('textAdjustmentCompatible', accessibilities)
    >0 THEN 'fontSize' ELSE '' END AS displayTransform_fontsize, CASE WHEN CHARINDEX('
    multimediaTranscript', accessibilities) >0 THEN 'transcript' ELSE '' END AS
    adaptationtype FROM OER """];
  rr:predicateObjectMap [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:column "type";
          rr:termType rr:Literal
        ];
      rr:predicate :hasAccessMode
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:template "http://purl.org/accessible_ocw/ControlFlexibilityType/{
    controlFlexibility}";
          rr:termType rr:IRI
        ];
      rr:predicate :hasControlFlexibility
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:template "http://purl.org/accessible_ocw/AdaptationType/{adaptationtype}";
          rr:termType rr:IRI
        ];
      rr:predicate :hasAdaptationType
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:template "http://purl.org/accessible_ocw/DisplayTransformability.fontSize/{
    displayTransform_fontsize}";
          rr:termType rr:IRI
        ];
      rr:predicate :hasDisplayTransformability
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:column "noFlickering";
          rr:termType rr:Literal
        ];
      rr:predicate :hasHazard
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:column "hazard";
          rr:termType rr:Literal
        ];
      rr:predicate :isAtInteroperable_dr
    ], [ a rr:PredicateObjectMap;
      rr:objectMap [ a rr:ObjectMap, rr:TermMap;
          rr:column "url";
          rr:termType rr:Literal
        ];
      rr:predicate :hasURI
    ];
  rr:subjectMap [ a rr:SubjectMap, rr:TermMap;
      rr:class :DigitalResource;
      rr:template "http://purl.org/accessible_ocw/digitalResource/{id}";
      rr:termType rr:IRI] .
```

Listing 7.1: Mapping OER metadata to DigitalResources using R2RML (part)

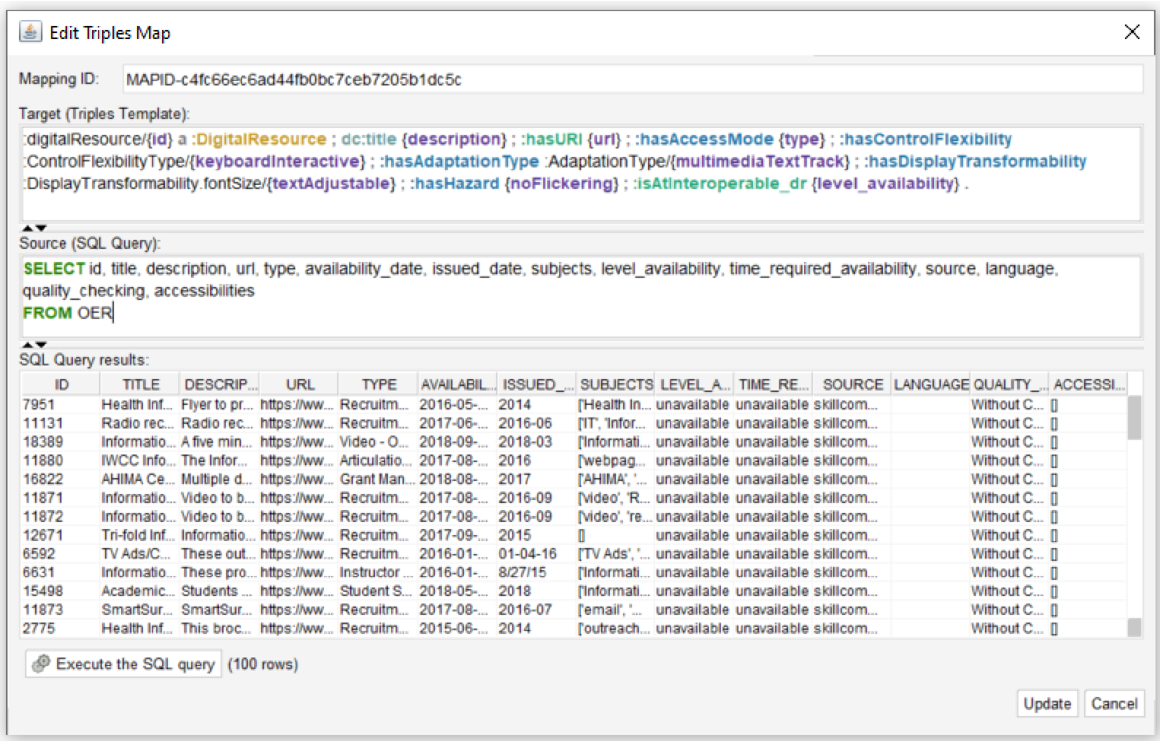


Figure 7.3: Ontop-Protégé editing mappings interface in

educational resources, in our study we used SkillsCommons. We are using a list that was processed by the quality prediction approach, introduced in Chapter 4, to extract resources with quality and accessibility metadata (i.e., CSV). The OER metadata is mapped to the ontology to generate the knowledge graph. *Recommender module* processes the learner profile and knowledge graph to retrieve the most appropriate educational resources.

7.3 Evaluation

In Section 6.7, we evaluated the ontology by describing W3C personas with the ontology concepts and relationship and answering competency questions. In order to evaluate the knowledge graph, we developed two use cases to describe learners needs and retrieve the list of matching educational resources.

The two use cases (recommended by experts): *Use case 1:* English Language educational resources that are relevant to visually impaired users, and *Use case2:* Business educational resources that are relevant to cognitively impaired users (i.e., intellectual and neurodevelopmental disabilities). For each use case, we went through our education dataset and filtered the educational resources according to the quality prediction model and the accessibility preferences which are required by each learner profile of the use case. Afterwards, we evaluated the accessibility of the OER search results manually (e.g., NVDA tool[6] was used to simulate the activities of visually impaired users) and using automatic

[6] https://www.nvaccess.org/

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX acc: <http://www.AccessibleOntology.com/GenericOntology.owl#>
PREFIX : <http://purl.org/accessible_ocw/>

select ?resource ?url
where {
    ?resource a :DigitalResource.
    ?resource :hasURI ?url.
    ?resource :hasAccessMode ?type.
    ?resource :hasAdaptationType :AdaptationType.transcript.
    FILTER(!EXISTS { ?resource :hasHazard :flashing.})
    ?resource :isAtInteroperable_dr "true".
    ?resource :hasDisplayTransformability :DisplayTransformability.fontSize.
}
```

Listing 7.2: **SPARQL query**. Use case 1: Retrieving educational resources that are relevant to learners with low vision.

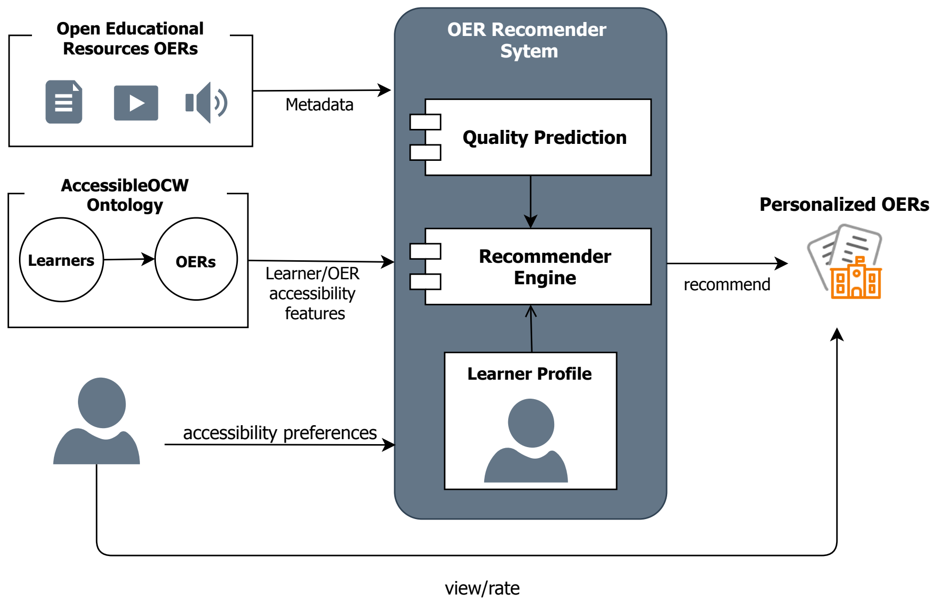


Figure 7.4: AccessibleOER Recommender Functional Architecture

accessibility checking approaches (e.g., Visual ARIA bookmarklet[7]). We focused on testing the most important accessibility feature for each use case (e.g., *Use case 1*: color and contrast, headings and order, images description, and *Use case 2*: readability test, Easy-to-Read test, text adjustment, availability of visual content). In general, most of the resulting OERs passed these accessibility tests except for some checks (e.g., *Use case 1*: images that did not have alternative description, and heading order that failed in PDF format files, and *Use case 2*: the Easy-to-read test). Although the readability checks passed, the feedback regarding the easy-to-read guidelines was not positive from the experts. They commented that, although the OERs provide several accessibility features, they were initially not

[7] https://whatsock.com/training/matrices/visual-aria.htm

created with easy-to-read guidelines.

Table 7.2: Use case 1: accessibility check

Accessibility checks	MS Office files	PDF files	IMSCC files
Accessible checking tool	Acrobat accessibility tool	MS accessibility checker	Visual ARIA bookmarklet[8]
Color and contrast	✓	✓	✓
Headings and order	✓	some checks failed	✓
Text adjustment	✓	check failed	check failed
Zooming	✓	✓	✓
Images description	some checks failed	some checks failed	some checks failed
Active links	✓	some checks failed	✓
Avoid flashing	✓	✓	✓

Use Case 1: Our approach retrieved around 70 *English Language* OERs that satisfy the quality model and accessibility preferences of learners with low vision and blind profiles. We selected a sample of 10 OER and evaluated the accessibility by using the NVDA tool[9] to simulate the activities of visually impaired users. In general, the OER were retrieved as Microsoft Office files (e.g., Word, PowerPoint), PDF files or IMSCC files. MS Office and PDF files are considered accessible file formats because they provide accessibility features for screen readers. The IMSCC files should be loaded in a Learning Management System (LMS); so their accessibility is highly dependent on the accessibility of the LMS (Canvas[10] was used in our testing). We tested the accessibility features of each format. The results are reported in Table 7.2. Finally, we selected a sample of OER that were **not** retrieved by our approach and tested their accessibility; we found that some of these OER are not accessible because they contain scanned PDF files which are not accessible by screen readers.

Use Case 2: Our approach retrieved around 50 Business OER that satisfy the quality model and accessibility preferences of learners with cognitive impairments. We selected a sample of ten OERs and evaluated the accessibility as per the cognitive impairment profile, as defined by the AccessibleOCW ontology. We matched the learner profile to the metadata of SkillsCommons [*color, contrast, hyperlinkActive, noFlickering, textAdjustable, textAdjustmentCompatible, educationLevel*]. We run the accessibility checks as visually impaired users (e.g., color, contrast, text adjustment) and we focused more on the readability of text (easy-to-read) and the availability of visual content representations, as shown in Table 7.3. The readability of the texts is evaluated by Flesch Kincaid Reading Ease [129]; a value between *60* and *80* is supposed to indicate an easy reading level. Also, we checked the presence of visual content, as it is more preferred to this type of learner [172]. Although the readability checks passed, the feedback regarding the easy-to-read guidelines was not positive from the experts. They commented that, although the OER provide several accessibility features, they were initially not created with easy-to-read guidelines. Finally, we selected a sample of OER that were not retrieved by our approach and tested their accessibility; we found that some of these OER are not accessible because they contain scanned PDF files which are not accessible by screen readers.

Moreover, we asked three experts (for visually impaired users) and two experts (for cognitively impaired users) to rate (between 0 to 5) the quality of recommended OER in terms of accessibility

[9] https://www.nvaccess.org/
[10] https://www.canvas.net/

Table 7.3: Use case 2: accessibility check

Accessibility checks	MS Office files	PDF files	IMSCC files
Color and contrast	✓	✓	✓
Readability test	✓	✓	✓
Easy-to-Read test	check failed	check failed	check failed
Text adjustment	✓	check failed	check failed
Visual content	✓	✓	✓
Avoid flashing	✓	✓	✓

features for each of the use cases. At the end, we received more than 100 ratings regarding the recommended OER. Table 7.4 shows the percentage of the rates in each use case. As can be seen, experts rated with a score of *3.41* out of *5* on average, which shows that our recommender system works well in satisfying these users' needs.

Table 7.4: Results of the validation by experts

Use Cases	Rate=0 (%)	Rate=1 (%)	Rate=2(%)	Rate=3(%)	Rate=4(%)	Rate=5(%)	Average Rate
Use Case 1 (English Language)	0	6	7	21	33	33	3.8
Use Case 2 (Business)	2	14	19	26	24	15	3.01
Average	**≈1**	**≈10**	**≈13**	**≈23**	**≈29**	**≈24**	**3.41**

7.4 Summary

We proposed a technical architecture to support OER recommendation by AccessibleOER knowledge graph. We showed a mapping example for SkillsCommons accessibility metadata and AccessibleOCW properties to enable queries on top of the AccessibleOCW. We used an example query to retrieve educational resources that are relevant to learners with low vision. We propose an OER recommender that OER metadata, quality prediction model, and user ratings to retrieve high-quality accessible OER relevant to the learner's profile. Finally, to evaluate our approach, we validated the accessibility of the resultant OER by manual and automatic checks and by collecting feedback from experts (i.e., average ratings (*3.41* out of *5*).

Part IV

Accessible OCWs - Best Practices

CHAPTER 8

Best Practices for Accessible OCW

This chapter describes our experience developing SlideWiki, an accessible OCW platform. Section 8.1 introduces the need for incorporating accessibility into the design and implementation of the platform. Section 8.2 discusses the early inclusion and evaluation of accessibility needs and guidelines at each stage of the agile development life cycle. Section 8.2 evaluates the accessibility of SlideWiki through technical and manual testing, and running trials. Section 8.4 describes examples of how the platform was modified to accommodate accessibility needs of learners. Finally, Section 8.5 evaluates the results and summarizes the lessons learned. In this chapter, we answer the question: is it enough to follow accessibility guidelines (e.g., WCAG) to develop an accessible platform?

Related publications

- **Mirette Elias**, Edna Ruckhaus, E.A. Draffan, Abi James, Mari Carmen Suarez-Figueroa, Steffen Lohmann, Abderrahmane Khiat, and Sören Auer. *Accessibility and Personalization in OpenCourseWare: An Inclusive Development Approach*. (Nominated for Best Full Paper Award) In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 279-283, IEEE.
- **Mirette Elias**, Abi James, Edna Ruckhaus, Mari Carmen Suárez-Figueroa, Klaas Andries de Graaf, Ali Khalili, Benjamin Wulff, Steffen Lohmann und Sören Auer. *SlideWiki - Towards a Collaborative and Accessible Platform for Slide Presentations*. In 13th European Conference On Technology Enhanced Learning (EC-TEL) 2018 Practitioner Proceedings, 1-13, CEUR Workshop Proceedings.

8.1 Accessibility Inclusion in OCW Development Life Cycle

Accessibility requirements defined by the web accessibility guidelines (e.g., WCAG) provide developers with a series of success criteria and best practices that support the implementation of an accessible web service. These guidelines describe general accessibility requirements (e.g., color contrast, headings order) and some of them are now supported by the HTML and CSS definitions (e.g., alt-text, aria-role) to address different needs of learners and assistive technologies when interacting with web applications. However, more accessibility requirements can be defined depending on the functionality of the system. These requirements emerge when learners start to interact with the system; as people with disabilities use different tools and techniques for performing tasks. For example, learners with visual impairments receiving information through audio require a reduced presentation interface that allows them to reach the main functionalities in a less confusing manner and to avoid information overload; these learners use the keyboard as input and to have a flexible interaction, they require headings and descriptive texts [23]. Addressing the accessibility requirements for OCW functionalities can be found under the various Success Criteria, but not all developers are aware of the technical nuances of some of the requirements. Therefore, direct interaction and evaluation of the proposed system from the very beginning of the planning and design stages, by learners with disabilities, allows for the detection of any potential barriers that need to be overcome.

According to a statistical analysis of how practitioners interpret accessibility development and design in practice, the following findings were highlighted: 1) accessibility is not properly integrated into software projects; 2) accessibility is always considered short-term, focusing mostly on UI design, despite the need for implementation requirements; 3) manual testing with end-users is important to obtain feedback; and 4) evaluating accessibility is heavily dependent on the project domain [173].

A conceptual accessible software development was proposed to combine user-centered and agile approaches for including accessibility needs and patterns in the development process [174]. In this chapter, we explain a practical agile development approach that was used in SlideWiki, an OCW that represents educational materials in the form of a slide presentation. The SlideWiki project adopted accessibility in all its components; this means that texts, images, forms and navigation should be accessible and understandable by as many people as possible with or without disabilities, in order to experience the best possible interactive experience. The platform was optimized to meet the accessibility WCAG 2.0, level AA (ISO/IEC 40500:2012), and the team also applied the requirements of the European standard EN 301 549 V1.1.2 (2015-04).

8.2 Accessibility in Agile Software Development Methodology

SlideWiki is an open and accessible OCW authoring platform that aims to foster the creation and sharing of qualitative, rich and engaging educational content following the 5R principles of OER. The platform allows educators to create, edit, translate and reuse HTML-based slide presentations complemented with comments, links to sources and supporting materials as well as questions to help learners. SlideWiki uses an open-source code base[1] to encourage others to contribute to the project as well as contribute back to the open-source community. The platform uses the format of slide decks to represent OER, as slide presentations provide a comprehensive means for demonstrating knowledge in a short, concise, and illustrative form. Slides are grouped together into a deck that represents an OER. Authors can import existing slide presentations provided in PowerPoint or Open presentation formats. They can also attach slides from decks they or other authors have created.

Managing digital accessibility throughout the project allowed for its inclusion to be directly embedded into the agile development process; which supported the response to user feedback during each sprint (i.e., a sprint is a fixed period of time during which a specific task has to be completed). The development team was provided with resources to foster accessible development approaches and collaborated with accessibility experts to improve this aspect of the build. Feedback from the different trials was continuously collected and communicated to the team, and tasks were planned for the following sprints accordingly. This allowed accessibility to be managed across all project phases.

[1] https://slidewiki.github.io

8.2.1 Planning

The accessibility requirements (e.g.WCAG 2.1) should be specified at the beginning and incorporated into sprint planning, designing the technical architecture as well as features and interfaces. This helped the team to select technologies that supported accessible development and to develop accessible design patterns, as well as to highlight areas of development that needed to be prioritized due to accessibility and ease of use. For example, selecting code libraries by the extent to which they were already created with accessibility in mind whiles ensuring that all new features were regularly checked against the WCAG 2.0 [175] during development. SlideWiki employed an inline HTML5-based WYSIWYG (What-You-See-Is-What-You-Get) editor for authoring the slides. This is accessible to assistive technology users and creates accessibility-compliant content.

8.2.2 Development

During each development sprint, accessibility expertise was available to assist with code-reviews and acceptance testing. Design decisions were made to ensure that the developments complied with learners' accessibility requirements. For example, slide templates have been designed to assist with structuring the content to aid accessibility and reuse by ensuring that content is structured with appropriate headings, list and table tags. As developers enhanced their accessibility skills they were able to ensure that issues were identified as early as possible in the development cycle. Developers could request accessibility testing of different prototypes to identify which would provide the most accessibility support.

8.2.3 Testing

Components were tested prior to being merged into the platform as part of the Quality Assurance (QA) stage. In this stage, components, were reviewed to ensure they conformed to functional and accessibility requirements. Issues raised in the QA phase were addressed by developers prior to merging them into the platform, or new tasks were created for future sprints if significant work was required. For example, if not all interactive components were keyboard accessible, this would be noted during QA testing.

8.2.4 Release

Prior to any new release of the platform, the development team undertook a range of testing tasks to confirm that it performed as expected. These testing tasks were written based on the expected performance and user documentation. This allowed updated components to be tested within the platform, as often accessibility issues were found only when tested using a task involving several steps. Issues identified during the testing tasks were either addressed immediately (bugs), logged for future improvement (non-critical issues) or, if significant issues were identified, code was removed from the release, and an alternative solution was planned. For example, the component library for the user interface was found to have bugs when supporting screen reader access in some drop-down menus. This required a separate research task, prototype and the testing of an alternative component library.

8.3 Evaluating Accessibility

Feedback from trials was embedded within the development cycle allowing for early evaluation of the functionality of the platform. The accessibility of the platform was evaluated by technical and manual tests, as well as running trials.

8.3.1 Technical and Manual Tests

The W3C Website Accessibility Conformance Evaluation Methodology (WCAG-EM) reporting system [176] was used to provide a more in-depth assessment. This provided the authors with a way of evaluating a sample set of web pages as advised in the European Commission Web Accessibility Directive Expert Group (WADEX) [177]. These checks were compared to the functional approach used by Web2Access [178]. The WCAG-EM system provides individual results for each Success Criteria (SC) under the four principles of WCAG 2.0 (ISO/IEC 40500:2012) for each chosen page; an overview of the results is shown in Table 8.1. The Web2Access approach has been used throughout the agile development process of SlideWiki as a way of evaluating the dynamic aspects of the service. However, it has been found that neither method is ideal for informing issues that arise with individual components on the site. These had to be logged in an Excel spreadsheet and submitted using the Zephyr capture feedback form on Jira [179] that alerted the development team of ongoing problems.

Manual checks were used throughout the development of SlideWiki to evaluate any hidden accessibility issues that could not be caught by the use of automatic accessibility checkers such as WAVE [25], Tenon [180] and the Visual ARIA browser extension [181]. The free screen readers NVDA [182] for Windows-PC and VoiceOver [183] for iOS tablets, phones, and Mac OS provided information related to the code and the way the browsers/user agents interacted with the platform.

Table 8.1: Overview of WCAG-EM results

Principle	Perceivable	Operable	Understandable	Robust	Total
Level A	8/9	6/9	4/5	1/2	**19/25**
Level AA	3/5	1/3	4/5	0/0	**8/13**

8.3.2 Running Trials

Among a total of sixty eight trials relating to the evaluation of the accessibility of the platform, three involved disability user groups: one trial for visually impaired users, and two trials for intellectually impaired users in vocational and professional training centers. Table 8.2 represents the number of contributions for each type of trial. The accessibility checks focused on the main functionalities of the platform, which were used by the trial participants: 1) *accessing the homepage and searching*, 2) *creating and editing decks/slides* and 3) *viewing slideshows*. Aside from the accessibility guidelines and checks, these trials provided additional accessibility requirements and highlighted issues which affected the development and re-design of various components of both the SlideWiki platform and the content of the slide decks.

1. **Visual Impairment Trial.** Authors who specialized in creating material for visually impaired users and trainees, who were themselves visually impaired. Face-to-face meetings were conducted

Table 8.2: Summary of trial contributions

Number of	Authors	Decks	Slides	Trainers	Trainees
Visual Trial	4	8	94	2	5
Cognitive Trials	16	46	1,390	6	10

between authors and the development team, and the platform was tested and evaluated by visually impaired users using their assistive technologies (e.g., Braille display and screen readers).

2. **Cognitive Impairment Trials.** Authors and trainers of this trial were specialized in *Easy-to-read* methodology and trainees were users with intellectual disabilities. The platform was tested and evaluated by the authors and trainees. Table 8.3 represents examples of the suggested requirements to improve the functions of the platform for visually impaired (VI) users and those with cognitive impairments (CI).

Table 8.3: Examples of trial requirements

1. Accessing the homepage and searching
- Providing large images and icons representing the main functions and facilitating ease of use (CI) - Providing a quick access to the search of decks (CI) - Dropdown or any list fields should appear in alphabetical order (CI) - Providing descriptive images whenever possible to make the functions easy to understand. (CI) - Provide a simpler version (i.e., concise text) with clear access to the main functions (VI) - Search results display is redundant and too complex to understand (VI, CI)
2. Viewing, creating and editing decks/slides
- Providing a simple editor version for blind users; visually impaired users were typically not interested in formatting the content on the slides but in creating and accessing the slide content using their assistive technologies. (VI) - Allowing action buttons to be positioned in the upper part of the page in order to be easily reachable by screen readers rather than going through the whole page to find the buttons. (VI) - Improving the importing function as preservation of text format and images is especially important when importing *Easy-to-read* presentations(CI)
3. Viewing slideshows
- Providing live share/presentation rooms where the trainer can share the slides and the trainees can follow the navigation (VI) - Providing shortcuts for moving through slides in presentation mode and making sure that these shortcuts do not contradict their assistive technologies. (VI) - Text to speech in presentations (CI)

*(VI) Visual Impairment - (CI) Cognitive Impairment.

8.4 Platform Personalization

Personalization in SlideWiki was carried out by analyzing and including the accessibility needs of the different user groups included in the trials. Some of these needs were addressed over the whole platform (i.e., supporting screen readers), and others were addressed by allowing customization to the platform features (i.e., searching for Easy-to-read materials). Feedback from the trials was collected at regular intervals in order to gather accessibility requirements which were then analyzed and reassigned as tasks for further development. The following sections define the main functions of the platform and the design decisions taken to meet the particular needs that arose from the disability user group trials, in order to make the platform accessible and easy to use.

8.4.1 Homepage and Search

The homepage was initially designed with a decorative homepage which included a carousel (i.e., a slideshow for cycling through elements) that is available with ‘easy to reach’ text alternatives fulfilling certain criteria mentioned in WCAG 2.0. In the original design, it was possible to pause the carousel and reach all the other elements on the page, with a set of informational text documents in the footer. However, the carousel was disturbing users with intellectual disabilities and the middle part was crowded with information with less focus on the main functions of the platform (i.e., searching for content). These elements made the homepage too complex for those with intellectual and visual impairments and they found it hard to access the decks and slides on the platform.

The homepage was redesigned, as shown in Figure 8.1, by removing the carousel instead, a large UI component was included to access the search feature, and large icons were added to indicate what is available on SlideWiki; more pictorial components were added to make the content and functions of the platform (e.g., adding flags to the language selection field) easier to understand. Some text on the homepage was replaced to make complex concepts easier to understand and reformatted with respect to the *Easy-to-read* guidelines. For example, the terms ‘courses’ and ‘attach’ were used instead of ‘presentation’ and ‘append’, because it was found that these words were not familiar to users with intellectual disabilities.

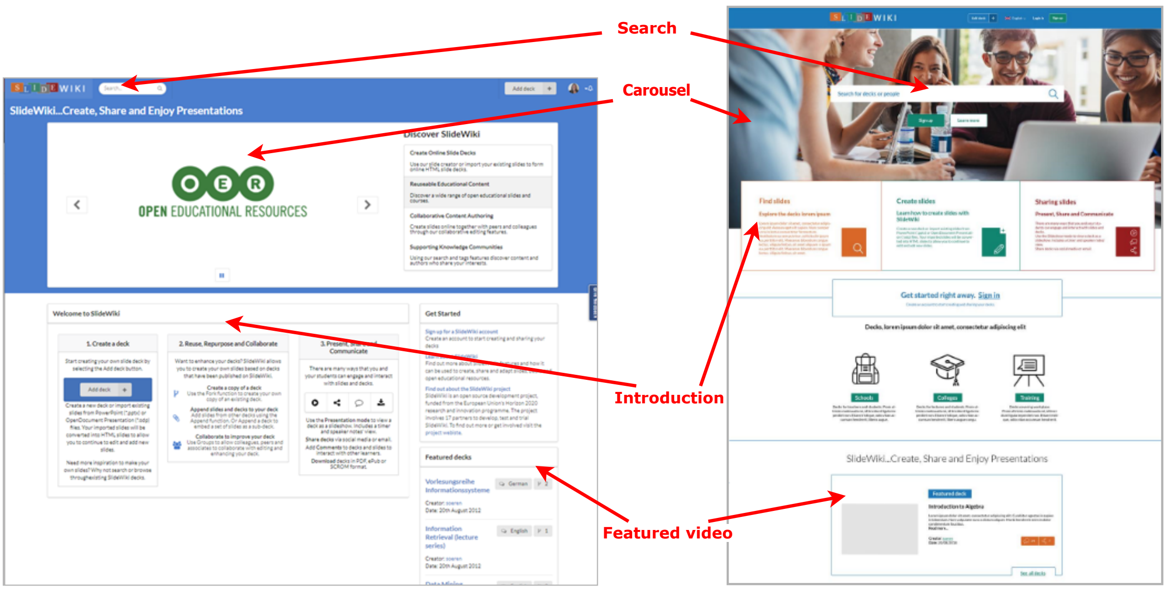
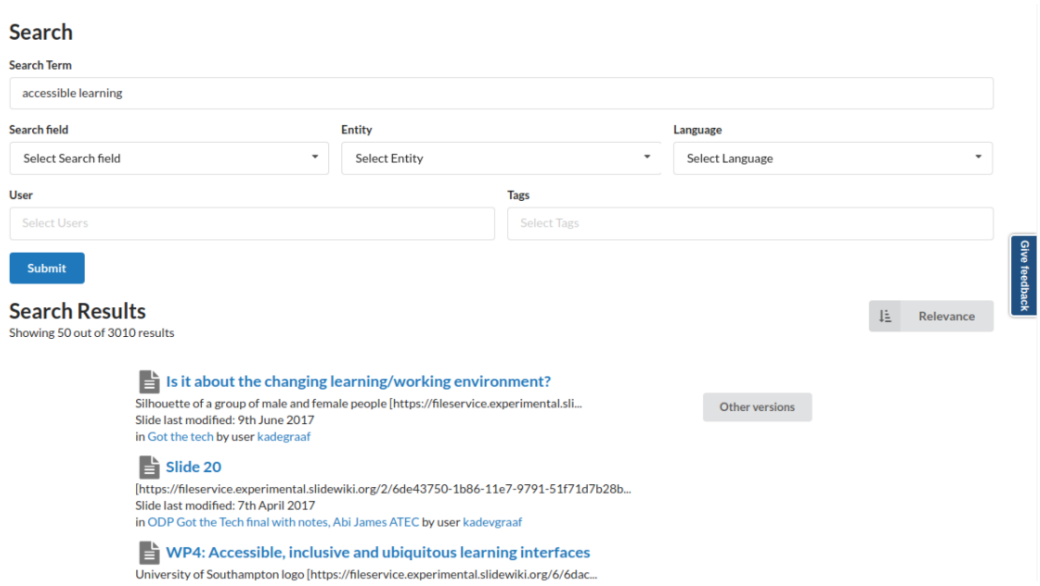
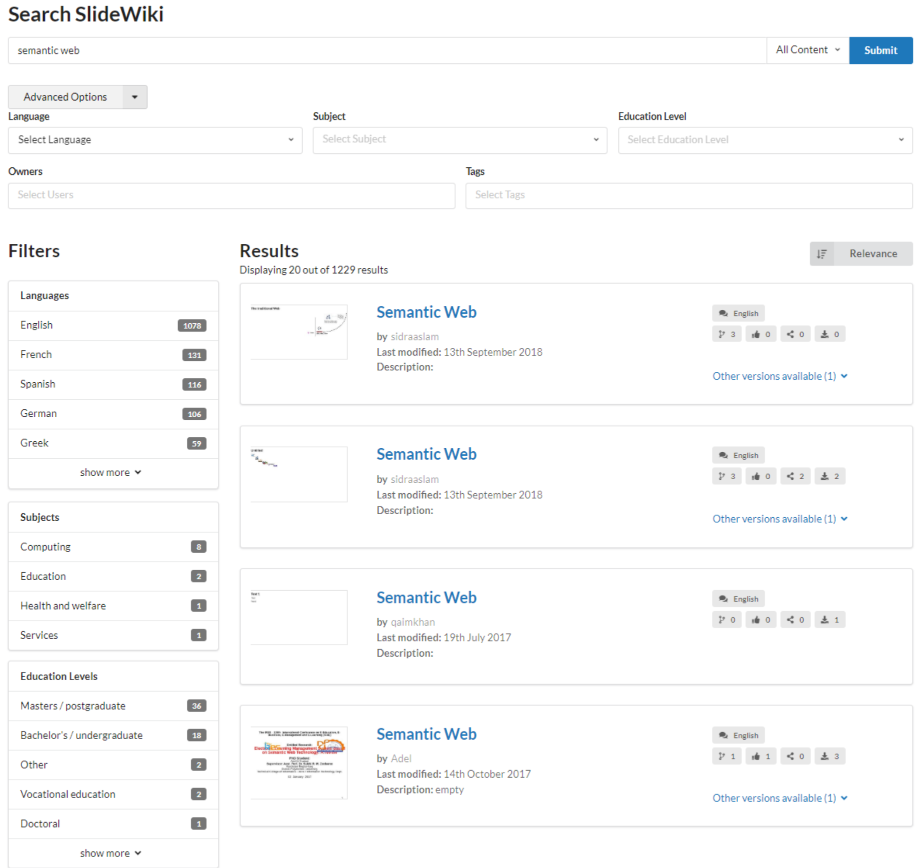


Figure 8.1: SlideWiki homepage old and new design

The previous search feature was not totally successful, so the interface for the search results was redesigned to include a left hand collection of filters for language, owners, subjects, education levels, tags and ‘Easy to read’. These extra features provided lists of decks or slides as soon as a word has been typed into the search field, as illustrated in Figure 8.2.



(a) Old design



(b) New design

Figure 8.2: SlideWiki search results old and new design

8.4.2 Viewing, Creating and Editing Decks/Slides

The deck view is composed of a tree component on the left side with two options; either to view the slide name or a thumbnail in order to represent an easy overview of the slide content, as requested by the cognitive impairment trials. The navigation is easy, and a screen reader user hears all the complete titles, as illustrated in Figure 8.3. A user can fork (i.e., reuse and extend) an existing deck or create a new one. The platform uses the CKEditor toolbar, an accessible code library for authoring content that provides positive interactions with assistive technologies. Using accessible libraries has saved time and provides added benefits to all users. However, many of the unique features have required innovative coding and this has meant that ongoing accessibility testing has taken up a considerable amount of time. Most of the editor features have been relocated to a left hand menu system that has clearer choices and offers easy access to the word-processing toolbar without covering the top menu buttons, as illustrated in Figure 8.4(a). The editor was redesigned to be simpler including the most commonly accessed tools and different editing modes, such as Markdown-based syntax to make it easier for visually impaired users to use the editor, as illustrated in Figure 8.4(b). In addition, authors of the content are prompted to add alternative text to images as these are uploaded, to provide support for screen reader users. It is particularly important that an author completes this task because only they understand the context of their image and may have a specific audience in mind.

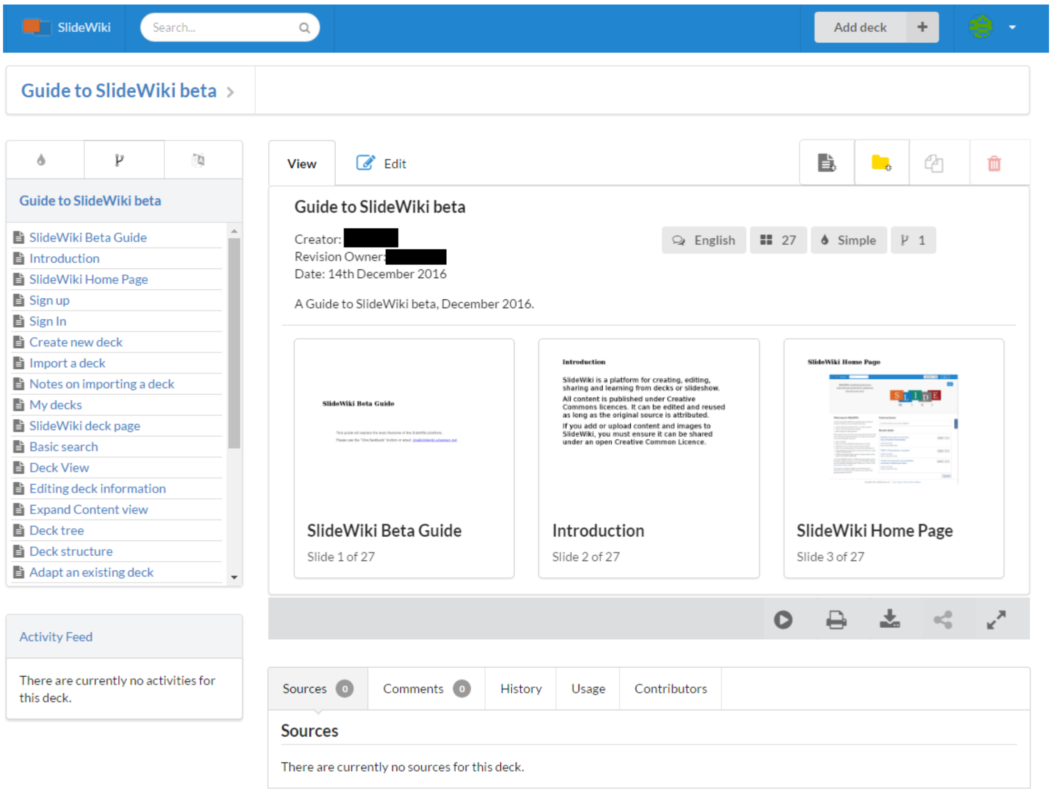
8.4.3 Viewing Slideshows

The slideshow presentation mode opens a new tab that allows the user to see the slide in full screen with a navigational button to move sequentially through the slides. The addition of a menu providing a deck view enables users to jump to different slides when in presentation mode. This has helped usability and screen reader access, along with the addition of slide numbers. On the deck view page, the deck activity can be viewed via a live session for the deck to which participants can be invited. All aspects can be reached with keyboard access; this was requested by trainers of visually impaired users to facilitate the teaching process in their session (i.e., users can follow the slides at the same time as their trainer is working through the presentation).

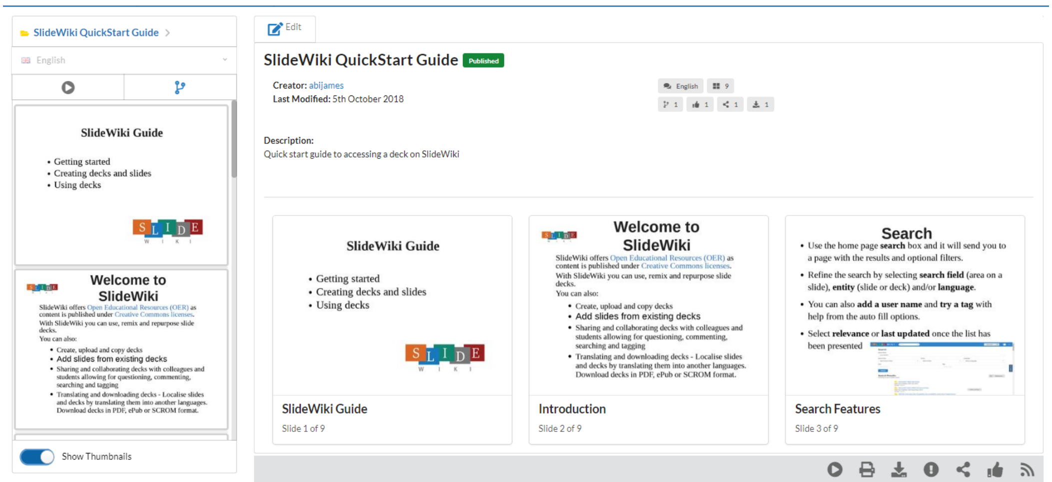
8.5 Evaluation Results & Lessons Learned

WCAG 2.0 guidelines were incorporated into the evaluation results as well as feedback regarding the accessibility barriers encountered by users with visual and cognitive impairments in the early stages of the SlideWiki development life cycle. This included all design decisions (i.e., designing UI and compatibility of functions to assistive technologies) that affected the development process over the three years. The above practices and considerations helped in the process of selecting technologies that would support accessible development and accessible design patterns as well as highlighting areas of development that needed to be prioritized due to accessibility, ease of use and inclusion requirements.

The accessibility of the platform was analyzed against WCAG 2.0 recommendations, as the latest version of WCAG 2.1 was not available at the time. Manual checks were used as well as automated accessibility testing tools, but in essence, it was the feedback from the trials that highlighted issues that could not have been foreseen just by using the guidelines and accessibility checking processes. So, although the project was targeting WCAG 2.0 AA overall, some *Operable* principles at level A and

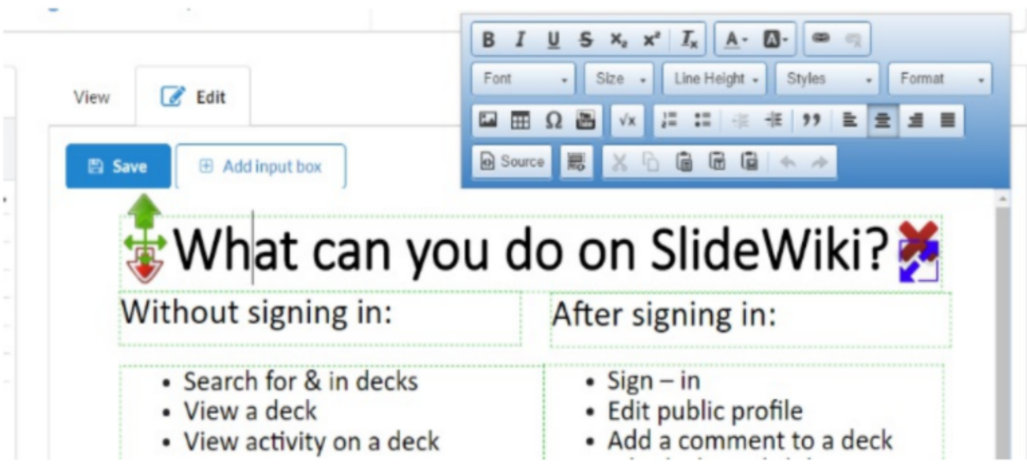


(a) Old design

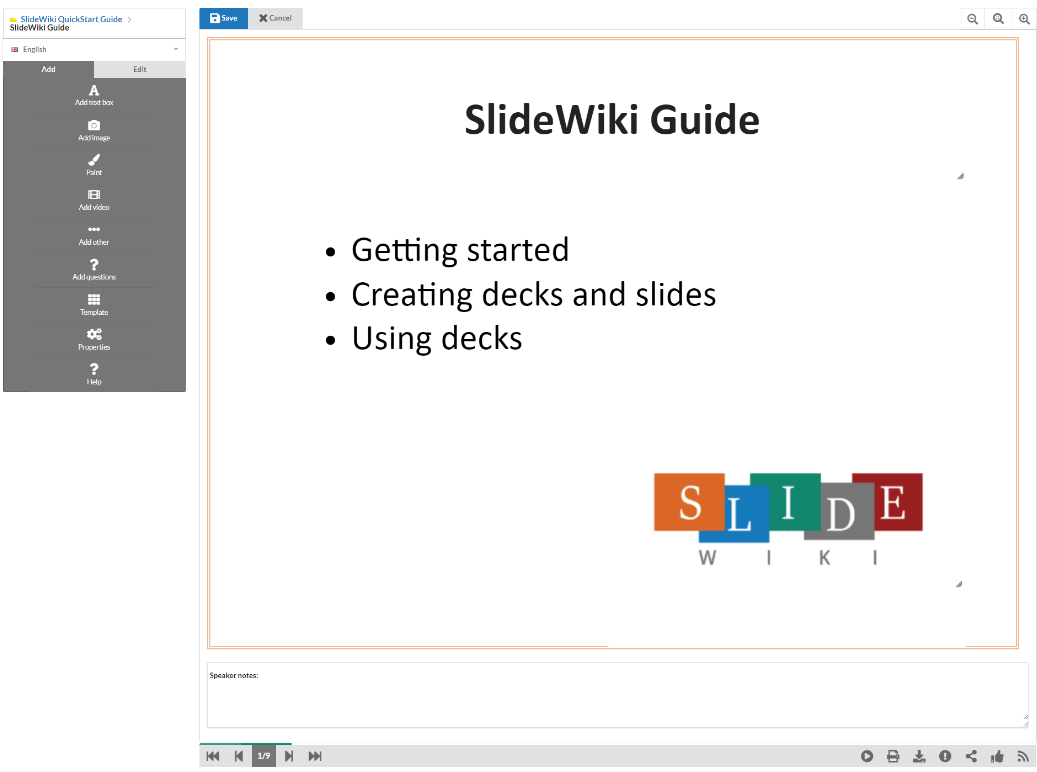


(b) New design

Figure 8.3: Deck view page of SlideWiki old and new design



(a) Old design



(b) New design

Figure 8.4: Editor of SlideWiki old and new design

AA failed in places. This was due to the incomplete accessibility of fields (i.e., some drop down lists and automatically generated text options) caused issues for NVDA screen reader users.

Towards the end of the project, a survey was undertaken to evaluate the final changes that were carried out in accordance with the trial findings. The survey evaluated the main functional alterations using levels of satisfaction and data was collected from the trial leaders rather than users. This was due to the fact that the latest release of the project occurred after the user trials had finished. The interface changes were accepted by all the participants with over 50% satisfaction. However, some comments and improvements were also included as feedback.

Involving users in the inception of the design process and the evaluation of a prototype or any simple representation of the platform interface has the potential to help to improve the guidance of the design and development process and can in turn avoid any reworking. However, despite accessibility being prioritized from the very beginning of the SlideWiki project and special considerations being made when selecting components and code libraries, there remained accessibility challenges during the implementation phases. Time can also be wasted when slight changes are made by developers without reference to the impact their changes may have on accessibility. There may also be the need for the reworking and redesign of components if there is a lack of involvement of those with disabilities in the initial design phase. This was a lesson learnt with the first version of SlideWiki, though it had many users.

In addition to primary platform functionality, editors should encourage and provide guidelines for authors to help the production of accessible OERs. This is a general lesson to be learnt, but in the case of SlideWiki efforts have been made to validate slide decks when they have been saved, to ensure that they have included accessibility requirements such as, checking the existence of slide headings, headers for table rows and columns and alternative text for images; as explained in Chapter 9. Due to time constraints this work was not integrated into the platform during the time of the project, however a prototype of this service was implemented as a trial and exists on the GitHub[2].

8.6 Summary

This chapter has shown how accessibility, usability and personalization have been handled throughout the development life cycle of the SlideWiki project processes including planning, development, testing and release. The involvement of users with disabilities, from the first phase of the development process, affected many of the design decisions taken during the project's lifetime and in more recent times. There have been discussions about recognised accessibility guidelines that have been used to address and evaluate the accessibility of the platform and the fact that compliance does not necessarily mean every part of an online platform will be accessible or easy to use. Among the lessons learnt, was that more effort should be made to evaluate the accessibility of code libraries and new technologies before they are published. This would save much development time and reworking. Knowledge gained from the changes made to ensure accessibility should also be shared with the community.

[2] https://github.com/slidewiki/accessibilitycheck-service

CHAPTER 9

Developing Accessible Open Education Resources - Slide Presentations

Creating and sourcing accessible OER is a challenge. Although slides are one of the primary forms of educational resources, there has been little focus on what is required to make slides containing different media accessible and how to encourage authors to improve accessibility. Section 9.1 introduces slides presentation as one type of OER and Section 9.2 identifies the components of slide presentations that require accessibility. Section 9.3 evaluates six different approaches to encourage authors in resolving accessibility issues. Finally, Section 9.4 summarizes the results and reports findings.

Related publications

- **Mirette Elias**, Abi James, Steffen Lohmann, Sören Auer and Mike Wald. *Towards an Open Authoring Tool for Accessible Slide Presentations.* In 16th International Conference on Computers Helping People with Special Needs (ICCHP) 2018 Proceedings, 172-180, Springer.

9.1 Accessibility Requirements of OER

To ensure OER are accessible, it is important to provide teachers and learners with disabilities with appropriate user interfaces (UIs) for reading, browsing, and authoring the materials. An OER can be represented in various formats, including text documents, slides, videos, and audio files. While considerable research has been conducted on the accessibility of individual media and text documents [184], one of the most common e-learning formats is slides for use in lectures and other teaching contexts.

Slides are created to represent information concisely with a structured layout in order to help learners easily recall knowledge. A slide *deck* comprises of a collection of slides which can make up a course, lecture, or any other form of presentation on a specific topic. One slide can be considered to be the equivalent of a paragraph of text in that it should convey a single topic or concept. However, whereas a paragraph usually only contains text, a slide can include different types of media, such as images, tables, audios, and videos. Slides are also widely used independently of a presenter, as they provide a readable and printable version of the content. Furthermore, they can be exported to other types of formats, such as static PDF documents or video slideshows.

Slides can pose particular accessibility challenges due to the frequent use of images, bulleted lists, and tables. In addition, the spatial layout of content on a slide is often used to convey information. The experience for a disabled user accessing these different types of content can be highly dependent on the quality of the accessibility information (such as the captions, audio descriptions, and 'alternative' text) used to annotate the slide. While some annotations can be automated, the authors of the slides are usually most suited to undertake this task, as they are the subject experts.

9.2 Accessibility Requirement of Slides

As a first step to identify the accessibility requirements of slides, an analysis was undertaken of the relevant components and properties of slides and decks. A deck has three components: 1) meta-data, 2) outline, and 3) slides.

The *deck meta-data* defines the properties of a deck (e.g., language, date, topic). It also contains the *theme* defining the visual presentation of the content within the deck. Each theme uses CSS to set the font size, font type, font color, and background color. As the theme is used to set the visual elements of a deck, this can be used to manage accessibility by offering color and font combinations that meet accessibility guidelines. The default theme of the platform includes high contrast and common color combinations for those visual difficulties. The inclusion of additional meta-data concerning the accessibility of a deck and its content becomes useful for educators when searching for OER. Such meta-data could be used to report decks that contain slides that have been checked for accessibility or to report the complexity of the text within the slides, as explained in the OER quality evaluation metrics in Chapter 4. This is linked to the needs of learners to filter search results; as explained in Chapter 6.

The *outline* refers to the structure and organization of the slides within the deck, which is important for learners to be able to navigate through the slides and recognize the structure of the presentation using different assistive tools. Each slide in the index contains an ID and a name, which is human-readable when viewing the structure of the deck. The slide name is equivalent to a page or document title and is independent of the title used within the slide content. To meet accessibility guidelines, authors should be encouraged to give each slide within a deck a unique name.

A *slide* is the fundamental part of a deck; it is composed of:

- The slide layout defines the location of the different content components within the slide and may also convey meaning.
- The slide content is made up of elements that may contain a heading, normal text (a short paragraph), a list, symbols and equations, tables, charts and images, hyperlinks, or embedded media such as a video.

A slide can only be considered to be fully accessible when each of the content elements within it meets the accessibility requirements for that type of media. In addition, the information indicated by the layout must be conveyed appropriately through the reading order and accessibility annotations. Predefined layouts, for example, with input boxes using predefined styles for the slide heading and a box for text and list content, can assist authors with managing the reading order if they are encouraged to use them. However, there is always a risk that authors will convey information through the layout (for example, if they use a number of components to create a diagram) and this will need to be described to readers who rely on non-visual access through accessibility annotations.

In order for the content created within the slide editor to be accessible, the following must be met: 1) comply with accessibility guidelines, and 1) allow authors to annotate the content with additional accessibility information [43]. The first step taken to meet these requirements was to select an authoring toolbar that conforms to the W3C ATAG 2.0) guidelines [185]. While such an authoring tool can generate accessible content, a review of the potential slide content elements identified six areas that would require input from the slide author, as outlined in Table 9.1.

Table 9.1: Accessibility requirements for the slide content elements

Slide content element	Accessibility added by the system	Author actions required to improve accessibility
Slide title	Set as heading using the respective HTML tag.	Ensure that each slide has a unique title.
Textbox	Authoring toolbar creates appropriate HTML tags text styling, lists and hyperlinks.	Ensure that lists and styles are added using the authoring toolbar.
Image	Interface provided for adding *alt* text and captions to images.	Ensure that the *alt* text is meaningful. Where multiple images are combined to form a diagram, the *alt* text should describe the diagram appropriately.
Embedded content	An *iframe* can be accessed using the keyboard, alternative input devices and assistive technologies. An interface is provided for adding a title or caption for embedded elements.	Ensure that each *iframe* has a title and that the site provides accessible controls. If the content contains video or audio media, and it does not have closed captions and/or an audio description, then a transcript and description should be provided in the speaker notes or attached to the slide.
Equations	Equations are embedded within slides as MathML.	Ensure authors avoid adding equations as images.
Tables	Tables are created as HTML, and an interface is provided for setting headers and adding a caption or text summary.	Define which rows and/or columns are headers and provide a caption or text summary of the table.

9.3 Approaches for Ensuring Authors Address the Accessibility Requirements of Slides

As part of an iterative, user-centered design process, six approaches were identified for encouraging authors to improve the accessibility of their slides:

1. **Require**: Require authors to address accessibility issues on each slide before they save their deck. Authors would be notified of accessibility issues and the actions they need to undertake to make their slides accessible before they can publish their slides as OER.

2. **Guidance**: Assist authors to make their content accessible as they create it. Authors would be presented with guides and hints on how to make their slides more accessible as they add content.

3. **Encourage**: Encourage authors to check and correct accessibility issues once they have created a slide. Authors would be informed of potential accessibility issues when they attempt to save a slide and be encouraged to address the issues.

4. **Rate**: Encourage authors to make their slides accessible by including accessibility as a factor in rating and search results. The number of accessibility issues would be considered a factor in

rating decks and ordering search results. Decks with the least number of issues would be rated higher.

5. **Crowd-source**: Encourage other users to improve the accessibility of slides in an attempt to crowd-source accessibility enhancements. Users could add accessibility information to other authors' decks. This would increase their prestige on the platform as they will have contributed content. However, their changes to the deck may not be as accurate as the annotations that would have been created by the original author.

6. **Automatic**: Attempt to automatically fix accessibility issues. Some techniques can be used to automatically improve the accessibility of slide content, but this may result in incorrect accessibility annotations being added to slides.

Each approach presents different advantages and disadvantages to authors and users who rely on accessibility conformance. This must be balanced against the goal of encouraging authors to create OER, with the potential to be accessible through an efficient and satisfying user experience.

In order to establish which approach would be most effective to encourage authors to create accessible slides, a survey was distributed to lecturers and teachers creating content within the SlideWiki project (Appendix B). Each approach was explained in the survey with an illustrated mock-up. Authors were requested to rank each approach using a five point Likert scale. In addition, the survey included a question about how much time the authors were willing to spend on accessibility issues per slide, and a free-text question was provided for additional comments. Thirteen authors responded to the survey; their results are presented in Figure 9.1.

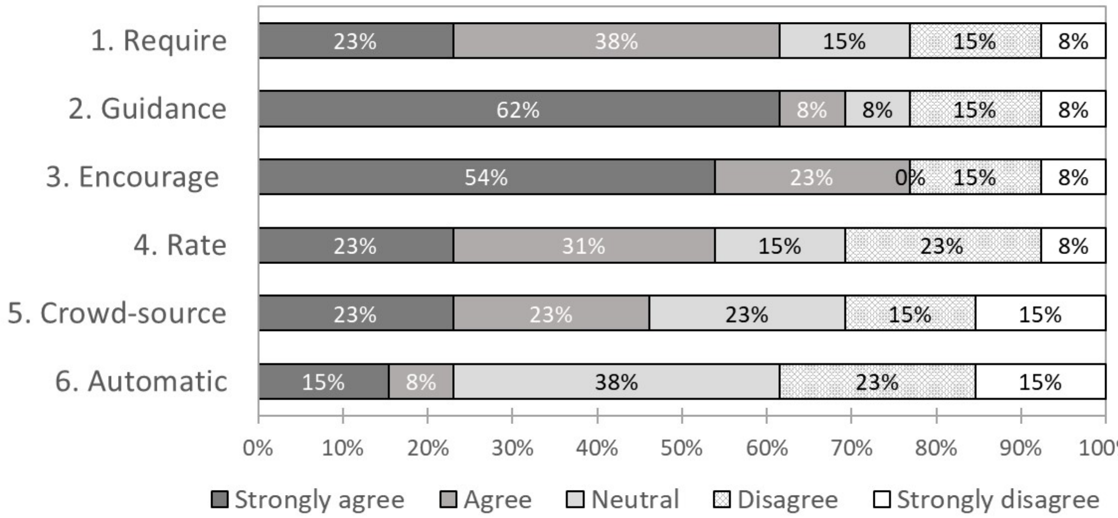


Figure 9.1: Chart of the responses by slide authors to questions of whether they agreed with each proposed approach to improving the accessibility of slides.

The approaches "encourage" and "guidance" received the most positive responses from authors with 77% and 69% in agreement, respectively. This shows that many authors would like to be made aware of potential accessibility issues and would like information on how to address these issues.

Responses for the “require” approach, which would ensure that authors addressed accessibility issues before publishing their deck, were also positive overall with 62% of respondents agreeing with this approach. Automatically correcting accessibility issues was the least popular approach with only 23% responding positively. Comments from authors indicated that they were concerned about the quality of automatic annotations and their content being altered without their approval. Similarly, there were mixed views on whether other users should be allowed to improve the accessibility of authors’ slides using the “crowd-source” approach, as concerns were raised about changes being made to authors’ slides without their knowledge. The authors did not show a clear preference on whether decks should be rated on their accessibility.

Figure 9.2 illustrates the amount of effort that authors would be willing to spend on accessibility issues. Authors were asked to say how long they were prepared to spend on fixing accessibility issues on a slide: 1) no time, 2) two minutes, 3) five minutes or 4) as long as it takes to create a slide. More than half of the respondents indicated that they felt two minutes was a reasonable time to fix accessibility issues on a slide, and 38.5% were willing to spend longer than two minutes. Only one respondent indicated they were not willing to spend any time addressing accessibility issues.

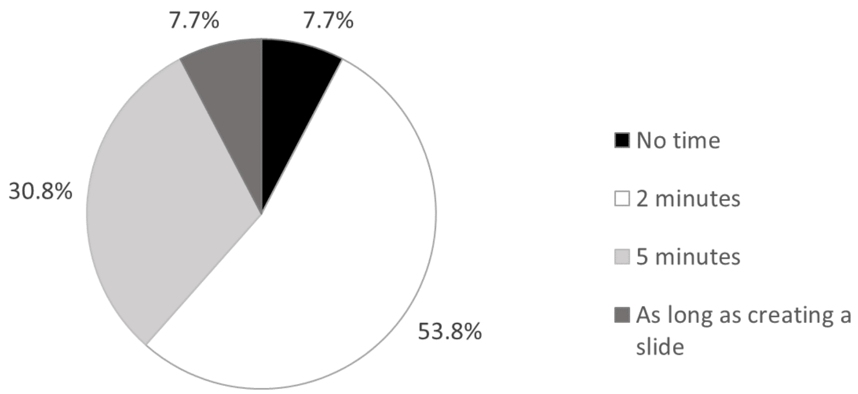


Figure 9.2: Chart of responses by slide authors to the question ”How long are you willing to spend improving the accessibility of a slide?”

9.4 Discussion

Despite slide presentations being one of the most common forms of learning material, there has been little work on investigating how these can be made accessible to all users. Accessibility guidance has tended to focus on materials that form a linear document or web page. By considering common elements in slides, six areas were identified as requiring the author’s input (cf. Table 9.1). This is a more straightforward list of requirements for authors to review than WCAG 2.0 [175], which contains at least 60 success criteria.

Responses from authors indicate that there is a preference to be encouraged to improve the accessibility of slides, as long as the process is efficient and not too time consuming. However, the two approaches that are preferred by the authors (“encourage” and “guidance”) would rely on their judgment and goodwill to resolve issues.

The survey was small; it was clear that quality and content ownership as well as the usability of the accessibility approach would affect how likely authors were to engage with improving the accessibility of slides. Improving accessibility cannot be separated from usability. It is important to ensure that the tools for creating accessible content are efficient and effective, as poor usability could result in lower usage and mitigate the objective of creating more accessible content.

Of particular interest were the concerns about the quality of the automatic accessibility annotations. Authors want to be able to check and confirm any amendments to their slides before they are published. This would limit the efficiency and usability gains of automated processes. On the other hand, the use of automatically generated image descriptions is increasing, and studies of their use in social media tools have shown that blind and visually impaired users tend to accept automatic descriptions if they are aware of their possible ambiguity [186]. However, the quality and provenance of learning content are particularly important when encouraging the adoption of OER. Therefore, having a level of ambiguity within accessibility annotations may not be appropriate in a learning context and requires further investigation.

9.5 Summary

Encouraging authors of OER and OCW to consider the needs of disabled learners and to meet accessibility requirements is vital for inclusion. Despite the wide use of slide presentations in education, few studies have considered the related accessibility requirements. This chapter has reviewed the elements that make up slide presentations and has determined which of these can impact the experience of users with accessibility needs. By providing a slide editing tool for creating accessible content, there are mainly six elements commonly used within slides that require the author to undertake actions to ensure the slides are accessible. Willingness to spend time fixing accessibility issues is increased if support is offered, as long as it is an efficient process. As a result of this work, it is intended that the SlideWiki platform will warn authors of potential accessibility issues and provide them with guidance as they create content. The authors' concerns about automatic correction of accessibility issues should be noted and future studies are needed to consider whether the impact of providing potentially inaccurate accessibility information benefits or hinders learners.

Part V

Conclusion and Future Work

CHAPTER 10

Conclusions and Future Work

In this thesis, we study the problem of representing accessibility needs and preferences of learners and including them in OCW platform and OER. In Part I, we describe the challenges and research questions addressed in Chapter 1. Chapter 2 defines the domains and terminologies used and Chapter 3 discusses the standards, guidelines and state-of-the-art of web accessibility and open education. Part II focuses on the quality and accessibility of open educational resources and how to evaluate them. Chapter 4 proposes metrics for evaluating educational resources and a set of these metrics is implemented in SlideWiki, an open OCW platform. Chapter 5 focuses on the OER metadata with the aim of analyzing accessibility and evaluating the quality of existing OER to enhance search and recommendation functions. Part III depicts the semantic solution for representing web accessibility needs of learners and educational resources. Chapter 6 explains in detail AccessibleOCW ontology and Chapter 7 shows how the ontology is utilized to recommend educational resources based on the learners profiles. Part IV reports our guides and best practices for developing an accessible OCW. Chapter 8 focuses on how accessibility was included in the development life cycle of SlideWiki. Chapter 9 explains the accessibility preferences in slide presentations and the approaches used to encourage authors to create accessible material. Finally, we conclude our work in Chapter 10 and present the future work and directions to this research.

10.1 Revisiting the Research Questions

> **RQ1**: How to evaluate the quality and accessibility of educational resources?

This research question is addressed in two directions. In Chapter 4, we focus on evaluating the quality of open educational resources. According to the state-of-the-art and our experience with developing an OCW platform, we propose the main dimensions to evaluate the quality of OER and propose metrics to help learners to find good quality OER and guide OCW platforms to improve their content. In Chapter 5, we concentrate on the quality of metadata that describes educational resources, with the goal of identifying accessibility and quality from OER metadata and developing a prediction model to improve the search results and recommend OER.

> **RQ2**: How can ontologies be used to represent the accessibility needs and preferences of learners in OCW?

This research question is addressed by developing AccessibleOCW ontology. The aim is to semantically represent the accessibility needs of learners and the accessibility features required in an OCW platform. Chapter 6 represents AccessibleOCW ontology which semantically defines the accessibility requirements of OCW domain. Using ontologies helps to represent the complex domain model for accessibility needs and skill sets as well as content properties of OER. The ability to reuse and enhance these semantic definitions in other projects is another fundamental advantage of using ontologies. Chapter 7 describe how ontology is used to map learners to the most appropriate educational material. We explain how we integrated the exiting OER dataset to the AccessibleOCW ontology to generate the knowledge graph. We queried this knowledge graph to find OER that matches the learners' profiles. We also presented how our work was integrated into a recommender system. Employing a knowledge graph has the advantage of being linked with other ontologies and Linked Open Data (LOD).

> **RQ3**: How to include these accessibility needs in the design and implementation of OCW platform and OER?

This research question reports our experience with developing an accessible OCW (SlideWiki). Chapter 8 explain how accessibility requirements were defined in the project and how the inclusion of learners in all the development stages is important to develop an inclusive and accessible platform. We discuss that only following guidelines and standards do not guarantee an accessible and personalized learning experience. Each person is different and the learning requirements differ from on person to another. When it comes to accessibility needs, it is not only the superficial representation of content that matters but the organization and meaning of words also matter. In Chapter 9, we explain how it is important to study and analyze the accessibility needs of developing/authoring an educational material as the type and requirements differ from one learning representation to another. We also discuss the importance of encouraging authors to create accessible material and we studied how accessibility should be addressed in a slide presentation.

10.2 Future Work

Digital education is essential for the learning process. The reuse of open educational resources and self-learning has become part of day-to-day learning. Including accessibility needs and preferences in this open system is important to the inclusion of many learners consuming a variety of learning resources. In this section, we proposed future directions to continue the contributions of this thesis.

Automatic quality evaluation of OER. We establish evaluation metrics that assess the quality of OER. These metrics provide guidance to OER content authors to create good quality content and learners to select good quality content. Developing an automatic evaluation method with a rating or rewards system that appears on each OER will encourage authors to provide good quality material and prioritize their efforts. This will also allow learners to select resources that successfully pass the quality evaluation metrics and have higher rates than others. It is also worth mentioning that, according to our survey on creating accessible materials, authors prefer to include and fix accessibility issues when creating educational materials themselves. This automatic quality evaluation of OER can check and provide comments for authors to improve their educational material with timely feedback.

Extending and Reusing AccessibleOCW ontology. Ontologies are developed with the aim of reuse. AccessibleOCW ontology is reusing ACCESSIBLE ontology to represent user disabilities and web accessibility guidelines and standards. We integrated the accessibility needs of learners and the accessibility description for educational materials. This work can be extended and reused by other platforms that aims to develop accessible educational material. This ontology can also be integrated with other education ontologies to include accessibility needs, for example, EduCOR [187].

Including accessibility in software development life cycles. In our thesis, we discussed our experience with including learners with accessibility needs in the agile development life cycle of SlideWiki. Including users with accessibility needs, finding ways to elicit their requirements, and evaluating iteratively the functions of the platform against their needs is still an open area of research. Identifying procedures and best practices, and integrating them in the development life cycle of software will open a new window for including more users in the systems and widening the skills and knowledge of users who have accessibility needs.

Accessibility of OER Assessments. Designing and representing learning questions and assessments is another challenge when dealing with learners with disabilities. For example, using multiple choice can be preferable over essay questions for some disabilities. Using an ontology to describe the guidelines and list of targeted disabilities would aid in constructing appropriate questions and assessments for impaired learners. Further research is needed for defining such guidelines and tailoring them to provide features for learning checks and progress.

APPENDIX A

List of Publications

1. Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Metadata Analysis of Open Educational Resources.* (Nominated for Best Short Paper Award) In 11th International Conference on Learning Analytics & Knowledge, 2021 Proceedings, ACM.

2. **Mirette Elias**, Mohammadreza Tavakoli, Steffen Lohmann, Gábor Kismihók, and Sören Auer. *An OER Recommender System Supporting Accessibility Requirements.* In 22nd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) 2020 Proceedings, 57:1-57:4, ACM.

3. **Mirette Elias**, Allard Oelen, Mohammadreza Tavakoli, Gábor Kismihók, and Sören Auer. *Quality Evaluation of Open Educational Resources.* In 15th European Conference On Technology Enhanced Learning (EC-TEL) 2020 Proceedings, 410-415, Springer

4. Mohammadreza Tavakoli, **Mirette Elias**, Gábor Kismihók, and Sören Auer. *Quality prediction of open educational resources a metadata-based approach.* In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 29-31, IEEE.

5. **Mirette Elias**, Edna Ruckhaus, E.A. Draffan, Abi James, Mari Carmen Suarez-Figueroa, Steffen Lohmann, Abderrahmane Khiat, and Sören Auer. *Accessibility and Personalization in OpenCourseWare : An Inclusive Development Approach*. (Nominated for Best Full Paper Award) In 20th International Conference on Advanced Learning Technologies (ICALT) 2020 Proceedings, 279-283, IEEE.

6. **Mirette Elias**, Steffen Lohmann und Sören Auer. *Ontology-Based Representation for Accessible OpenCourseWare Systems.* In *Information* 2018, 9(12), Multidisciplinary Digital Publishing Institute.

7. **Mirette Elias**, Abi James, Edna Ruckhaus, Mari Carmen Suárez-Figueroa, Klaas Andries de Graaf, Ali Khalili, Benjamin Wulff, Steffen Lohmann und Sören Auer. *SlideWiki - Towards a Collaborative and Accessible Platform for Slide Presentations.* In 13th European Conference On Technology Enhanced Learning (EC-TEL) 2018 Practitioner Proceedings, 1-13, CEUR Workshop Proceedings.

8. **Mirette Elias**, Abi James, Steffen Lohmann, Sören Auer and Mike Wald. *Towards an Open Authoring Tool for Accessible Slide Presentations.* In 16th International Conference on Computers Helping People with Special Needs (ICCHP) 2018 Proceedings, 172-180, Springer.

9. **Mirette Elias**, Steffen Lohmann and Sören Auer. *Ontology-based Representation of Learner Profiles for Accessible OpenCourseWare Systems.* In 8th International Conference on Knowledge Engineering and Semantic Web (KESW) 2017 Proceedings, 279-294, Springer.

10. **Mirette Elias**, Steffen Lohmann, and Sören Auer. *Towards an Ontology-based Representation of Accessibility Profiles for Learners.* In 2nd International Workshop on Educational Knowledge Management (EKM) 2016 Proceedings. Co-located with 20th International Conference on Knowledge Engineering and Knowledge Management (EKAW), EKM@EKAW 51-59, CEUR Workshop Proceedings.

11. **Mirette Elias**, Steffen Lohmann, and Sören Auer.*Fostering accessibility of OpenCourseWare with semantic technologies – a literature review.* In 7th International Conference on Knowledge Engineering and the Semantic Web (KESW) 2016 Proceedings, 241-256, Springer.

APPENDIX B

Survey - Evaluating Accessibility Motivation Approaches

Evaluating different approaches to encourage the use of particular accessibility features to support all users, including those with disabilities.

We would like to encourage authors to make their content in SlideWiki as accessible as possible. We have identified potential approaches for encouraging or enforcing authors to make sure they complete the sort of accessibility tasks only those who understand the context of the content can apply, such as alternative text to describe images for those who are blind and use screen readers. As part of our research, we would like to gather input from potential authors regarding the approaches they feel are acceptable. This research will be presented at a conference in July 2018.

Currently, some accessibility information needs to be added manually to slides. This includes titles for iframes used for embedded content where an additional section of content has been added to a slide and labelling headers in tables (the row above or column beside the data) as well as meaningful alt-text for images mentioned above.

In the following survey, we present mock-ups of six different approaches we could use to encourage authors to improve the accessibility of slides. Please indicate how you would feel about each approach if it was implemented in SlideWiki.

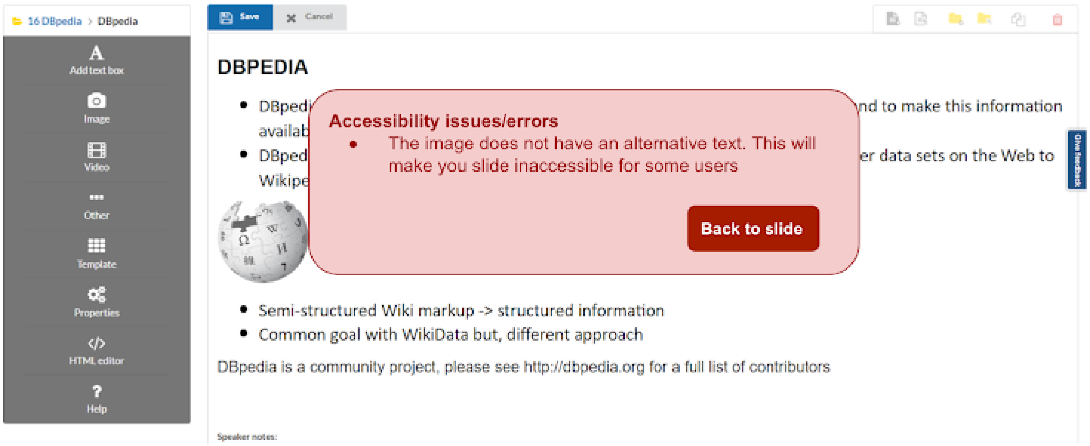
Thank you for your assistance!

*Required

Approach 1: Require authors to complete accessibility actions on each slide before they save their deck

With this approach, authors would be notified of additional actions they need to undertake to make their slides accessible before they can publish their slide.

1. How much do you agree with the following statement: "I am happy to be required to fix accessibility issues before saving my slides to make them accessible for all users." *



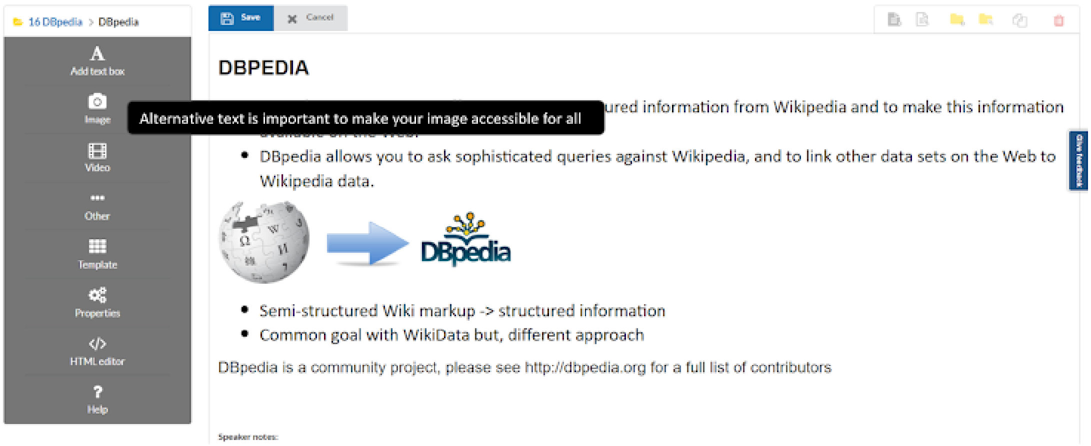
Mark only one oval.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly disagree

Approach 2: Encourage authors to complete accessibility actions on each slide as they create the content, for example, through providing hints and tips.

In this approach, authors would be presented with guides and tips on how to make their content more accessible as they add items to their slides.

2. How much do you agree with the following statement: "I would like to see accessibility tips and hints while editing my slides to help me make it more accessible to all users." *



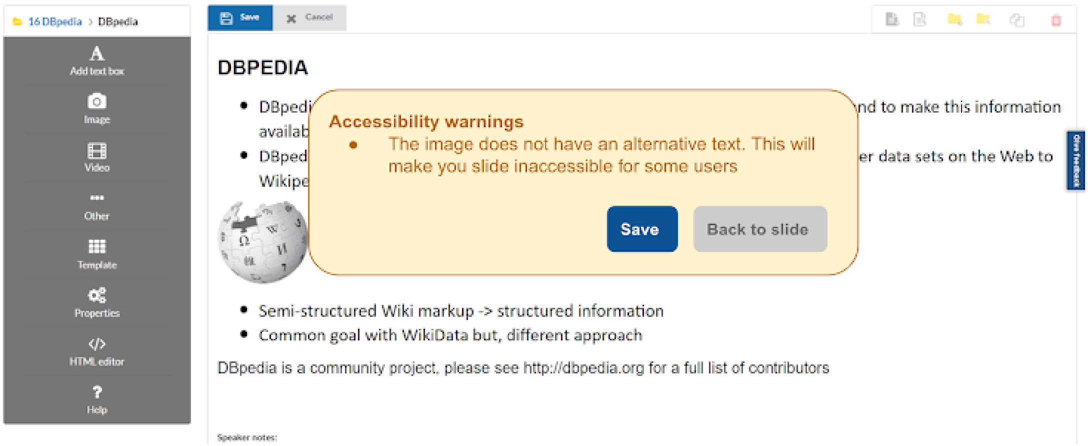
Mark only one oval.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly disagree

Approach 3: Encourage authors to check and correct possible accessibility issues once they have created a deck, through the use of a rating system that rewards authors.

When an author saves their slide, they will informed of accessibility issues and encouraged to fix them before saving.

3. How much do you agree with the following statement: "I would like to see a list of accessibility warning when I save a slide and have the option to fix them or ignore them." *



Mark only one oval.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly disagree

Approach 4: Encourage authors to make their decks accessible by including accessibility as a factor in rating and search results.

With this approach, the number of accessibility alerts would be considered as a factor in rating decks and ordering search results. Decks with the least number of warnings would be rated higher.

4. How much do you agree with the following statement: "I would be happy for my decks to be rated in terms of accessibility as this would encourage me to fix any accessibility issues." *

Mark only one oval.

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

Approach 5: Encourage other users to improve the accessibility of slides in an attempt to crowd-source accessibility enhancements.

In this approach, other users could add accessibility information to your deck. This would improve their rating on the platform as they will have contributed content, but their additions to your deck may not be as appropriate as the content you would have written as the author of the deck.

5. How much do you agree with the following statement: "I would be encouraged to fix accessibility issues on other slides in order to increase my reputation or rating." *

Mark only one oval.

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

Approach 6: Attempt to automatically generate as many accessibility annotations as possible

Use techniques to automatically improve the accessibility of slide content. This may result in incorrect accessibility information being added to slides.

6. How much do you agree with the following statement: "I would like the accessibility of my slides to be fixed automatically, even if this might not resolve all the issues or be accurate." *

Mark only one oval.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly disagree

7. How long would you be willing to spend on a slide to improve its accessibility?

Mark only one oval.

- ◯ 2 minutes
- ◯ 5 minutes
- ◯ As long as it would take me to create a slide
- ◯ No time
- ◯ Other: ____________________

8. Thank you for taking the time to complete this survey. If you have any further suggestions or comments please note them below.

APPENDIX C

Survey - Assessment of OER Quality Evaluation Metrics

Assessment of OER Quality Evaluation Metrics

This survey assesses our proposed metrics for evaluating the quality of Open Educational Resources (OER). The aim of these metrics is to provide guidelines for the authoring tools to assist authors in creating high-quality educational resources. The metrics focus on the three main components of OER:

1. Content Structure defines the organization and navigation of the educational resource.
2. Learning Content refers to the representation form/format of the learning material.
3. Self Assessment refers to the questions that are designed to evaluate the learning process.

Each category is composed of a set of dimensions and metrics. The survey is expected to take 10 minutes to complete. The survey will be open until Thursday 23/4/2020.

Your feedback is valuable and will help us in our research. We really appreciate it.

---

*Required

1. What is your current occupation?

   Mark only one oval.

   - ◯ PhD student
   - ◯ Instructor

2. How many open educational portals (e.g. Opencourseware, MOOCs) did you use before? *

   Mark only one oval.

   - ◯ 1 portal
   - ◯ 2 portals
   - ◯ more than 2 portals

3. What was your purpose of using open educational portals (e.g. OpenCourseWare, MOOCs)? *

Tick all that apply.

- [ ] Learning purpose (e.g. exploring new subject)
- [ ] Teaching purpose (i.e. reusing existing material for teaching)
- [ ] Authoring purpose (i.e., creating your own material on an educational portal)

Content Structure

Content Structure defines the structure of an educational resource, the navigation between its components, and the metadata describing the educational resource (i.e., level, subjects). The design of the content structure should provide a clear overview of the course, simple and predictable navigation structure.

4. How much do you agree with the following statement: "In general, I am satisfied with the quality of the content structure and navigation of the OERs which I am currently using or used in the past" *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

5. 1. Clearness of the taxonomies - Please rate the Importance *

The naming given to OER components should be self-explanatory and consistent with the content of the OER. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
1.1 OERs should have short and descriptive file names	⬭	⬭	⬭	⬭	⬭
1.2 The titles of OERs should be coherent with the file names	⬭	⬭	⬭	⬭	⬭
1.3 OER titles should include a number to indicate their order (e.g., Lecture 1: OER title)	⬭	⬭	⬭	⬭	⬭

6. 2. Easiness of navigation - Please rate the Importance *

The navigation structure of the OER components should be simple and predictable. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
2.1 The hierarchical design provides easy navigation	⬭	⬭	⬭	⬭	⬭
2.2 The number of hierarchical levels should not exceed the depth of 3 levels	⬭	⬭	⬭	⬭	⬭

7. 3. Adaptability of the structure - Please rate the Importance *

The extent to which a hierarchical structure can be personalized with respect to the learner needs and preferences. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
3.1 Adaptability mechanism should be provided to allow personalization	⬭	⬭	⬭	⬭	⬭

8. 4. Discoverability of the content - Please rate the Importance *

Discoverability shows how an OER can be found and used through the educational services (e.g., search and recommender systems); which is realized by metadata. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
4.1 The OERs should be described by metadata					
4.2 The metadata of the OER should adhere to a standardized metadata description and/or metadata of quality controlled OERs					
4.3 The metadata can be extracted from quality controlled OERs					

9. The above metrics are useful for evaluating the quality of OERs in terms of content structure. *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

10. If you have any further comments or suggestions, please note them here.

Skip to question 11

Learning Content

Learning content refers to the learning material and its representation (e.g. videos, text document, slides).

11. How much do you agree with the following statement: "In general, I am satisfied with the quality of the learning content and representation of the OERs which I am currently using or used in the past" *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

12. 1. Quality of text - Please rate the Importance *

The correctness and comprehensiveness of the content text. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
1.1 There should be a mechanism to check the correctness of text spelling and grammar	⬭	⬭	⬭	⬭	⬭
1.2 The text should be simple to address different types of learners (e.g. cognitive impaired users, non-native English speakers)	⬭	⬭	⬭	⬭	⬭

13. 2. Adaptability of content - Please rate the Importance *

The availability of multiple content format and representation to address different preferences and needs of learners (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
2.1 The content of the OER should be available in different formats (e.g., videos, text document) to address the different preferences of learners	⬭	⬭	⬭	⬭	⬭
2.2 The content of the OER should be availability in multiple representation (e.g., multiple color contrast)	⬭	⬭	⬭	⬭	⬭
2.3 These content types should be consistent with each other (e.g., versioning control)	⬭	⬭	⬭	⬭	⬭

14. 3. Compatibility of content on multiple devices - Please rate the Importance *

The extent of interoperability on different type of devices. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
3.1 The OER content should be accessible on various devices (e.g., mobile, tablet)	⬭	⬭	⬭	⬭	⬭
3.2 There should be a mechanism to check the compatibility of OER content on these devices	⬭	⬭	⬭	⬭	⬭

15. 4. Accessibility of content representation - Please rate the Importance *

The accessibility of content to learners with accessibility needs (e.g., visually impaired). (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
4.1 The content representation should comply to the accessibility guidelines (e.g. WCAG, WAI)	◯	◯	◯	◯	◯
4.2 A validation approach should be available to check the accessibility of the content representation.	◯	◯	◯	◯	◯

16. 5. Multilinguality of content - Please rate the Importance *

Availability of content/material in multiple languages. (1=Less important and 5=Very Important)

Mark only one oval per row.

	1	2	3	4	5
5.1 The availability of resources in more than one language.	◯	◯	◯	◯	◯
5.2 The existence of translation approach (e.g., automatic, semi-automatic, crowd-sourcing techniques)	◯	◯	◯	◯	◯
5.3 The availability of synchronization approach for the material translation	◯	◯	◯	◯	◯

17. The above metrics are useful for evaluating the quality of OERs in terms of learning content and its representation. *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

18. If you have any further comments or suggestions, please note them here.

____
____
____
____
____

Skip to question 19

Self-assessment

Self-assessment of OER includes availability of questions and answers for evaluating learners understandability

19. How much do you agree with the following statement: "In general, I am satisfied with the quality of the self-assessment and evaluation of the OERs which I am currently using or used in the past". *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

20. 1. Availability of self-assessment - Please rate the Importance *

Mark only one oval per row.

	1	2	3	4	5
1.1 The existence of self-assessment material					
1.2 The availability of answers					
1.3 The average number of questions covering the content (e.g. questions should 80% of content)					
1.4 The availability of question generation approach (i.e. generating, questions, answers, distractors)					

21. 2. Variety of self-assessment questions - Please rate the Importance *

Mark only one oval per row.

	1	2	3	4	5
2.1 The availability of different types of self-assessment questions (e.g., MCQ, short answer)					
2.2 The number of questions per assessment type (e.g. comprehensiveness, problem-solving)					

22. The above metrics are useful for evaluating the quality of OERs in terms of self-assessment. *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

23. If you have any further comments or suggestions, please note them here.

Overall Evaluation

24. Usefulness: In general, these dimensions and metrics are useful for evaluating the quality of OER *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

25. Coverage: This study covers the most important criteria for evaluating the quality of OERs *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

26. Thank you for taking the time to complete this survey. If you have any further suggestions or comments please note them below.

APPENDIX D

Survey - Evaluating Learner Profile with accessibility needs

Evaluating preferences of Learner Profile

This questionnaire is used to evaluate the aspects that can be used to define the needs and preferences of learners with accessibility needs, and suggest the appropriate type of educational resources for each type of learner. The definitions used in this survey are based on the IMS Access for All (https://www.imsglobal.org/activity/accessibility) specifications.

*Required

1. I would like to evaluate the learner profile of the users with the following disability

Mark only one oval.

- Blindness (text cannot be read at any magnification) *Skip to question 2*
- Low vision (including color blind) *Skip to question 7*
- Deaf and hard of hearing *Skip to question 12*
- Cognitive, language, and learning disabilities (including low literacy) *Skip to question 17*
- Physical disabilities *Skip to question 22*

Blindness

Total blindness where text cannot be read at any magnification

2. A learner would prefer as an input requirement *

Tick all that apply.

- [ ] full keyboard control
- [ ] full mouse control

3. A Learner would prefer to avoid hazard content like

Tick all that apply.

- [ ] Flashing
- [ ] Sound
- [ ] Motion simulation

4. A learner would prefer an educational material with

Tick all that apply.

- [ ] simplified content
- [ ] enriched/complex content

5. Learners are using assistive technologies *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

In this question, we want to know the preferred type of educational material with respect to the learners' preferences

We provide four answers:
1. No alternative, which means that no change is required for this type of content.
2. Text alternative, such as an audio transcript, a video caption, and an image alternative text.
3. Audio alternative, such as adding an audio description to a video to clarify different visual details which are not clear from the sound track, or providing a text-to-speech technology adaptation.
4. Visual alternative, like changing the page colors and formats using CSS, allowing Zoom feature, and using sign language

6. If the educational material is in the following forms, the learners would prefer which type of alternatives *

Tick all that apply.

	No alternative	Text alternative	Audio alternative	Visual alternative
Text content	☐	☐	☐	☐
Audio content	☐	☐	☐	☐
Visual content (video or image resources)	☐	☐	☐	☐
Color (Information is conveyed that requires the ability to perceive color)	☐	☐	☐	☐
Text on image (Information is conveyed using text where the text is embedded in an image, e.g., charts)	☐	☐	☐	☐
Orientation (containing direction information, e.g. an icon which indicates going to the above section)	☐	☐	☐	☐
Position (Information is conveyed that requires the ability to distinguish the relative locations of items using vision.)	☐	☐	☐	☐
Item size (Information is conveyed that requires the ability to distinguish the relative sizes of items using vision.)	☐	☐	☐	☐

Low Vision

Low vision including color blind users

7. A learner would prefer as an input requirement *

Tick all that apply.

- [ ] full keyboard control
- [ ] full mouse control

8. A Learner would prefer to avoid hazard content like

Tick all that apply.

- [ ] Flashing
- [ ] Sound
- [ ] Motion simulation

9. A learner would prefer an educational material with *

Tick all that apply.

- [ ] simplified content
- [ ] enriched/complex content

10. Learners are using assistive technologies *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

In this question, we want to know the preferred type of educational material with respect to the learners' preferences

We provide four answers:
1. No alternative, which means that no change is required for this type of content.
2. Text alternative, such as an audio transcript, a video caption, and an image alternative text.
3. Audio alternative, such as adding an audio description to a video to clarify different visual details which are not clear from the sound track, or providing a text-to-speech technology adaptation.
4. Visual alternative, like changing the page colors and formats using CSS, allowing Zoom feature, and using sign language

11. If the educational material is in the following forms, the learners would prefer which type of alternatives *

Tick all that apply.

	No alternative	Text alternative	Audio alternative	Visual alternative
Text content	☐	☐	☐	☐
Audio content	☐	☐	☐	☐
Visual content (video or image resources)	☐	☐	☐	☐
Color (Information is conveyed that requires the ability to perceive color)	☐	☐	☐	☐
Text on image (Information is conveyed using text where the text is embedded in an image, e.g., charts)	☐	☐	☐	☐
Orientation (containing direction information, e.g. an icon which indicates going to the above section)	☐	☐	☐	☐
Position (Information is conveyed that requires the ability to distinguish the relative locations of items using vision.)	☐	☐	☐	☐
Item size (Information is conveyed that requires the ability to distinguish the relative sizes of items using vision.)	☐	☐	☐	☐

Deaf and hard hearing

12. A learner would prefer as an input requirement *

Tick all that apply.

- [ ] full keyboard control
- [ ] full mouse control

13. A Learner would prefer to avoid hazard content like

Tick all that apply.

- [ ] Flashing
- [ ] Sound
- [ ] Motion simulation

14. A learner would prefer an educational material with *

Tick all that apply.

- [ ] simplified content
- [ ] enriched/complex content

15. Learners are using assistive technologies *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

In this question, we want to know the preferred type of educational material with respect to the learners' preferences

We provide four answers:
1. No alternative, which means that no change is required for this type of content.
2. Text alternative, such as an audio transcript, a video caption, and an image alternative text.
3. Audio alternative, such as adding an audio description to a video to clarify different visual details which are not clear from the sound track, or providing a text-to-speech technology adaptation.
4. Visual alternative, like changing the page colors and formats using CSS, allowing Zoom feature, and using sign language

16. If the educational material is in the following forms, the learners would prefer which type of alternatives *

Tick all that apply.

	No alternative	Text alternative	Audio alternative	Visual alternative
Text content	☐	☐	☐	☐
Audio content	☐	☐	☐	☐
Visual content (video or image resources)	☐	☐	☐	☐
Color (Information is conveyed that requires the ability to perceive color)	☐	☐	☐	☐
Text on image (Information is conveyed using text where the text is embedded in an image, e.g., charts)	☐	☐	☐	☐
Orientation (containing direction information, e.g. an icon which indicates going to the above section)	☐	☐	☐	☐
Position (Information is conveyed that requires the ability to distinguish the relative locations of items using vision.)	☐	☐	☐	☐
Item size (Information is conveyed that requires the ability to distinguish the relative sizes of items using vision.)	☐	☐	☐	☐

Cognitive, Language, and Learning Disabilities

This category includes learners with low literacy

17. A learner would prefer as an input requirement *

Tick all that apply.

- [ ] full keyboard control
- [ ] full mouse control

18. A Learner would prefer to avoid hazard content like

Tick all that apply.

- [ ] Flashing
- [ ] Sound
- [ ] Motion simulation

19. A learner would prefer an educational material with *

Tick all that apply.

- [ ] simplified content
- [ ] enriched/complex content

20. Learners are using assistive technologies *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

In this question, we want to know the preferred type of educational material with respect to the learners' preferences

We provide four answers:
1. No alternative, which means that no change is required for this type of content.
2. Text alternative, such as an audio transcript, a video caption, and an image alternative text.
3. Audio alternative, such as adding an audio description to a video to clarify different visual details which are not clear from the sound track, or providing a text-to-speech technology adaptation.
4. Visual alternative, like changing the page colors and formats using CSS, allowing Zoom feature, and using sign language

21. If the educational material is in the following forms, the learners would prefer which type of alternatives *

Tick all that apply.

	No alternative	Text alternative	Audio alternative	Visual alternative
Text content	☐	☐	☐	☐
Audio content	☐	☐	☐	☐
Visual content (video or image resources)	☐	☐	☐	☐
Color (Information is conveyed that requires the ability to perceive color)	☐	☐	☐	☐
Text on image (Information is conveyed using text where the text is embedded in an image, e.g., charts)	☐	☐	☐	☐
Orientation (containing direction information, e.g. an icon which indicates going to the above section)	☐	☐	☐	☐
Position (Information is conveyed that requires the ability to distinguish the relative locations of items using vision.)	☐	☐	☐	☐
Item size (Information is conveyed that requires the ability to distinguish the relative sizes of items using vision.)	☐	☐	☐	☐

Physical disabilities

22. A learner would prefer as an input requirement *

Tick all that apply.

- [ ] full keyboard control
- [ ] full mouse control

23. A Learner would prefer to avoid hazard content like

Tick all that apply.

- [ ] Flashing
- [ ] Sound
- [ ] Motion simulation

24. A learner would prefer an educational material with *

Tick all that apply.

- [ ] simplified content
- [ ] enriched/complex content

25. Learners are using assistive technologies *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

In this question, we want to know the preferred type of educational material with respect to the learners' preferences

We provide four answers:
1. No alternative, which means that no change is required for this type of content.
2. Text alternative, such as an audio transcript, a video caption, and an image alternative text.
3. Audio alternative, such as adding an audio description to a video to clarify different visual details which are not clear from the sound track, or providing a text-to-speech technology adaptation.
4. Visual alternative, like changing the page colors and formats using CSS, allowing Zoom feature, and using sign language

26. If the educational material is in the following forms, the learners would prefer which type of alternatives *

Tick all that apply.

	No alternative	Text alternative	Audio alternative	Visual alternative
Text content	☐	☐	☐	☐
Audio content	☐	☐	☐	☐
Visual content (video or image resources)	☐	☐	☐	☐
Color (Information is conveyed that requires the ability to perceive color)	☐	☐	☐	☐
Text on image (Information is conveyed using text where the text is embedded in an image, e.g., charts)	☐	☐	☐	☐
Orientation (containing direction information, e.g. an icon which indicates going to the above section)	☐	☐	☐	☐
Position (Information is conveyed that requires the ability to distinguish the relative locations of items using vision.)	☐	☐	☐	☐
Item size (Information is conveyed that requires the ability to distinguish the relative sizes of items using vision.)	☐	☐	☐	☐

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Acronyms

AfA DRD IMS Global Access For All Digital Resource. 22, 46, 48, 61, 65–68

AfA PNP IMS Global Access for All Personal Needs and Preferences. 22, 61, 64, 67, 68

ATAG Authoring Tool Accessibility Guidelines. 15, 105

CSS Cascading Style Sheets. 20, 24, 28, 104

CSV Comma Separated Value(s). 81

DCMI Dublin Core Metadata Initiative. 48

HTML HyperText Markup Language. 20, 27–29

HTTP HyperText Transfer Protocol. 18

ICF International Classification of Functioning, Disability and Health. 21, 23, 61, 69

IMS AfA IMS Global AccessForAll. 22, 61, 62, 65, 69, 70, 78

IMS CP IMS Content Packaging. 35, 37, 38

IMS SS IMS Simple Sequencing. 38

LOM IEEE Standard for Learning Object Metadata. 38, 46

LRMI Learning Resource Metadata Initiative. 38, 48

MOOCs Massively Open Online Course. 11, 12

OBDA Ontology-Based Data Access. 81, 82

OCW OpenCourseWare. iii, 3–8, 10–15, 19, 25, 27–30, 33, 40, 49, 59–62, 73, 78, 91, 92, 108, 111, 112

OER Open Educational Resource. iii, 4–15, 25, 27, 28, 33–35, 37–46, 49–55, 59, 60, 62, 65, 69, 79, 80, 82, 86, 87, 103–106, 108, 111–113

OWL Web Ontology Language. 17, 18

R2RML RDB to RDF Mapping Language. 81, 82

RDF Resource Description Framework. 17, 18, 38, 48, 60, 79, 81

RDFS Resource Description Framework Schema. 17

RIF Rule Interchange Format. 17

SPARQL Simple Protocol and RDF Query Language. 17, 18, 59, 61, 62, 74–76, 79, 81

SWRL Semantic Web Rule Language. 17, 61, 62, 64, 75

Turtle Terse RDF Triple Language. 59, 82

UAAG User Agent Accessibility Guidelines. 15

URI Uniform Resource Identifier. 16, 18, 60, 66, 67

W3C World Wide Consortium. 15, 17, 18, 20, 27, 28, 73, 78, 81, 84, 105

WAI-ARIA Web Accessibility Initiative – Accessible Rich Internet Applications. 20, 23, 24, 27

WCAG Web Content Accessibility Guidelines. 4, 5, 15, 20, 23, 27–29, 34, 40, 62, 91–93, 98, 107

WHO World Health Organisation. 4

WWW World Wide Web. 15

XML Extensible Markup Language. 16, 17, 37, 38