Gate2Math: Open multilingual smart library for mathematical resources supporting efficient learning
2022-1-EE01-KA220-HED-000089461

A comprehensive review on OER in the framework of the ERASMUS+ project Gate2Math

Contents

Introduction and Objectives

Gate2Math, henceforth the project, is an ERASMUS+ project, entitled "Open multilingual smart library for mathematical resources supporting efficient learning" granted by the European Union Commission, under the 2022 Call of the Partnerships for Cooperation (Key Action 2) and identified as 2022-1-EE01-KA220-HED-000089461. The Gate2Math consortium is led by the TTK University of Applied Sciences (Tallinn, Estonia) with the participation of the following partners: Instituto Politecnico do Porto (Porto, Portugal), Universitat Politècnica de Catalunya (Barcelona, Catalonia, Spain), Universitatea Tehnica Cluj-Napoca (Cluj Napoca, Romania), Campus 02 Fachhochschule Der Wirtschaft GMBH (Graz, Austria) and Tallinn University (Tallinn, Estonia).

The main objective of the project is to implement and put into service for the international educational community an efficient Gate2Math smart library for the optimal selection of open and multilingual (7 different languages) educational resources (OER) in the field of mathematics teaching in the context of engineering. The scope of the content includes open resources from a theoretical point of view, practical, applied and assessment, covering the contents of Algebra, Calculus, Geometry, Statistics and Probability, among others.

The first step in order to have an accurate and scientific assessment model to be used across the project, when managing the OER and evaluating their quality and teaching performance, is located in the work package 3, activity 2 (WP3/A2), named "OER Assessment model and scope". After reviewing the current state of the art on types, characteristics and adequacy of OERs, the Key Performance Indicators (KPI) focused on technical, teaching and accessibility aspects will be determined. Once the assessment model is available it will be possible to determine the scope (i.e. type of educational resources to be considered and mathematical concepts across the engineering curricula to be treated) of the OER to deal with and to be incorporated into the Gate2Math smart library.

In accordance with the previous aims, this document is the output of the research work done by the Gate2Math consortium in this WP3/A2 activity and it is structured as follows. Chapter 1 collects the main definitions and concepts related to OER, in order to base the subsequent work. In Chapter 2 national regulations on OER standardization and use will be described. OER classification, including description and learning objectives, can be found in Chapter 3. Chapter 4 deals with the state of the art and a comparative analysis on OER assessment methodologies, the definition of the KPIs for OER quality assessment and a comprehensive rubric for OER assessment will be performed. A final Chapter 5 reviews the OER movements and the OER developing groups across the world. In order each section to be self contained, links to the sources of information are included along the text and the References section is located at the end of each chapter. The report ends with a discussion and conclusion section.

1. OER main definitions and concepts

The concept of Open Educational Resources (OER), as recognised today, is quite new since it appears in the context of the digital era. However, OER core idea has a deep history and many antecedents as it is connected to the history of Open Education and Open Learning, which dates back from long ago (Nyberg, 1975). OER has its roots in the concept of open access to information and knowledge. The idea of sharing educational resources and making them available to anyone, anywhere, and at any time has been around for centuries. For instance, the Greek philosopher Socrates freely shared his knowledge and thoughts with all those who were interested without seeking any payment or compensation (Corey, 2002).

However, the emergence of digital technologies and the internet in the late 20th century facilitated the development of OER as we know them today. One of the earliest proponents of open access to educational materials was the Massachusetts Institute of Technology (MIT) in the early 2000s. MIT launched the OpenCourseWare (OCW) initiative in 2001, which made all of its course materials available for free online (MIT, 2001). This initiative inspired other institutions to follow suit, and today it is recognised that this was the basis and motor for thousands of OER initiatives around the world.

In 2002, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) coined the term "Open Educational Resources", to describe teaching, learning, and research materials in any medium that reside in the public domain or have been released under an open licence that permits their free use and repurposing by others. Specifically, in their final report, UNESCO recommends the “first” OER definition (UNESCO, 2002, p. 24):

> *“The open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes.”*

Since then, UNESCO has been actively promoting the use of free educational resources.

In 2007, the concept of OER was associated with the idea of open content, which in turn was based on the idea of free and open source software (Wiley, 2007). The William and Flora Hewlett Foundation, which had financed numerous early OER programs, proposed a new definition of OER, which includes non-digital resources and focuses on different types of OER (Atkins, Brown, & Hammond, 2007, p. 4):

> *“OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge.”*

In the same year, the Organisation for Economic Co-operation and Development (OECD) recognises the following OER definition (OECD, 2007, p. 10):

> *"…digitized materials offered freely and openly for educators, students, and self-learners to use and reuse for teaching, learning, and research."*

This definition emphasises the digital nature of OER and their openness, which means that they are available to use and adapt without cost or permission. It also highlights the multiple uses of OER, including for teaching, learning, and research by educators, students, and self-learners. However, the authors of the OECD (2007, p.38) report felt the need to clarify the words in the accepted definition and to state that, at that point, it was "impossible to give the concept a definitive definition", recognizing that OER were "still in its infancy and practices and technologies are rapidly changing", explicitly mentioning that "In the coming years, it will be necessary to return to the question of how OER should be defined".

Also in 2007, another description appears, right on the basis of the second strategy call in the Cape Town Open Education Declaration (Cape Town Open Education Declaration, 2007):

> *"… open educational resources should be freely shared through open licenses which facilitate use, revision, translation, improvement and sharing by anyone. Resources should be published in formats that facilitate both use and editing, and that accommodate a diversity of technical platforms. Whenever possible, they should also be available in formats that are accessible to people with disabilities and people who do not yet have access to the Internet."*

In 2011, the concept of OER, in its simplest form, was described by Bucher (2011, p. 5) as:

> *"… any educational resources (including curriculum maps, course materials, textbooks, streaming videos, multimedia applications, podcasts and any other materials that have been designed for use in teaching and learning) that are openly available for use by educators and students, without the need to pay royalties or license fees."*

In 2012, the first World OER Conference, organised by UNESCO, marked a turning point. It approved the 2012 Paris OER Declaration, which included a broader definition of OER (UNESCO, 2012, p.1) as:

> *"…teaching, learning, and research materials in any medium, digital or otherwise, that are in the public domain or have been released under an open license that permits no-cost access, use, adaptation, and redistribution by others with no or limited restrictions. Open licensing is built within the existing framework of intellectual property rights as defined by relevant international conventions and respects the authorship of the work."*

In 2019, UNESCO (2019, p. 5) points out another definition that mentions the "5R" feature

(described further) that is currently, and commonly, recognised as an intrinsic part of the OER meaning :

> *"Open Educational Resources (OER) are learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others."*

Since the beginning of the 2010 decade, UNESCO and the Commonwealth of Learning (COL) are recognised supporters and promoters of OER, having assumed an OER policy in 2013 and 2011, respectively (Miao, Mishra & McGreal, 2016). Even funding agencies such as the Hewlett Foundation and Wellcome Trust have adopted open access policies as part of their strategic development. All these organisations, and others, have launched a number of initiatives aimed at increasing awareness of OER and supporting their adoption and implementation around the world as, for instance, OER World Map - which provided an up to date database of OER initiatives[1], OER Research Hub - a project that was funded by the Hewlett Foundation in 2012[2], among many other projects. All these projects and ventures work towards a common objective of a sustainable and open education opportunities in accordance with Sustainable Development Goal 4 (SGD4) (United Nations, 2015, p. 19) for providing quality education to all individuals regardless of their gender, social or economic status, and to promote lifelong learning opportunities for all, which Learning Objectives are particularly described by UNESCO (UNESCO, 2017).

In this sense, it can be said that the primary goal of OER is to make educational resources accessible to everyone, regardless of geographic location, socioeconomic status, or other barriers. By providing free and open access to educational resources, OER can help to democratise education and promote lifelong learning.

Since their appearance, OER have been increasingly recognised as powerful tools for improving access to quality education and reducing costs for learners. OER have the potential to promote lifelong learning and address inequalities in education by allowing anyone with an internet connection to access and use high-quality educational resources for free (Wiley, Bliss, & McEwen, 2014)

Overall, UNESCO sees OER as a key component of efforts to achieve the United Nations

[1] The OER Worldmap (Blog) was a project funded by The Hewlett Foundation that was hosted and developed by the North Rhine-Westphalian Library Service Centre from 2014 to 2022. https://oerworldmap.wordpress.com/2022/03/22/goodbye-world/

[2] This Project ended in 2015 and it transitioned to a "portfolio-based approach, encompassing a range of open education related projects". However, as observed in its webpage (in March 2023), the more recent post/news is from November/2019 - http://oerhub.net/

Sustainable Development Goals, particularly those related to quality education systems that are inclusive, equitable, and accessible to all learners. Here are some of the UNESCO OER initiatives related to quality education:

- OER and Quality: UNESCO has developed a set of guidelines for the production and evaluation of OER, which are intended to help ensure that OER are of high quality and can effectively support teaching and learning. These guidelines cover aspects such as accuracy, accessibility, pedagogical effectiveness, and adaptability (UNESCO, 2011).
- ICT Competency Framework for Teachers: this is an UNESCO project that had its first steps in 2008 with the purpose of informing educational policy makers, providers of professional learning and working teachers on the role of ICT in educational reform. Currently, the supporting document is in its 3rd version (UNESCO, 2018) and this project has its basis on a OER Commons Hub[3].
- Inclusive Education in open and distance learning: in 2016 UNESCO presented a set of guidelines on the inclusion of learners with disabilities (UNESCO, 2016). This document focuses on open and distance learning (ODL) in different educational environments where technology plays an increasingly important role. This includes fully remote settings as well as b-learning frameworks where students use technology mediated settings alongside traditional methods. Further developments can be seen in Kanwar et al. (2017).
- The UNESCO OER Recommendation: In 2019, UNESCO adopted a Recommendation on OER, which encourages Member States to promote the development, sharing, and use of OER as a means of improving the quality and accessibility of education. The Recommendation emphasises the importance of ensuring that OER are accessible to all learners, including those with disabilities, and that they are available in a variety of languages (UNESCO, 2019).

In the recent years, a number of guidelines, definitions and concepts were developed to aid in the growth of the OER movement, including:

- **Open Pedagogy** – This is an approach to teaching and learning that uses OER to create more collaborative and engaging learning experiences. Open pedagogy involves allowing students to participate in the creation and adaptation of OER, which can lead to more relevant and personalised learning materials (Wiley, 2013).
- **OER-enabled Pedagogy** – This concept involves using OER as a foundation for teaching and learning, but also goes beyond just using open resources. OER-enabled pedagogy involves incorporating open practices, such as collaborative learning, into the teaching process to create more interactive and engaging learning experiences (Cronin, 2017).
- **Open Educational Practices (OEP)** – This is a broader concept that encompasses both OER and open pedagogy. OEP involves using open practices, including the use and creation of

[3] https://www.oercommons.org/hubs/unesco

OER, to promote access to education, improve teaching and learning, and encourage collaboration and sharing among educators and learners (Ehlers & Conole, 2010).

- **Open Textbooks** – This concept refers to textbooks that are openly licenced and available for free online. Open textbooks can provide significant cost savings for students, and also offer opportunities for customization and adaptation by educators (Hilton & Wiley, 2011) .
- **Open Educational Resources for Development (OER4D)** – This concept involves using OER to support the development of education in low-income countries. OER4D initiatives aim to promote the use of open resources to improve access to education, increase the quality of teaching and learning, and support capacity-building in education systems (Hodgkinson-Williams & Trotter, 2018).
- **5R's of Open Educational Resources (OER)** – This concept was proposed by David Wiley, a prominent advocate for open education. The 5R framework has been widely adopted and is considered a foundational concept in the field of open education. The 5R's provide a set of guidelines for creating and using OER in a way that maximises their potential to support teaching and learning while promoting openness, collaboration, and innovation. The 5R's of OER are (Wiley, 2014):
    - **Retain** – The ability to make OER accessible and available for future use, by storing them in repositories or other digital archives.
    - **Reuse** – The ability to use existing OER in new and different contexts to support teaching and learning.
    - **Revise** – The ability to adapt, modify, or alter existing OER to better suit the needs of a specific audience or educational setting.
    - **Remix** – The ability to combine different OER to create new resources that meet specific learning objectives or address particular learning needs.
    - **Redistribute** – The ability to share OER with others, either by making them publicly available or by sharing them with specific individuals or groups.
- **Open Science** – The specific definition of this concept is quite wide (UNESCO, 2021, Annex – p.4) encompassing several movements and practices aimed at making scientific knowledge openly available, accessible, and reusable for everyone.
- **Open Scientific Knowledge** – This concept is defined by UNESCO (2021) and it agglomerates several Scientific Publications, Open Research data, OER, Open source software and source code and Open hardware that are available in the public domain under (5R) open policies.
- **Free and Open Source Software (FOSS)** – it's a software that is distributed with a licence to use, modify, and distribute the software without any restrictions. One must beware that "Free" in FOSS does not necessarily mean "free of cost" , but rather it refers to the freedom to use, analyse, modify and distribute the software (Free Software Foundation, n.d.) and the original source code is made freely available and may be redistributed and

modified (UNESCO, 2021)[4] .

- **Open Data** – According to the Open Data Foundation, "Open data is data that can be freely used, re-used and redistributed by anyone - subject only, at most, to the requirement to attribute and share alike" (Open Data Foundation, n.d.). The particular case of **Open Research Data** (UNESCO, 2021, Annex – p.5) can be considered a subset of the global Open Data concept, regarding data that is collected, produced, or used in the context of academic research.
- **Open Access to Scientific Information (OA)** – This concept refers to "the online availability of scholarly information to everyone, free of most licensing and copyright barriers—for the benefit of global knowledge flow, innovation and socio-economic development"[5].
- **Open Licence** – is related to authorising open use of all kinds of creative works/resources (Open Licensing of Educational Resources, n.d.). This should be mentioned in the plural (licences) since there are many different types of open licences, each with its own specific terms and conditions. The most commonly used licensing model is from the **Creative Commons (CC)** organisation. In this sense, despite the "open" adjective, there are several recognised "levels of openness" and many times it is not easy to distinguish between them. A brief summary of the "freedom" of usage is presented in Figure 1, in a clear schematic way regarding the corresponding CC model option that enables authors to maintain ownership while determining the terms and conditions for open usage of their works.

[4] Several specific considerations about FOSS in https://en.unesco.org/freeandopensourcesoftware

[5] https://www.unesco.org/en/open-access-scientific-information?hub=704

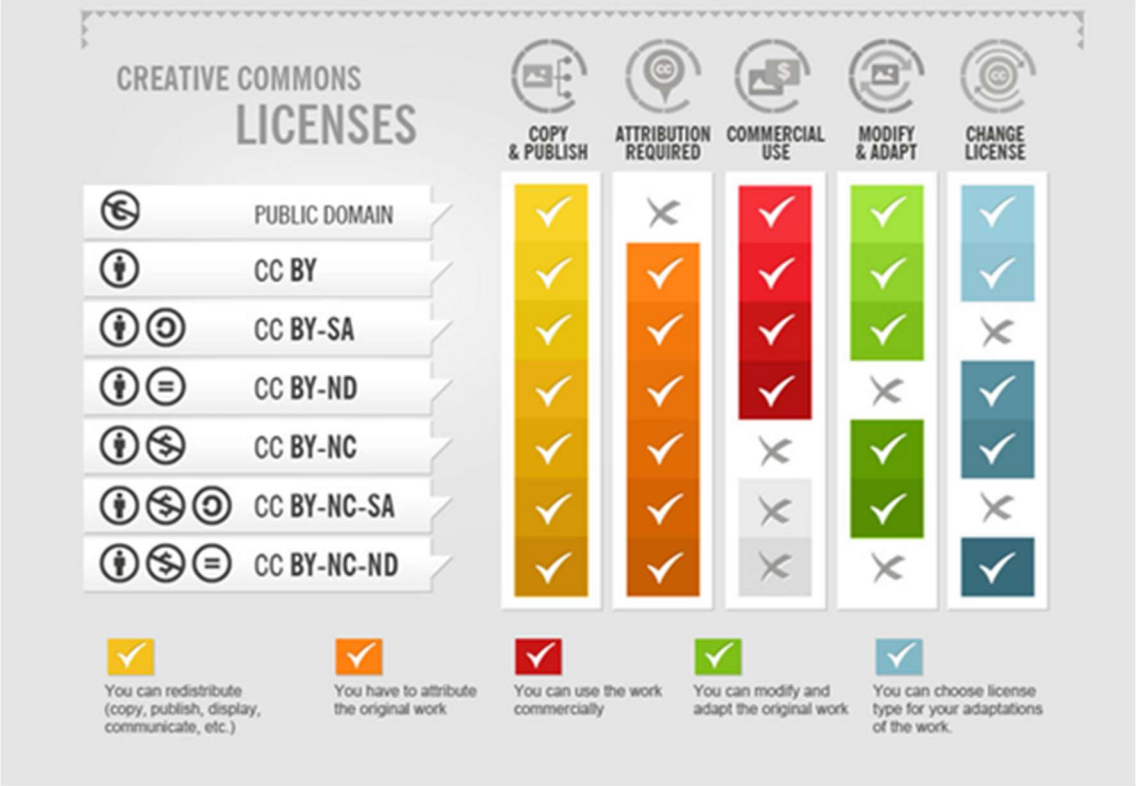

Figure 1. CC licences model options. From: How To Attribute Creative Commons Photos by Foter, CC BY 3.0.

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2. Regulations concerning OER standardization, use and support

With the *Digital Education Action Plan*, the European Commission provides recommendations for successful digital education and training as support for the member states. A first version of the action was created in 2018, however in 2020 it was revised and published under the name Digital Education Action Plan (2021-2027) (European Commission, 2023, p. 1). This action plan is a political initiative of the European Union, with the aim that a common idea for digital education for the European area is developed and so that the individual member states can be supported in their own political programs (European Commission, 2023, p. 1), and is seen as a "key enabler to the vision of achieving a European Education Area by 2025".[6]

The action plan is, among other things, also a reaction to the COVID-19 pandemic, in which the ministries of education were faced with the challenges of implementing teaching and learning as distance learning and/or in digital form due to the political measures. On the one hand, this led to the development of new innovative approaches; on the other hand, it also made people aware of the challenges, especially in terms of access to (digital) technologies, and difficulties that digital teaching and learning scenarios present (European Commission, 2023, p. 4).

A key objective of the action plan is to promote the digital transformation of education and training in the member states through funding. In particular, the member states are to build up competencies for digital education, and the EU recommends the following measures to this end (European Commission, 2023, p. 6):

- development of a (coherent) strategy for digital education,
- creation of a tool for review and evaluation of digital education and training measures,
- a whole-of-government approach to digital education and training,
- building and strengthening partnerships with teachers,
- investing in high-quality, accessible, inclusive and secure digital education and training.

The Digital Education Action Plan comprises two strategic priorities that will be implemented with the help of fourteen actions: "fostering the development of a high-performing digital education ecosystem and enhancing digital skills and competences for the digital transformation" (European Commission, 2023, p. 1).

The Council for National Open Science Coordination (CoNOSC), which is a network of national coordinators for open science (OS) in the UN European Region, highlights the differences between how countries formally organize OS policy development (see Figure 2) (Treadway & Proudman, 2022, p. 2).

[6] https://education.ec.europa.eu/focus-topics/digital-education/action-plan

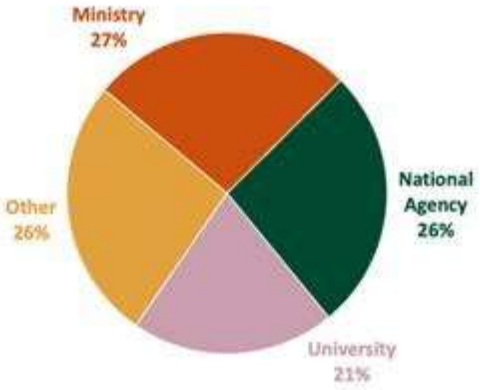

Figure 2. Open Science formal policy developers in the UN European Region (Treaway & Proudman, 2022, p. 2).

There is a roughly even balance between those who work in a ministry, national agency (usually those who are delegated responsibility for coordinating all research and funding) and those who work in other organisations. Responsibility for policy can be shared among several ministries or departments, or belong to a single organisation with multiple areas of responsibility (Treadway & Proudman, 2022, p. 2).

Some countries such as France (Ministry of Higher Education, Research and Innovation, 2021), Finland (Open Science Coordination in Finland, 2020) and Slovenia (Državni zbor Republike Slovenije, 2022) have a specific national OS strategy or policy, while others, such as Romania or the Czech Republic, include OS in several strategies or policies, or develop OS in combination with other policy areas. In other European countries, there are some differences in the approval of the OS policy: in Finland, before the policy is approved and implemented, it must be agreed with 100% of the stakeholders. In Ireland or Hungary, OS policy is approved by a coalition of interested institutions, and in Switzerland and Belgium by constitutionally autonomous federal entities (Treadway & Proudman, 2022, p. 3).

In the following, the regulations for the development and use of OER in selected countries are presented in order to gain an insight into the implementation and approach. The selection is mainly based on available literature in English and contains mostly European countries, but we also give a short overview of the situation in some countries outside Europe.

2.1. Australia

The Federal Parliament of Australia establishes the national education policy. But each of the six states and two territories has the right to make education laws. Parliament only prevails over state law in the event of inconsistency (Commonwealth of Australia, 2016, p. 26).

Higher education is administered by the Department of Education and Training, including the Higher Education Standards Commission appointed by the Minister of Higher Education. All higher education courses in Australia must be accredited by the Higher Education Quality and Standards Association (TEQSA). The understanding of OER in Australia is in line with the

understanding of the Paris Declaration (UNESCO, 2012).

The commitment to digital transformation is evidenced by the latest *Digital Economy Strategy 2030* (Commonwealth of Australia 2021), and is ranked third in the world for open data initiatives after Canada and the UK. In addition, all states and territories in Australia have their own digitalization strategies. Some of these focus more on government and/or industry digitalization (e.g. Northern Territory Government 2018) rather than education specifically, but such as: The *Queensland Digital Strategy* (Queensland Government 2017, p. 16) refers to the introduction of digital technologies in education, including partnerships with industry, universities and researchers.

Other strategies are quite progressive, explicitly mentioning the use of open and reusable data, cloud infrastructure, and investments in repositories. The *Australian Capital Territory's Digital Strategy* (ACT Government, 2016), for example, aims to promote "the use of open data and access to services for those at every level of digital maturity" (p. 10), as well as impact "across all organisations". The *NSW Digital Strategy* (Government of New South Wales, 2018) explores ways to use predictive tools to measure data quality as well as remove legal barriers to digital transformation, while the *Tasmanian Digital Strategy* (Government of Tasmania, 2019a) includes a focus on developing opportunities for citizens to develop lifelong digital skills learning in line with their *Adult Learning Strategy* (Government of Tasmania, 2019b).

Figure 3. Digitalization strategies in Australia (Bond, 2022, p.60).

Australia's school sector is strongest in terms of OER. The *National Digital Learning Resources Network* is a resource collection, delivery infrastructure and metadata standards for Australian schools operated by Education Services Australia. Access to resources relevant to Australian and state curricula is provided through Scootle.[7] Scootle is a national repository of over 20,000

[7] https://www.scootle.edu.au/ec/p/home

teaching and learning resources for Australian schools in line with the Australian curriculum, including several Creative Commons-licenced OER (Bond, 2022, p. 27).

2.2. Austria

In February 2022, the Federal Ministries of Education, Economy and Research (BMBWF), of Digitalization and Business Location (BMDW) and of Climate Protection, Environment, Energy, Mobility, Innovation and Technology (BMK) adopted the *Open Science Policy Austria*.[8] This document is based on the recommendations of the Open Science Network Austria (OANA, formerly Open Access Network Austria) and the objectives of the EU in the field of research and data education. OANA[9] was founded in 2012 by the Austrian Science Fund[10] (FWF) and the Austrian University Conference[11] (UNIKO) and publishes recommendations for an OS Strategy in Austria in autumn 2020 (BMBWF, BMDW & BMK 2022, p. 1). OS includes all disciplines from the environment of science, i.e. research, teaching, projects etc., among the principles is the use of OER for education and in university teaching (BMBWF 2022, p. 35).

The *Austrian Open Science Policy* is based on the international principles of OS (BMBWF, BMDW & BMK 2022, p. 7). Thus, Austria is "involved in the development of open, transparent and inclusive science and promotes fair treatment of research processes and their results" (BMBWF, BMDW & BMK 2022, p. 12). The communication and sharing of knowledge is seen as an essential part of OS, thus OER represent an essential part of open learning resources. The following measures are formulated within the framework of the *Open Science Policy* (BMBWF, BMDW & BMK 2022, p. 16):

> *"Austria would like to make its contribution to making the learning materials created in Austria in whatever form publicly accessible and in open formats, for example using established open data standards. In a first step, the relevant repositories will be linked and thus made publicly accessible. In this way, Austria wants to make learning content available to the scientific community on the one hand and make learning more flexible and adapt it to individual needs on the other."*
>
> *"The Forum New Media Austria (FNMA) has already prepared "Recommendations for the Integration of Open Educational Resources at Universities in Austria". The currently running project "Open Education Austria Advanced", in which several universities are involved, is concerned with the implementation of a corresponding infrastructure."*

[8] https://www.bmbwf.gv.at/Themen/HS-Uni/Hochschulgovernance/Leitthemen/Digitalisierung/Open-Science/Open-Science-Policy-Austria.html

[9] https://www.oana.at/en/

[10] https://www.fwf.ac.at/en/

[11] https://uniko.ac.at/index.php?lang=EN

> *"Universities and universities of applied sciences are therefore called upon both to create infrastructures for storing OER and to share them with others. Staff working at universities and universities of applied sciences should be encouraged to post their content and share it in open formats where possible and appropriate."*

Since 2015, the Federal Ministry of Education, Economics and Research has published *Austrian National Development Plan for Public Universities* (GUEP[12]), which is the basis for the development plans and performance agreements of the 22 public universities in Austria. In these documents, objectives are defined for two performance periods (6 years) and updated every three years. Currently, the third version of GUEP (2022-2027) is in force, and the fourth version (GUEP 2025-2030) has already been prepared and was published at the end of 2022.[13]

The GUEP 2022-2027 contains seven objectives, among others to improve the quality and efficiency of teaching (BMBWF 2019, p. 5). As a measure to improve didactics, among other things, the "use of Open Educational Resources (OER) to increase self-learning as well as ubiquitous unrestricted access to knowledge" (BMBWF 2019, p. 54; translated) will be implemented by 2024. In addition to BMBWF and the universities, the association Forum Neue Medien in der Lehre Austria (fnma) is responsible (BMBWF 2019, p. 54).

Specifically, the document mentions the following implementations (BMBWF 2020, p. 54):

- increased use of Massive Open Online Courses (MOOCs)
- cooperative use of offerings from other universities

In the updated GUEP 2025-2030, only six objectives are now defined, although improving the quality and efficiency of teaching remains a key component. Among the implementation goals, the STEM[14] subjects are mentioned (BMBWF 2022, p. 27) and the goals are more specific, e.g., that digital teaching and learning formats are developed and increasingly used (BMBWF 2022, p. 26; translated):

- *Reflective development and use of digital as well as innovative teaching and learning formats and resources (e.g., Open Educational Resources [OER], Massive Open Online Courses [MOOCs], etc.) in order to pursue new ways of flexible and target group-oriented teaching and learning on site, hybrid, or digital.*
- *Creating experimental spaces to test innovative (digital) teaching and assessment methods.*

As part of the national project *Digital Action Plan Austria*, Austrian universities are also being addressed as active shapers of the digital transformation (BMBWF 2022, accompanying

[12] Gesamtösterreichischer Universitätsentwicklungsplan

[13] https://www.bmbwf.gv.at/Themen/HS-Uni/Hochschulgovernance/Steuerungsinstrumente/GUEP.html

[14] Science, Technology, Engineering and Mathematics

document "Universitäten und Digitale Transformation im Jahr 2030").

2.3. Canada

Canada is a huge country in every way - geographically, socially, politically and economically. It consists of 10 provinces, each of which was a confederation at different times. Therefore, Canada does not have a single unifying educational system or policy at the national level. The implementation of OER in Canada is hampered at the national level due to the issue of jurisdiction outlined above and the absence of any powerful body advocating OER (Conrad & Veletsianos, 2022, p. 117).

However, OER and digitalization are thriving in mostly academic and library structures, led and supported by their active stakeholders and advocates in higher education institutions (Conrad & Veletsianos, 2022, p. 118). In keeping with Canada's tradition of decentralization in education policy and practice, each of Canada's 10 provinces and two territories manages education independently and has moved closer to digitalization and OER at its own pace (Conrad & Veletsianos, 2022, p. 180).

At the national level, there are many organisations and consortiums that support open education efforts. These multi-provincial organisations operating outside of federal and provincial law include *Creative Commons Canad*a, *Canada OER* (a task force that shares information and promotes open education) and the *Canadian Alliance of Student Associations*. The Ontario and British Columbia associations include special groups created to promote open and digital education initiatives, as well as existing groups that have expressed an interest in OER and open education. In British Columbia, these include *BCCampus*[15], the *BC Open Education Librarians* (an open practice group), the *Education Technology Users Group* (a group of educators and practitioners interested in improving learning and teaching through technologies) and *OpenETC* (a group of educators and educational technologists that develops and maintains an open and educational technology infrastructure for higher education institutions in British Columbia) (Conrad & Veletsianos, 2022, p. 138).

For example, *eCampusOntario*[16] is the most inclusive collaboration in Ontario, which includes the following: implementation and maintenance of digital access projects, development and implementation of a metadata strategy, digital curation, development and promotion of OER. *ECampus Ontario* is Ontario's largest, most comprehensive and ambitious OER tool, operated by a government-appointed board and providing educators and students with access to over 250 free and open licenced educational resources through the hosting of its *Open Library*, launched in 2017 in partnership with *BCCampus* (Conrad & Veletsianos, 2022, p. 131).

[15] https://open.bccampus.ca/what-is-open-education/canadas-open-education-initiatives/

[16] https://www.ecampusontario.ca/

2.4. China

The political structure in different countries to some extent influences the development of national standards for the creation, dissemination and quality assurance of OER in higher education (Zawacki-Richter et al., 2023).

China, in this sense, has a highly centralised political structure that is driving the digital transformation of education and is using OER to improve the quality of learning and teaching in the higher education sector (Xiao & Zhang, 2022). In addition to the Ministry of Education, which has been developing specifications for the construction of modern distance education resources since 2000, the China e-learning technology standardization committee has already developed several national and association standards related to the digitalization of education, including OER (Zawacki-Richter et al., 2023).

2.5. Estonia

The most important events in the field of education are determined by the *Education Strategy 2021-2035*, adopted by the Estonian government in November 2021. It prioritizes funding and development programs for implementation (Ministry of Education and Research 2021a, p. 28). As part of the educational strategy, digital solutions increase the accessibility, diversity and effectiveness of Estonian education. Public schools and vocational schools have a high-level digital infrastructure (Ministry of Education and Research 2021a, p. 14).

Schools in Estonia are autonomous, as the National Curriculum leaves the school free to develop its own curriculum. Higher education is flexible and accessible. It is supported by a wide range of forms of study, taking into account learning and work experience in studies, as well as the opportunity to work while studying (Ministry of Education and Research 2021a, p. 19). In Estonia, digital competency systems for teachers and students have been created and widely used, complemented by self-assessment tools, other tools and several professional development initiatives.[17]

Since 2018, digital education and mentoring in Estonian schools has been carried out as part of the Digital Accelerator program for the development of digital competencies, in which the entire teaching staff of the school participates. To coordinate the development of digital competencies, a working group has been created, which includes: the Estonian State Department for Education and Youth (Harno), experts from Tallinn University, the University of Tartu and various schools.[18] The *Digital Competence Framework for teachers* is adapted from *DigCompEdu 2019* and the *Digital Competence Framework for students* is adapted from *DigComp 2.1*.[19] There is also an additional adapted version of the framework for students with special needs. Educational

[17] https://digipadevus.ee/

[18] https://www.educationestonia.org/innovation/digital-competence/

[19] https://digipadevus.ee/

materials on primary, general and vocational education at all levels are free and available on the state portal *E-schoolbag*.[20] Part of the educational data in Estonia is open to all on *HaridusSilm*[21].

2.6. Finland

Since Open Science (OS) and research have reached different levels of maturity in Finland, a national project "Open Research, Development and Innovation work, open learning, and the innovation ecosystem of Finnish UAS" has been created in the ecosystem of Finnish universities of applied sciences, which aims to strengthen and development of OS and Open Education (OE) activities (Kärki et al., 2021, p. 162). Finnish universities, together with the research community, have developed a national declaration of OS and research for 2020-2025. This declaration defines the goals of a research culture, open access to research publications, open access to research data and methods, and educational resources (Kärki et al., 2021, p. 163).

The Declaration on Open Science and Research, signed by 66 organisations (most of which are universities), represents a common vision that states that open science and research should be integrated into the daily work of researchers and support not only the effectiveness of research results, but also the quality of research (Open Science Coordination in Finland, 2020, p. 1). The Open Science and Research Policy in Finland details strategic principles, goals and action plans in four areas (see Figure 4): a culture of open scholarship, open access to scientific publications, open access to research data and methods, and open education and open access to educational resources (Open Science Coordination in Finland, 2020, p. 3).

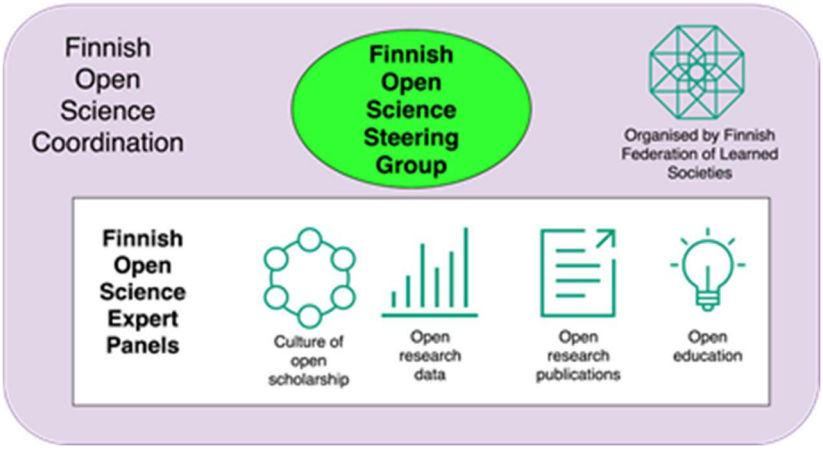

Figure 4. The four areas of the Finish Policy for Open Science and Research (Expert Panel in Open Education, 2021, p. 4).

The development, implementation and coordination of OER in Finland is carried out by several expert groups and organisations as (Expert Panel in Open Education, 2021, p. 8):

- Expert Group on Open Education, which is part of the Finnish National Open Science

[20] https://www.educationestonia.org/infosystems/

[21] https://www.haridussilm.ee/ee

Coordination;

- Open Universities and Open Universities of Applied Sciences, which offer open learning at most higher education institutions throughout Finland;
- Association of Finnish e-Learning Centers (an independent non-profit organisation) promoting digital teaching and learning;
- Finnish eLearning Centre, which is involved in many EU funded projects such as Erasmus+;
- Digivisio 2030[22] is a joint project of all higher education institutions in Finland, the goal of which is to open national learning resources for use by the individual and society.

For the Finnish Higher Education and Research Community work is being developed to define its Policy on Open Education and Educational Resources (see Figure 5) (Expert Panel in Open Education, 2021, p. 9).

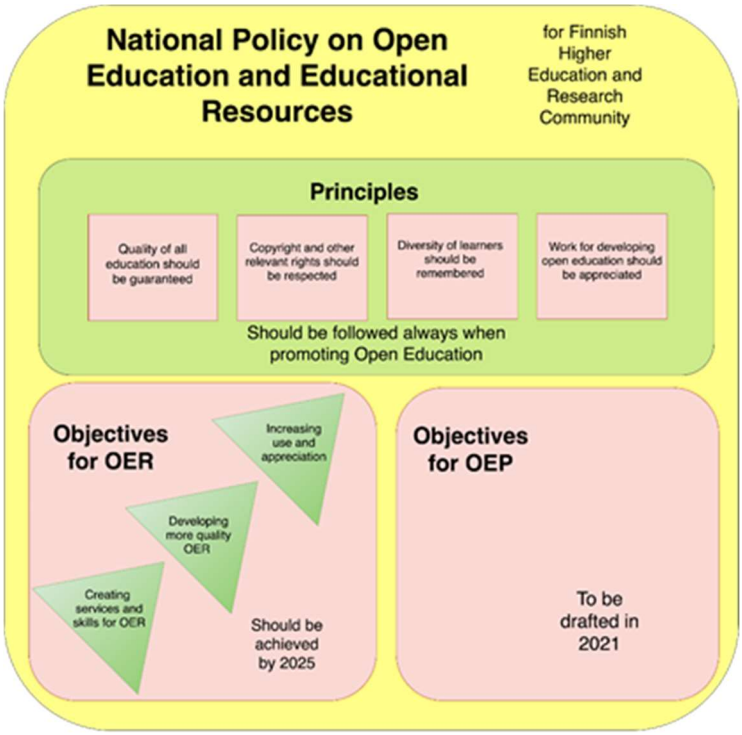

Figure 5. Policy on Open Education and Educational Resources for Finish HE (Expert Panel in Open Education, 2021, p. 10).

Since 2000, the openness of education and the development of OER in Finland has grown rapidly and is currently supported by the Ministry of Education and Culture through the creation of the Open Educational Resources Library[23] (Kärki et al., 2021 , p. 163).

The National Policy on Open Education and Open Educational Resources recommends the use of the OER Library to better reach all higher education institutions (Open Science Coordination in

[22] https://digivisio2030.fi/

[23] https://aoe.fi

Finland, 2022, p. 19). The library is developed by the Ministry of Education and Culture, the National Agency for Education and CSC - IT Center for Science and is a platform for sharing and searching OER in every sector of education, from early childhood education to higher education and lifelong learning. The library allows you to share your OER in a permanent location, find OER with a CC licence and good metadata, create and share collections of OER, give each OER a permanent Uniform Resource Identifier (URI), and also offers application programming interfaces to allow OER to be there, where there is training. The Open Educational Resources Library uses the Learning Resources Metadata Initiative metadata schema (or more specifically, its national profile) to ensure international compatibility (Expert Panel in Open Education, 2021, p. 5).

2.7. Germany

As early as the 2000s, digital summits were held in Germany, focusing on the topic of digital transformation in various areas, including one aspect relating to the digitalization of education and science.[24] In 2019, the Federal Ministry of Education and Research (BMBF[25]) published the digital strategy *Digitale Zukunft. Lernen. Forschen. Wissen*.[26] The digital strategy defines five areas on which the focus will be placed in the coming years. Digitalization in these areas is to be driven forward and strengthened with flagship initiatives (BMBF 2019, p. 5):

1. live, work and do business better and sustainably;
2. strengthening digital education and training and its institutions;
3. create knowledge and innovations from data;
4. secure technological sovereignty and scientific leadership for Germany;
5. create trust and provide security;

In the area of education, the focus is on the digitalization of schools with the *DigitalPakt Schule* initiative. (BMBF 2019, p. 5)

In February 2021, the initiative *Digitale Bildung*[27] was launched in Germany, with the aim of "promoting the competence development of learners on their educational path in a digitally shaped world" (BMBF 2022, p. 5). In 2022, the BMBF published the OER strategy as a consequence of the digital education initiative. The aim of this strategy paper is to develop ideas and concepts for digital educational materials and to drive digital education forward so that the culture of teaching and learning is sustainably changed (BMBF 2022, p. 3). In order to advance

[24] https://www.bildung-forschung.digital/digitalezukunft/de/unsere-ueberzeugungen/digitalstrategie-der-bundesregierung/digitalstrategie-der-bundesregierung_node.html

[25] Bundesministerium für Bildung und Forschung

[26] Digital Future. Learn. Research. Knowledge.

[27] digital education

this process, accompanying research projects for the networking of OER actors and software projects for the targeted development of open educational materials are being funded, including the establishment of an OER information center (BMBF 2022, pp. 3-4) .

The OER strategy comprises six fields of action, the implementation of which is to be advanced with the help of funding for existing and new projects and (cross-educational) collaborations, the development of training and continuing education offerings, and the provision of guidance (BMBF 2022, pp. 8-19):

1. anchor and build up OER competence of pedagogical experts;
2. develop new collaborations: from OER to Open Educational Practices (OEP);
3. establish technical foundations and structures for OER and OEP;
4. support innovation and cross-learning education with OER;
5. accompany OER with user-centered, application-oriented and networking research;
6. implementation: bring together initiatives and actors in digitally supported OER practice.

2.8. Portugal

In 2018, the national initiative *Iniciativa Nacional Competências Digitais e.2030, Portugal INCoDe.2030* is established in Portugal (by the XXI Constitutional Government) with the aim of developing a strategy for the country's digital development within the national reform programme (Diário de República 2021, p. 23). The strategy was already elaborated in 2016 and implemented on a test basis the following year (Diário de República 2021, p. 23).

For implementation, an action plan for digital transformation (*Plano de Ação para a Transição Digital*, PATD) is adopted, which as a strategy paper contains measures on the cornerstones of *INCoDE.2030* (Diário de República 2021, p. 23). Digitalization is based on three aspects - people, economy and administration - which are summarised under the keywords

- Capacity building and digital inclusion
- Businesses' digital transformation and
- Public services' digitisation

The digitalization of the population includes, among other things, digital education as part of the area of *capacity building and digital inclusion* (PORTUGAL DIGITAL 2020, p. 3). The measures for the digitalization of education are to take place already in primary and secondary schools, but no concrete actions are mentioned (see following instructions):

- *Technologies integration in the different curricular areas of basic and secondary education, aiming at improving continuous learning quality, as well as innovation and development of the educational system, providing children and young people with the*

necessary for their full personal and professional fulfillment. Just as equal opportunities in access to quality digital educational equipment, resources and investment in the digital skills of teachers, and trainers in the context of the training modalities of the National Qualifications System;

- *The widening of the training offer of higher education institutions and their approach to companies, ensuring response to the specific needs of the labor market in terms of digital skills.*

(PORTUGAL DIGITAL 2020, p. 15)

2.9. Romania

"*Creating Attractive Open Educational Resources*" in Romania is one of the activities of the Strategic Initiative for the digitalization of Education *SMART-Edu 2021-2027*, implemented by the Ministry of Education and Science.[28] The education digitalization strategy *SMART-Edu* is focused on European initiatives and programs that support the role of digital technologies in the development of education and training systems:[29]

- The European Commission's communication regarding the new Action Plan for Digital Education 2021-2027 - "Resetting Education and Training for the Digital Age".
- Communication from the European Commission regarding the creation of a European Education Area until 2025.
- The new European Skills Agenda for sustainable competitiveness, social equity and resilience.
- Council recommendation on vocational education and training for sustainable competitiveness, social equity and resilience.
- UNESCO Recommendation on OER.

In addition to the Ministry of Education and Science, the *OER Coalition* is engaged in the promotion of OER, whose members are: Ministry of National Education and Scientific Research (MENCS), The OER Coalition Romania, Center for Public Innovation (CPI), Association for Technology and Internet (ApTI) and Creative Commons Romania, Kosson, University of Timisoara, Moodle Romania и Evaluation. The leader of the coalition is Center for Public Innovation (CPI) (Hugyecz, 2018, p. 11). Unlike most other universities, the University of Timisoara is a pioneer in course development and research into the state of open education, open access, OER and MOOCs in Romania (Hugyecz, 2018, p. 15).

2.10. Spain

Educational resources in Spanish universities are heterogeneous and have limited openness, as they tend to be published in duplicate on platforms that are unrelated (Santos-Hermosa et al.,

[28] https://www.smart.edu.ro/

[29] https://www.smart.edu.ro/

2020, p. 16). In the 2020-2021 academic year, a digital program was launched to promote the technological transformation of education *Educa en Digital*, approved by the Council of Ministers of Spain.

This program aims to address major gaps in digital education such as access to technology, quality in the use of digital tools, and training in the development and use of digital tools in the context of information and communication technology (ICT) skills (Educa en Digital 2020, p. 3).

The main objectives of the digitalization and digital skills development plan are:

1. *Increasing digital competence in education, including students, teachers and educational centers.*
2. *Realize the digital plan of the Education Center by providing equipment, transforming spaces, conducting training and applying artificial intelligence methods to facilitate the teaching and learning process.*
3. *Creation of OER in digital format.*
4. *Encourage the use of advanced digital methodologies and skills.*

(Educa en Digital 2020, p. 4)

The unit of the Ministry of Education and Training responsible for the integration of ICT and teacher training at non-university educational stages is the National Institute for Educational Technology and Teacher Training (INTEF), whose main areas are:[30]

- *Preparation, promotion and dissemination of educational materials and other documents in support of teachers, as well as the development and implementation of specific programs aimed at the scientific and didactic renewal of teachers.*
- *Preparation and distribution of materials on digital and audiovisual support for all areas of knowledge.*
- *Implementation, in cooperation with the autonomous communities, of specific teacher training programs for the development of digital competence through the application of information and communication technologies in the field of non-university education.*
- *Development and evolutionary support of applications, platforms and portals for the educational sphere, as well as the creation of social networks and communities of teaching practice to facilitate the exchange of experience and resources between teachers.*

The Spanish Universities and Research Libraries Network (REBIUN) is a stable body in which all Spanish universities and research libraries are represented. REBIUN is made up of libraries from

[30] https://intef.es/quienes-somos/

76 member universities of CRUE[31] (50 public universities and 26 private universities) and CSIC (Spanish National Research Council). One of REBIUN's permanent working groups is the Repository Working Group, whose main activities are: recommendations, guidelines and common actions to adapt institutional repositories to new needs that arise and contribute to making repositories become a key infrastructure for promoting open access and the development of open science in universities.[32]

Some results from the working group:[33]

- Guidance for evaluating institutional research repositories
- Guidance for evaluating conservation processes in institutional research repositories
- Matomo analytics guide and its integration with Openaire to send statistical data
- Set for OER
- Resources and services for the dissemination of open access monographs published by Spanish university presses.

2.11. Sweden

On 25 November 2019, Sweden was one of the Member States that unanimously accepted the UNESCO recommendation on OER.[34]

In 2020, the Swedish government introduced the Research, Freedom, Future - Knowledge and Innovation for Sweden bill, which emphasizes open access to quality resources for learning in formal education and for lifelong learning. The Royal Library (National Library of Sweden) is entrusted with coordinating the work on open access to scientific publications (Utbildningsdepartementet, 2020, p. 16).

[31] Conference of Rectors of Spanish Universities

[32] https://www.rebiun.org/

[33] https://www.rebiun.org/grupos-trabajo/repositorios#/

[34] https://www.motesplatsoer.se/

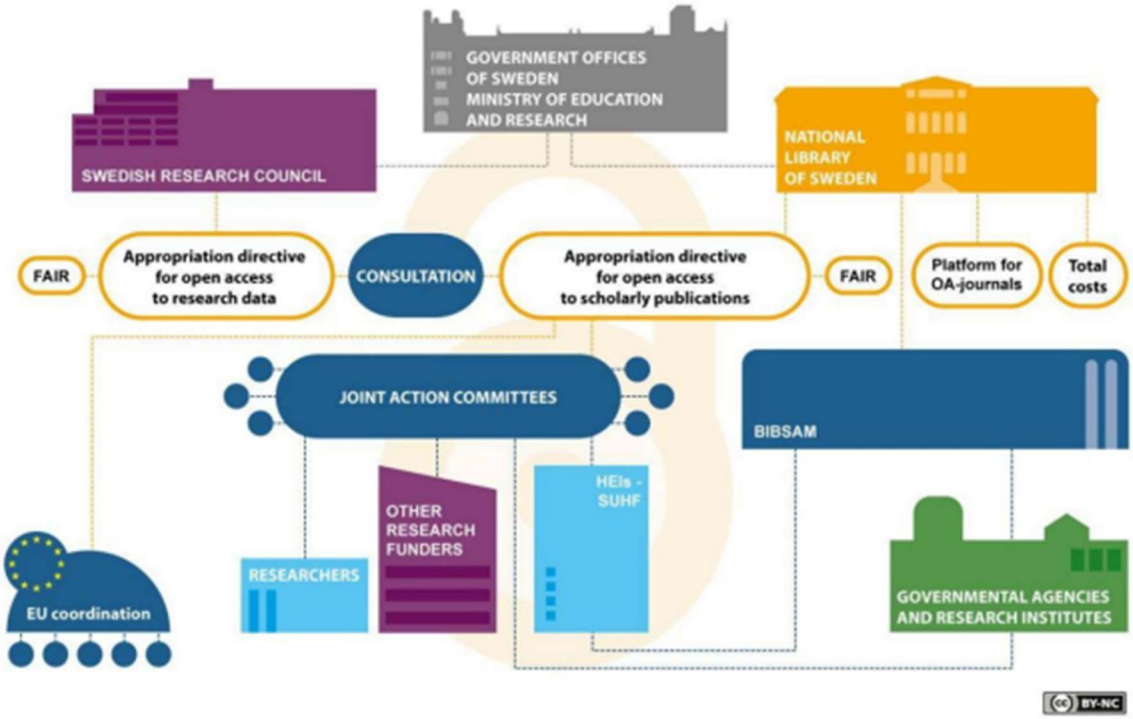

Figure 6. The relationship between the National Library's and the Research Council's respective coordination assignments for open access and other relevant stakeholders (NLS, 2022, p. 11).

In 2021, the Government of Sweden instructed the Royal Library, based on the opinion of the State Board of Education, universities and colleges, the Office of National Heritage, the offices of university presidents, the Swedish Research Council, and other relevant institutions and organisations, to map and analyse the use of OER (Ossiannilsson et al., 2023, p. 233).

The result of this commission is the Coordination of the work on open access to scientific publications from the National Library, which affects several main areas: cost increase, harmonization of principles, prerequisites under copyright law, technical conditions and research incentive structures (NLS, 2022, p. 7). The National Library highlights the need to harmonize principles and what a national open science policy can do, based, among other things, on the new UNESCO recommendation. Concerning copyright and open access, based on a report on developments at the European level regarding the various legal frameworks for self-archiving, the grounds for revising the relevant legal framework in Sweden are shown (NLS, 2022, p. 30).

With regard to the digitization of scientific publications and the FAIR principles, the need to use metadata is indicated, which should comply with the FAIR principles (NLS, 2022, p. 33). The assessment of the current situation concludes with a discussion of the need to develop incentive systems and evaluate researchers (NLS, 2022, p. 41). The National Library is currently developing guidelines for open science in collaboration with the Swedish Research Council, universities and

university colleges, and other interested organisations, to be submitted by September 2023.[35]

2.12. USA

Education in the United States is primarily the responsibility of the state and local governments. It is States and communities, and public and private organisations of all kinds, that create schools and colleges, develop curricula, and determine admission and graduation requirements. But despite this, the Ministry of Education at the federal level administers programs that cover all areas of education and range from preschool education to postdoctoral studies.[36]

On May 23, 2012, the President issued the Presidential Memorandum "Building the Digital Government of the 21st Century" to deliver better digital services to the American people.[37] In 2015, the Every Student Succeeding Act (ESSA) was signed into law. This is US Federal Education Act K-12, which promotes educational opportunities and student outcomes.[38] The digital government strategy aligns with many of the Department of Education's digital projects and initiatives, which aim to promote student achievement and prepare for global competitiveness by improving the quality of education and ensuring equal access. Digital services, open data and technologies have great potential to fulfill this mission.[39]

The Department of Education's Office of Educational Technology developed in 2017 the National Education Technology Plan (NETP), which sets out a national vision and blueprint for technology-based learning, drawing on the work of leading education researchers, heads of districts, schools and higher educational institutions, class teachers, developers, entrepreneurs, and non-profit organisations (Office of Educational Technology, 2017, p. 3). For OER, NETP recommends the following (Office of Educational Technology, 2017, p. 83):

- *Support the development and use of openly licensed educational materials to promote innovative and creative opportunities for all learners and accelerate the development and adoption of new open technology-based learning tools and courses*.
- *Create a comprehensive map and database of connectivity, device access, use of openly licensed educational resources, and their uses across the country*.

NETP recommends engaging partner organisations and building institutional and pedagogical capacity for the use of free and open licenced educational content, such as those indexed through

[35] https://www.kb.se/samverkan-och-utveckling/nytt-fran-kb/nyheter-samverkan-och-utveckling/2022-06-21-the-national-library-has-been-tasked-with-developing-national-guidelines-for-open-science.html

[36] https://www2.ed.gov/about/overview/fed/role.html

[37] https://obamawhitehouse.archives.gov/the-press-office/2012/05/23/presidential-memorandum-building-21st-century-digital-government

[38] https://www.ed.gov/essa?src=rn

[39] https://www2.ed.gov/digitalstrategy/index.html

the #GoOpen node (Office of Educational Technology, 2017, p. 40).

The Office of Educational Technology launched, in 2015, the #GoOpen national movement[40], which encourages states, school districts, and educators to use openly licenced educational materials to transform teaching and learning. The goal of this project is to empower teachers and save money typically spent on static textbooks, while further investing in the transition to digital learning (Office of Educational Technology, 2017, p. 77). Platforms and organisations such as Illinois Open Educational Resources[41], CK-12[42], SkillsCommons[43] and OER Commons[44] are specifically designed to enable teachers to discover open content and adapt it for their students as needed (Office of Educational Technology, 2017, p. 77).

In order to increase the use of open textbooks and other resources, some higher education institutions have created their own initiatives:

- Rice University - OpenStax[45]. A library of free, high-quality, peer-reviewed, openly licenced high school and college textbooks, as well as cutting-edge educational research and an innovative high school algebra curriculum.
- California State University - MERLOT[46]. This platform is one of the largest collections of open resources and textbooks in the world and collaborates to create user communities with institutions, consortiums of institutions and states to provide students with access to these resources.
- University of Minnesota - Open Textbook Network[47]. The University of Minnesota has partnered with more than 200 campuses to provide professional teacher training and training on how to use open resources in the classroom. (Office of Educational Technology (Supplement), 2017, p. 32)

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[40] https://oercommons.org/hubs/GoOpen#all-groups

[41] https://ioer.ilsharedlearning.org/

[42] https://www.ck12.org/student/

[43] http://als.skillscommons.org/

[44] https://oercommons.org/

[45] https://openstax.org/

[46] https://www.merlot.org/merlot/

[47] https://www.cehd.umn.edu/research/

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#GoOpen https://oercommons.org/hubs/GoOpen#all-groups https://ioer.ilsharedlearning.org/

3. OER classification

OER are freely accessible resources used for learning, education, and training purposes (Pawlowski and Bick 2012). These resources encompass various types such as literature, scientific material, systems, technologies, open content, and associated artifacts like lesson plans (Clements and Pawlowski 2012). The characteristics and requirements of OER have been extensively studied, emphasizing qualities like flexibility, adaptability, free usage, easy sharing, and long-term accessibility (EDUCAUSE 2018). These conditions apply broadly to all types of OER, but they lack specificity and can be subjective. Their open nature may help improve teaching and learning (Miao et al. 2019).

OER can be classified based on fields, formats (text, multimedia, interactive), and educational use (instructional, collaboration, practice, evaluation) (Christoforidou and Georgiadou 2022; PAHO). They can be categorised as text-based, multimedia, interactive, learning management systems, open data, and open-source software (Christoforidou and Georgiadou 2022). OER have diverse educational uses, such as curriculum development, personalised learning, research, and distance education (PAHO). They benefit not only teachers and students but also the wider community, fostering collaboration and accessibility (PAHO).

One of the main objectives of Gate2Math project is to establish an efficient open smart library for learning. To this end, it is necessary to define precise and measurable requirements for each type of OER. This ensures high-quality resources while addressing the technical limitations of the smart library. Table 1 provides a summary of the various OER types described in the open literature, accompanied by brief definitions. Additionally, Table 2 presents a compilation of the most suitable OER for an online smart library focusing on mathematical resources. Specific requirements are proposed for each type of OER to meet the needs of the smart library.

Table 1. Existing OER enumeration.

No.	OER	Type	Description/Definition	Learning objective (aim)
1	Applets	Applications	Very small applications, especially utility programs performing one or a few simple functions.	Understanding of specific utility functions, Ability to use applets to solve specific tasks, Ability to modify applets for specific needs.
2	Software tools	Applications	Digital programs or applications that enable users to perform specific tasks or functions, such as coding, data analysis, or graphic design.	Ability to use digital programs for specific tasks, Understanding of the functionality of specific software tools, Ability to select appropriate software tools for specific needs.

3	Open-source software	Applications	Software that is freely available and can be modified, improved, and distributed by anyone.	Understanding of open-source software philosophy, Ability to modify and contribute to open-source software, Ability to use open-source software for specific tasks.
4	Scripts	Applications	A set of written content, instructions, or codes used for teaching, programming, or performing a specific task.	Ability to write and modify scripts for specific tasks, Understanding of programming concepts, Ability to automate tasks using scripts.
5	Quizzes	Assessments	Short assessments designed to evaluate understanding and knowledge retention on a topic.	Evaluation of understanding and knowledge retention on a topic, Identification of knowledge gaps, Identification of areas needing further study.
6	Tests	Assessments	Assessments designed to measure knowledge, understanding, or skill acquisition, typically presented in a standardised format with a set of predefined questions or tasks on a module.	Measurement of knowledge, understanding, or skill acquisition, Identification of areas needing further study, Evaluation of learning outcomes.
7	Audio resources	Audio Content	Freely available recorded audio content used for teaching, learning, and research purposes.	Enhanced listening skills, Understanding of content covered, Ability to relate content to specific topics or subject areas.
8	Podcasts	Audio Content	Audio or video recordings that can be downloaded or streamed online, often used to share information, ideas, and stories.	Enhanced listening skills, Understanding of content covered, Ability to relate content to specific topics or subject areas.
9	Lectures	Audiovisual Content	Formal presentations intended to be given by instructors or experts on a particular subject or topic.	Understanding of subject matter, Ability to take effective notes, Ability to synthesize information.
10	Presentations	Audiovisual Content	Formal talks or visual displays that communicate information or ideas to an audience.	Enhanced communication skills, Understanding of content covered, Ability to synthesize information.

11	Wikis	Collaborative Materials	Collaborative platforms where users can create, edit, and contribute to a shared database of information, often used for collaborative research or knowledge management.	Collaborative writing skills, Understanding of shared knowledge creation, Ability to contribute to a shared database of information.
12	Course modules	Course Materials	Structured units of learning that can be combined to create a complete course, often designed to cover a specific topic or skill.	Understanding of specific topics or skills, Ability to combine modules for a complete course, Ability to apply knowledge gained.
13	Curricula	Course Materials	Comprehensive plans for learning that outline the goals, objectives, and activities of a particular educational program or course.	Understanding of program goals and objectives, Ability to apply knowledge gained to a specific program or course, Ability to evaluate program effectiveness.
14	Curriculum maps	Course Materials	Visual representations of a curriculum that show how different topics, skills, and learning objectives are connected and sequenced.	Understanding of program structure, Identification of how different topics, skills, and learning objectives are connected and sequenced, Ability to evaluate program effectiveness.
15	Full courses	Course	Complete courses that cover a wide range of topics and skills, often delivered online or through distance learning.	Understanding of a wide range of topics and skills, Ability to apply knowledge gained, Ability to evaluate course effectiveness.
16	MOOCs	Course	Massive Open Online Courses, which are typically free online courses that can be accessed by anyone with an internet connection.	Understanding of a specific topic or skill, Ability to apply knowledge gained, Ability to evaluate course effectiveness.
17	Syllabus	Course Materials	A document that outlines the content, structure, and expectations for a course of study, including readings, assignments, and assessments.	Understanding of course content and expectations, Ability to plan and organize study time, Ability to prepare for assessments.
18	Textbooks	Course Materials	Comprehensive instructional materials that provide structured content, examples, and exercises	Enhanced understanding of a specific topic or subject area, Ability to apply knowledge gained, Ability to evaluate and critique instructional materials.

			related to a specific topic or subject	
19	Classroom notes	Educational Materials	Informal notes taken by instructors during class that summarize key concepts, insights, and discussions.	Understanding of key concepts, insights, and discussions, Ability to apply knowledge gained, Ability to organize and synthesize information.
20	Experiments	Educational Materials	Controlled tests or investigations designed to answer a scientific or research question.	Understanding of scientific or research methods, Ability to design and conduct experiments, Ability to analyse and interpret results.
21	Lesson plans	Educational Materials	Structured plans for teaching and learning that outline the goals, objectives, and activities of a particular lesson or unit.	Understanding of specific topics or skills, Ability to plan and organize lesson time, Ability to evaluate lesson effectiveness.
22	Open educational practices	Educational Materials	Teaching and learning practices that use OER and other open resources to promote access, equity, and innovation in education.	Understanding of open education philosophy, Ability to use OER for teaching and learning, Ability to evaluate effectiveness of open educational practices.
23	Portfolios	Educational Materials	Collections of work or evidence that demonstrate a learner's achievements, skills, and growth over time.	Ability to reflect on personal growth and development, Ability to showcase achievements and skills, Ability to set and evaluate goals.
24	Projects	Educational Materials	Hands-on activities that require learners to apply their knowledge and skills to solve a problem or create something new.	Ability to apply knowledge and skills to real-world situations, Ability to work collaboratively, Ability to evaluate project effectiveness.
25	Scenarios	Educational Materials	Real or hypothetical or real situations or case studies that are used to explore and develop problem-solving and decision-making skills.	Ability to explore and develop problem-solving and decision-making skills, Ability to apply knowledge and skills to real-world situations, Ability to evaluate scenario effectiveness.
26	Tutorials	Educational Materials	Step-by-step guides or demonstrations that teach a specific skill or process, often presented in a video or interactive format	Ability to follow step-by-step instructions, Ability to learn a specific skill or process, Ability to apply knowledge gained.

27	Worksheets	Educational Materials	Print or digital documents that contain structured exercises, questions, or activities that reinforce or test understanding of a particular topic or concept.	Reinforcement of knowledge and understanding of a specific topic or concept, Identification of areas needing further study, Evaluation of learning outcomes.
28	Games	Interactive Materials	Interactive activities designed to engage learners in a fun and challenging way, often used to teach specific concepts or skills.	Engagement with learning materials in a fun and challenging way, Ability to apply knowledge and skills to specific situations, Ability to evaluate game effectiveness.
29	Online exercises	Interactive Materials	Interactive activities that can be completed online to reinforce learning and test understanding.	Reinforcement of knowledge and understanding of a specific topic or concept, Identification of areas needing further study, Evaluation of learning outcomes.
30	Simulations	Interactive Materials	Interactive digital applications or models that simulate real-world scenarios or processes and allow users to learn through experimentation and exploration.	Understand complex processes and systems, Apply theoretical knowledge to practical situations, Develop problem-solving skills.
31	Virtual reality	Interactive Materials	Digital environments that simulate real-world experiences using advanced 3D graphics, audio, and other sensory inputs to provide immersive learning opportunities.	Experience and explore real-world scenarios, Develop practical skills in a safe and controlled environment, Enhance critical thinking and decision-making abilities.
32	Bibliographies	Reference Materials	Lists of sources used or referred to in a particular work, often organised by author or subject	Understand the scope of research on a particular topic, Evaluate the quality of sources used in a work, Develop skills in citing sources properly.
33	Open databases	Reference Materials	Digital collections of data or information that are freely accessible and open for use.	Find, access, and analyse large amounts of data, Understand data collection and management processes, Develop skills in data interpretation and visualization.
34	Case studies	Research Materials	In-depth analyses of a particular situation, event, or phenomenon, often	Understand real-world problems and their solutions, Apply theoretical knowledge to practical situations,

			used in teaching and learning to explore real-world problems.	Develop critical thinking and analytical skills.
35	Open access journals	Research Materials	Academic journals that are available online without any subscription or access fees.	Stay up-to-date with the latest research in a field, Understand the peer-review process, Develop skills in analyzing and evaluating research articles.
36	Short videos	Video Content	Video clips that usually last between a few seconds to a few minutes in length, which cover a wide range of topics and can be used for educational purposes.	Understand key concepts and ideas on a topic, Develop visual and auditory learning abilities, Enhance retention and recall of information.
37	Video lessons (long)	Video Content	Extended video presentations that cover a particular topic or concept in-depth, usually lasting between 30 minutes to several hours.	Gain in-depth knowledge on a particular topic or subject, Develop advanced analytical and critical thinking skills, Enhance listening and note-taking skills.
38	GIFs or animations	Visual Content	Simple animated images that illustrate a certain notion, concept etc.	Visualize and understand complex processes or concepts, Enhance memory retention and recall, Develop skills in creating simple animations for educational purposes.
39	Images	Visual Content	Visual representations of a certain person, thing, notion etc.	Enhance visual learning abilities, Understand visual representations of concepts and ideas, Develop skills in analyzing and interpreting visual data.
40	Infographics	Visual Content	Collections of imagery, data visualizations like pie charts and bar graphs, and minimal text that gives an easy-to-understand overview of a topic.	Understand complex data and information, Develop skills in interpreting and analyzing data visualizations, Enhance retention and recall of information.
41	Articles	Written Content	Pieces of writing on a particular subject in a newspaper or magazine, or on the internet.	Understand the scope of research on a particular topic, Develop critical reading and analytical skills, Enhance writing and communication skills.
42	Blogs	Written Content	Online journals or personal websites where individuals or groups can publish their	Gain insights and perspectives on a particular topic, Develop critical thinking and analytical skills,

			ideas, opinions, and experiences.	Enhance writing and communication skills.
43	Essays	Written Content	Formal pieces of writing that present an argument or analysis on a particular topic.	Develop advanced writing and research skills, Present a clear and persuasive argument on a particular topic, Enhance critical thinking and analytical abilities.
44	Papers	Written Content	Formal written documents that present research, analysis, or findings on a particular topic.	Conduct research and analysis on a particular topic, Develop advanced writing and presentation skills, Enhance critical thinking and analytical abilities.
45	Reports	Written Content	Formal written documents that present information, analysis, or findings on a particular topic.	Collect and analyse data and information, Develop skills in presenting and visualizing data, Enhance communication and analytical abilities.

With regard to which OER should be included in an online smart library for mathematical resources, there are a number of reasons for proposing those included in Table 2 but three of these reasons are worth mentioning:

- The chosen OER types are easy to customize in order to illustrate mathematics topics and notions.
- They are user-friendly and appeal to users in the target audience's generation.
- They allow for modularity as their atomic nature allows their integration in the teacher's curriculum easily and to the point.

Applets, Animations, games and online exercises should have an acceptable file size (max. 5 MB), have a universally acceptable format (like SVG or GIF) that also allows for portability, making it accessible from multiple platforms (desktop or mobile). They should contain metadata information including but not limited to a title, a short description and author. It should also contain alt-text and should contain colorblind-friendly graphics and large text so it is easily accessible to people with visual impairments.

Images should have a max. file size of 5 MB, be in a widely used format adapted for web (JPENG, PNG, SVG) and have the other requirements from animations. They should be provided in both low-resolution and high-resolution versions.

Datasets should be relatively small (1000 entries and at most 50 columns) so they can be easily analysed with any tool (e.g. MS Excel). They should be provided in an universally accepted format

(like CSV or TSV) and contain metadata. The author should be rightfully credited and there should also be a legend with what data each column contains and their format. A preview of 10 entries can be provided besides the full dataset. The intended educational purpose of the dataset should be presented.

Short videos and **simulations** should have a file size of max. 10 MB, come in an AVI or MP4 format. Like images they should have low-resolution and high-resolution versions and should adhere to the other requirements for images.

Scripts should have an acceptable file size (max. 5 MB), contain metadata information including but not limited to a title, a short description and author. They should not contain malicious code or any other code that does not contribute to their learning objective.

Quizzes should contain 5 to 10 questions of different close-ended types (e.g. short answer or multiple choice) and must have a rubric. They should be made available as a Word document (.docx) with a maximum size of 5 MB, contain metadata and cite the original author if needed. If the quizzes contain images, the images should adhere to the accessibility requirements of image OER.

Worksheets, **tests** and **scenarios** (or case studies), should have the same requirements as quizzes but can be provided in editable PDF format as well.

Tutorials can be provided in either video format or text format. If provided in a video format it should adhere to the short video OER requirements and if they are in a text format they should respect the format requirements from quizzes.

Infographics/Cheat sheets as OER, are visual representations that provide concise summaries of educational topics. They should have a maximum file size of 5 MB and be created in a universally accepted format like PNG or PDF for portability. Metadata information, including title, description, and author details, should be included. To ensure accessibility, alt-text descriptions, colorblind-friendly graphics, and large text should be incorporated. Infographics/Cheat sheets should present information accurately, using clear language and proper citations. They should be freely available for use and adaptation, with a clearly defined licence. By adhering to these requirements, Infographics/Cheat sheets become effective OER, offering visually engaging and easily understandable summaries for educational purposes.

Table 2. Proposed OER for Smart library.

No.	OER	Size	Format	Metadata	Author	Accessibility	Alt-text	Format flexibility	Portability	Other
1	GIFs / Animations	max. 5 MB	GIF, SVG	yes	yes	color blind friendly, large text	yes		desktop, mobile friendly	
2	Tutorials	max. 10 MB	AVI, MP4	yes	yes		yes	low-res/hi-res versions	desktop, mobile friendly	
		Word (.docx)	yes	yes		if it contains images, they need to follow the accessibility requirements from images				
3	Games/ online exercises	max. 5 MB	SVG, other	yes	yes	color blind friendly, large text	yes		desktop, mobile friendly	
4	Images	max. 5 MB	JPEG, PNG, SVG	yes	yes	color blind friendly, large text	yes	low-res/hi-res versions	desktop, mobile friendly	
5	Data sets	max. 1000 rows x 50 columns	CSV, TSV	yes (must contain column	yes		yes	sample preview (10 rows) / full version		

				legend)						
6	Short videos	max. 10 MB	AVI, MP4	yes	yes		yes	low-res/hi-res versions	desktop, mobile friendly	
7	Simulations	max. 10 MB	AVI, MP4	yes	yes	color blind friendly, large text, high contrast	yes	low-res/hi-res versions	desktop, mobile friendly	
8	Quizzes	max. 5 MB	Word (.docx)	yes	yes	if it contains images, they need to follow the accessibility requirements from images				5 questions (short answers, multiple choice), with rubric
9	Worksheets	max. 5 MB	Word (.docx), PDF	yes	yes	if it contains images, they need to follow the accessibility requirements from images				

10	Tests	max. 5 MB	Word (.docx), PDF	yes	yes	if it contains images, they need to follow the accessibility requirements from images				must have rubric
11	Curriculum maps	max. 5 MB	JPEG, PNG, SVG	yes	yes	color blind friendly, large text	yes	low-res/hi-res versions	desktop, mobile friendly	
12	Scenarios/case studies	max. 5 MB	Word (.docx), PDF	yes	yes	if it contains images, they need to follow the accessibility requirements from images				

The quality of OER is a complex challenge due to their context, versioning, and collaborative nature (Almendro and Silveira 2018). Ensuring quality through third-party assessment is difficult as quality is subjective and context-dependent (Butcher 2011). However, extensive research has been dedicated to the development of evaluation instruments like the Learning Object Review Instrument (LORI) and the Merlot evaluation model (Kay and Knaack 2008; MERLOT). Quality aspects include technological, pedagogical, content, and aesthetic/interface elements, along with considerations of file formats, size, metadata, and licences (Baas et al. 2022). Peer-review and user involvement through comments and ratings are recommended for quality control (Al Abri and Dabbagh 2018).

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4. OER assessment methodologies (OER-AM)

The 1999 Bologna Declaration and the technological development of the internet in recent decades have led to major changes in education systems. A large number of educational resources, mostly digital, have been created to support the student-centered teaching-learning process. In the face of this proliferation and the heterogeneity of this type of resource, we see the need to evaluate it. This idea has been reinforced by UNESCO when mentioning the importance of evaluating the quality of digital educational resources. Although UNESCO emphasizes that the process of evaluating the quality of an OER is fundamental to the teaching-learning process, it does not propose a specific methodology or protocol for OER assessment.

To propose a methodology for evaluating the quality of an OER, we will first analyse the existing literature on this subject, in order to state the concern over this issue for a long time in the international high educational community. So it is necessary to analyse which are the most important sources to establish a comparison between all of them, and to propose, in a rubric form, a tool for the quality assessment of the OER.

4.1. State of the art on OER-AMs

Pinto et al. (2017) carries out an interesting review of the scientific literature on the evaluation of electronic educational resources. The paper distinguishes six perspectives: systemic, heuristic, user-centered, pedagogical, multidimensional, and affective. Authors evaluate, select, and manage learning resources such as A Guide (British Columbia. Ministry of Education, 2000), LORI (Nesbit 2009), eValuator (Nokelainen 2004), SREB-SCORE ("Checklist for Evaluating Sreb-Score Learning Objects" 2007) and HEODAR (Morales Morgado et al. 2008), among others. More specifically the development of the Evaluareed tool is presented.[48] Although Pinto et al. (2017) does not directly refer to the evaluation of OER, it deals with many different aspects related to and becomes applicable for developing an OER assessment methodology.

UNESCO has several publications on OER. In its Basic Guide it is demanded: "Who guarantees the quality of OER?" Quality is subjective and depends on the context. So, it is not supportive of the existence of an organisation that regulates it. It leaves the responsibility to the institutions and educators who use them. But UNESCO also recognizes that: "As institutions share more and more educational content online, they will want to make sure they transmit a positive image of the institution and, therefore, may want to invest in improving its quality before making it available in repositories" (Butcher 2011). In the OER environment, quality assurance will be supported by the development of those repositories, which will provide at least the first levels of quality assurance.

In a complementary manner, Audrey Azoulay, General Director of UNESCO, on September 8th

[48] http://www.evaluareed.edu.es/

2022 on the occasion of International Literacy Day, stated "UNESCO Member States emphasised the need for more investment in education and increased international aid, along with more open, free, and high-quality educational resources."

In what follows, we introduce, in a chronological manner, the most relevant OER, or more extensively electronic educational resources, assessment methodologies (OER-AM) we have found in the literature. In each OER-AM we will summarize the main ideas behind the assessment strategy, the tool availability and references associated with it, as well as the potential existence of a rubric that incorporates them (Alsina et al. 2023).

4.1.1. LORI

LORI stands for Learning Object Review Instrument. It was developed in 2002 by academic researchers from the University of California and Simon Fraser University of Canada (Nesbit, Belfer and Archambault 2002).

This OER-AM offers the possibility of measuring, reporting, communicating, acting and monitoring the quality of Digital Educational Resources in their design, development and post-implementation stages, both to teachers and end users of the digital resource, as it allows for systematic reviews and comparisons with the measurements obtained to select and improve digital educational resources. It is a tool that allows a learning object evaluation based on nine variables or dimensions: quality of content, suitability of learning objectives, feedback, motivation, design and presentation, usability, accessibility, reusability, and compliance with standards. Variables are scored on a scale from 1 to 5. If the variable is not relevant to the evaluation of the learning object or if the evaluator does not feel trained to judge a particular variable, then it can be marked NA (Nesbit 2009).

LORI facilitates comparison between digital educational resources by providing a common review format. However, the result of applying LORI is a subjective appreciation of an educational digital resource (Adame 2015).

4.1.2. eValuator

It is a computer evaluation tool created by Nokelainen in 2006 that analyses aspects such as the responsibility of the student in their own learning, the work of the teacher as a facilitator of learning, etc. From this, the usability dimension, treated as pedagogical usability, is incorporated into the development and design of methods for evaluating and valuing the quality of electronic educational resources, expanding the traditional usability criteria.

eValuator includes 10 dimensions that are operational in 56 more specific characteristics or features. The 10 dimensions are: student control, student activity, cooperative/collaborative learning, objective orientation, applicability, added value, motivation, valuation of prior knowledge, flexibility, and feedback (Nokelainen 2004).

4.1.3. ECOBA

ECOBA stands for *Evaluación de Calidad en los Objetos de Aprendizaje* (in Spanish) and it is focused on the assessment of the quality of the learning aims. This instrument was developed by Ruiz González in 2007. ECOBA gives greater importance to the aspects of instructional design, in order to ensure the integration of the student within the learning process.

For the selection of the assessment instruments to be used, only those were taken into account that provided the possibility of a quantifiable result, where the observable dimensions were clearly defined. ECOBA was chosen because it offered a structured instrument using a form to measure the quality of educational resources (Pinto et al. 2017).

The evaluation moment occurs prior to the interaction of the students, so the evaluation is allowed within the very process of the object's development. Three main axes for evaluation are defined, allowing the determination of quality through each of these axes separately. It consists of an assessment system that allows for the level reached by an object within a scale, the importance of content, aesthetic, functional, and instructional design of objects, and the assurance of competence through activities Evaluation and Feedback (Aguilar et al. 2014).

4.1.4. TEMOA

TEMOA (formerly Knowledge Hub) is a catalog of OER for virtual environments developed by *Tecnológico de Monterrey.* Despite the fact that TEMOA was founded in 2007, its development has been much accelerated, and large universities such as Yale, the Massachusetts Institute of Technology (MIT), which already have large educational repositories, have recognised in TEMOA a great contribution to virtual education (Pérez et al. 2010).

This rubric instrument has been implemented in the OER catalog called TEMOA (www.temoa.info) with the aim of fostering the culture of sharing educational experiences through collaborative evaluation. The added value of the reviews that are carried out for the OER available in the catalog is increased by allowing multiple ratings by a community of users with different perceptions and information needs. The tool is available at https://educrea.cl/rubricas-evaluar-recursos-educativos-abiertos/ .

The items or questions used in this rubric instrument are the result of an adaptation based on the evaluation criteria of the Instrument for the Review of Learning Objects, LORI (2003), which has been tested to evaluate learning objects in other web-based systems. Each item is evaluated by means of a rating represented by "diamonds," where one diamond is the lowest rating and five diamonds are the highest possible rating.

4.1.5. HEODAR

HEODAR stands for *Herramienta para la evaluación de objetos didácticos de aprendizaje reutilizables* (in Spanish) and it is a tool for the evaluation of reusable learning objects and has been designed to take into account a wide variety of criteria for evaluating learning objects from a pedagogical and technical point of view.

It is worthy noted that, on the one hand, the pedagogical perspective allows evaluating the capacity for motivation, the suitability of the contents to the users to whom they are addressed, the interactivity, and the creativity. On the other hand, from a technical approach, curricular objectives are treated, that is, feasible information, correct and accurate information, objectives suitable for the user, as well as their activities and methodology.

In order to evaluate each of the criteria, a range that includes a numerical rating from 1 to 5 is included, with 5 being the highest. Each of the criteria within a category is evaluated individually, thus ensuring a more accurate evaluation. Finally, the average is calculated, where the final quality of the OER is reflected (Morales et al. 2008).

4.1.6. COdA

COdA stands for *Calidad de Objetos de Aprendizaje* (in Spanish) that means learning objects quality. It was developed by Fernández Pampillón, Domínguez Romero and Arma Ranero in 2012, within the framework of the Projects for Innovation and Improvement of the Quality of Teaching-PIMCD 268/2010-2011 and PIMCD236/2011-2012 granted by the Vice Rectorate for Development and Quality in Teaching of the Complutense University of Madrid (UCM) (Fernández-Pampillón et al. 2012).

For the development of COdA, quality assessment models have been considered educational content developed in Spanish universities, among which are UNED, the Virtual Campus of the UCM, the University of Murcia, and the University of Salamanca.

Unlike other quality tools, COdA is aimed at the teacher, who is the author, user, and evaluator of the learning objects. It is also an easy-to-use, effective, and reliable tool that collects the minimum set of criteria from national and international quality models on the didactic and technological quality of learning objects.

The rubric consists of a form with ten quality criteria, that serve as a guide for the creation and scoring of digital educational resources. It is intended for evaluation and effectiveness, both didactically and technologically, in a balanced manner. Didactic characteristics are: objectives and didactic coherence; quality of content, ability to generate reflection, criticism, and innovation; interactivity and adaptability, and motivation. Technical characteristics are: format and design, usability, accessibility, reusability and interoperability. Each criterion, in turn, is broken down into a series of subcriteria, whose fulfillment depends on the total score obtained in them. In this way, an extremely accurate assessment is obtained that leaves no section open to the evaluator's interpretation.

Quality criteria scores range from 1 (the minimum) to 5 (the maximum), and a good practice guide helps guide the score. With this model of evaluation, both the author of the learning object and the users, as well as possible external reviewers, can evaluate the digital educational resources (Fernández-Pampillón et al. 2012).

4.1.7. LORI-AD

LORI was used by students and teachers to evaluate the educational resources existing on the web, and when observing the results on the same resource they were very subjective, observing 2, 3 and 4 stars indicated in the same item. Therefore, it was decided to incorporate a series of discrete quantitative indicators into LORI, which would allow for a more objective assessment. The resulting instrument was named LORI-AD (Adame 2015).

LORI-AD can be used to review an educational resource before it is released to a repository or shared with the academic community. It allows those developing digital educational resources to consider the criteria that will be evaluated to take them into account when designing the resource. Being able to work with binary values 1 and 0 makes it easy for the evaluator to indicate whether or not the item is met, which enriches the result.

Resources must be evaluated by those who develop it, by end users, and by experts in the matter. If any of the criteria of the nine indicators do not apply, it is simply not assessed and it is not considered for the calculation. LORI-AD has been used by the educational community, and congruent results have been obtained in the evaluation of digital educational resources.

Adame (2015) proposes a minimum of 60 points, corresponding to 3 stars per educational resource, to consider it appropriate and to be able to use it internally, provided that in a short time it is improved to the score of five stars for its release in an open digital repository.

4.1.8. BC Campus

BC Campus has been developed by the Institute for the Study of Knowledge Management in Education (ISKME), 2014, in The Achieve OER Evaluation Tool Handbook. ISKME also provides OER tools and rubrics for OER. ISKME builds field-oriented open knowledge networks that catalyze the growth of communities that address timely educational challenges, such as university graduation, productivity, and changing educational policies (ISKME 2002).

ISKME is an independent, non-profit educational organisation whose mission is to make learning and knowledge exchange more participatory, equitable, and open. ISKME believes that the development of equitable and inclusive learning environments will contribute to the creation of a fairer society. It also provides support services to integrate the best of knowledge management (ISKME 2002).

Established in 2002, ISKME conducts social science research, develops research-based innovations, and facilitates innovation that enhances knowledge exchange in education. Headquartered in Half Moon Bay, Silicon Valley, California, ISKME supports innovative teaching and learning practices around the world, and is known for its pioneering open education initiatives. ISKME also helps policymakers, foundations, and educational institutions to design, evaluate, and continuously improve educational policies, programs, and practices. As such, ISKME helps schools, colleges, universities, and organisations giving them all the support to expand their ability to collect and share information and create open knowledge-based environments centered on learning and success (ISKME 2002).

The Achieve OER Evaluation Tool Handbook is also a tool for evaluating an OER and consists of eight rubrics, including: Degree of alignment to learning objectives, quality of explanation of the subject matter, utility of materials designed to support teaching, quality of technological interactivity, quality of institutional and practice exercises, opportunities for deeper learning, and assurance of accessibility (ISKME, 2014). Each of these sections contains several subsections where the quality of the OER is described in five levels. The five levels are as follows: 3: Superior, 2: Strong, 1: Limited, 0: Very Weak/Nothing, N/A: Not applicable (Achieve, 2014).

The OER Evaluation Tool is "adapted for use in the higher education context, by ISKME (2017), from Archive.org's Rubrics for Evaluating OER Objects, Achieve: CC-BY 3.0 Unported." Users are encouraged to use or modify the rubrics below for their own purposes.

The following rubrics comprise an evaluation system for objects found within OER. An object could include images, activities, assignments, assessments, full courses, and more. For the purpose of this evaluation, any component that can exist as a stand-alone qualifies as an object. The rubrics in this packet can be applied across content areas and object types. The tool is available at https://pgcc.libguides.com/oer/oerevaluation (College, 2023).

4.1.9. EVALUAREED

Zaharias (2009) argues that "motivation to learn" is the affective learning factor that can most influence the interaction of users with the e-learning application and proposes this motivation as a new measure of usability for e-learning design. To deepen this topic, the R&D project EVALUAREED (SEJ2007.62244) has been developed, which aims first to do a quantitative and qualitative analysis of electronic educational resources in Spanish universities, and secondly, through an exhaustive review of the scientific literature, to offer concrete guidelines to evaluate the quality of the different types of digital resources, ending with the realization of a software that helps to identify the quality and orient how to improve the resource. The final result will be to develop a portal on the evaluation of educational electronic resources that will have an automatic tool based on a checklist that will help identify the quality of the educational resources in higher education of the public domain present in Spanish universities, checking their level of quality and highlighting the strengths and points for improvement (Pinto, 2010).

The design of this tool is based on a methodology with a dual qualitative-quantitative approach. It is based on nine quality dimensions and 48 indicators. The quality dimensions are as follows: quality of content, learning aims and goals, feedback, usability, motivation, accessibility, technical requirements, intellectual property, and effectiveness of the resource in terms of learning (Pinto, 2010). The above mentioned indicators, which are the conditions that must be met for a positive score, are valued in some cases according to a measurement scale from 0 to 4 and in others by means of the binary option yes/no (Pinto et al., 2017).

4.1.10. IQOER

IQOER stands for Instrument for Quality Assurance of OER. It is an instrument to measure the quality of OER internationally. The project was developed by the Open Online University of

Hamburg[49] in which an international inventory of instruments and quality criteria for learning materials and OER was collected to develop a model and instrument for ensuring the quality of OER.

The starting point of the IQOER instrument was the low usage rate of OER. There is an unmanageable variety of OER materials and repositories, so teachers are often confused when choosing materials. Later on, 15 dimensions of the quality model were defined. Each quality dimension was evaluated on a scale ranging from red (low performance) to dark green (high performance), along the quality criteria (elements). To classify the quality level, typical anchoring examples are used for high, medium, and low-quality expressions. The description was largely defined by the participants of the OER Quality Workshop at the HOOU in June 2018 and in Hamburg (Mayrberger et al., 2018).

4.1.11. CREA con DUA.

CREA stands for "Creación de Recursos Educativos Abiertos", an initiative that is committed to DUA, or "*diseño universal para el aprendizaje*" (in Spanish) or UDL in English, standing for Universal Design for Learning. The CREA project was created by the Education and Employment Department of the Junta de Extremadura, incorporating a DUA approach to the OER. The proposed checklist allows to evaluate digital educational resources by following the UDL principles, with the intention of providing a model that guides towards a more universal and accessible design. UDL principles are based on three different roles: a) provide multiple means of representation in order to activate recognition networks and answer the "what" of learning, b) provide multiple means of action and expression in order to activate strategic networks and answer the "how" of learning, and c) provide multiple means of engagement in order to activate affective networks and answer the "why" of learning (Junta de Extremadura, 2019).

It consists of 50 items classified and graded according to mentioned UDL principles. The item's rating scale is in the range of 0 to 2. Ratings (0-1-2) will be based on two interrelated parameters: (a) quantitative: number of elements included in the educational resource per item; (b) qualitative: function and quality of every item according to the target purpose. The score range extends from 0 to 100. The closer the resource is to 100, the more UDL it will be. Different items could be classified according to different principles or guidelines. Nevertheless, they have been classified according to their most significant principles. Finally, in the observations section, the user can make any clarification or comment that will enrich the assessment.

4.1.12. MERLOT

MERLOT stands for the Multimedia Educational Resource for Learning and Online Teaching. MERLOT project began in 1997, when the California State University Center for Distributed

[49] HOOU, https://www.hoou.de

Learning (CSU-CDL)[50] developed and provided free access to MERLOT.[51] In July, 2000, twenty-three high education institutions became Institutional Partners of MERLOT. Leadership and responsibilities for the operation and improvement of processes and tools is currently driven by CSU.

The Merlot repository has a comprehensive review system for evaluating the quality of OER. This review is carried out by expert editors and by peer-review. In addition, the user review is based on a user rating (ratings) and suggestions or comments from them. Rubrics for OER Assessment represent an evaluation system for objects and can be applied across content areas and object types. OER objects include, but are not limited to, images, applets, lessons, units, and assessments. Any component that is self-contained is considered an object for evaluation purposes.

4.1.13. UNE 71362:2020

The Spanish standardization body has developed the standard UNE 71362:2020 Quality of Digital Educational Materials (DEM). It responds to the need to have a model and a tool that serves to evaluate the quality of digital educational resources. The technical committee CTN 71, Digital Habilitating Technologies, has developed a model with an extensive evaluation form in the form of a list of specific items grouped in 15 fields: didactic description, quality of content, ability to generate learning, adaptability, interactivity, motivation, format and design, reusability, portability, robustness and technical stability, structure of the learning scenario, navigation, operability, accessibility of the audiovisual content, and accessibility of the text content. Although this standard is not entirely focused on OER but on all digital educational material, it is being used by different institutions to guarantee the quality of OER.

The rubric proposed by this standard is in the form of one table per each criterion, in which specific items are described in detail and assessed (and commented if necessary). Each table/criterion is summarised in a global score (UNE 71362, 2020).

4.1.14. #IE_RED

The name IE_RED stands for "*Instrumento de Evaluación de Recursos Educativos Digitales*" (in Spanish) that means Instrument for the Assessment of Digital Educational Resources, an open resource from Conecta 13. Conecta 13 is a team of professionals in education, talent management, and professional development with a clear social vocation, giving a connectivist approach to digital content where any material can be used as a resource in a process of teaching and learning, although not all materials used in education arise with a didactic intentionality. The fundamental motivation is to provide a quality and permanent training service. To do this, they were based on the UNE 71362 standard, specifically in Annex F, where it includes the application

[50] www.cdl.edu

[51] www.merlot.org

profiles for teachers and students, as well as an instrument in the form of a rubric that allows them to score each of the criteria.[52]

4.1.15. CEDEC

CEDEC (*Centro Nacional de Desarrollo Curricular en Sistemas no Propietarios* (in Spanish)), that is, the National Center for Curriculum Development in Non-Proprietary Systems is a dependent body of the Ministry of Education and Professional Training in Spain, through the National Institute of Educational Technologies and Teacher Training (INTEF). It aims at designing, promoting, and developing digital educational materials through free software. It is intended to make available to the entire educational community digital materials and resources with free access that allow for deepening the implementation of information and communication technologies in the educational field.

Taking as reference the UNE 71362 standard, a list of indicators for the quality verification of OER has been proposed. An appendix with specifications for each indicator is provided, where these indicators are treated in much more detail. Indicators are the following: resource coverage, didactic methodology, contents, tasks, a teaching guide, the ability to generate learning, adaptability, interactivity, technical requirements, format and style, accessibility, licences and copyright, and inclusive communication (CEDEC, 2020).

4.2. KPIs for Quality Assessment in Efficient Learning

Previous to the comparative analysis among the different OER-AMs introduced in the Section 4.1, it is necessary to define under which assessment perspectives the quality of a OER will be based. In this sense, it is fully convenient to define the main approaches or specific glances connected with the performance of an OER as a tool for efficient learning. So, to determine the basic Key Performance Indicators (KPIs) associated to an OER will be the aim of this Section.

In regard to a proper KPI definition a key book reference is Santos-Hermosa and Abadal (2022). This book is a fundamental piece to address the current challenges of higher education and it refers to a collection of different evaluation guides to ensure the quality of OER. Specifically, it is a source of scientific inspiration that has allowed us to define the fundations for an adequate KPI conceptualization.

Based on the literature review, the proposed KPIs must be focused on the five dimensions connected with the teaching-learning process: the content (C), the didactics (D), the technical characteristics (TC), the accessibility (A), and the inclusive communication (IC). Within each of these approaches, different specific features are needed to be taken into consideration.

In what follows, we introduce the main concepts and ideas associated with the OER quality assessment for each of the KPIs above mentioned. Specific features will also be introduced and discussed.

[52] https://docs.google.com/spreadsheets/d/1SpzvZhxrQTVIKbwk4xWetZf9o2C988UOPWBWRV7Mr9s/edit#gid=2063103118

4.2.1. KPI-1: Content (C)

We understand by "quality content" that the information in the resource is objectively expressed with a balanced formulation of ideas and is detailed in the descriptions in reference to the topic addressed. OER must have academic and pedagogical value (Santos-Hermosa and Abadal, 2020).

- *Cover*. The cover is the first visual contact that the teacher or student has with the OER, so it is crucial. It should be visually appealing, with colors that attract attention, and the image should be suggestive and in accordance with the content of the feature.
  When some illustration, photograph, etc. appears and contains some type of introductory word, the letter must be clear and of an easy-to-read typology, neither too small nor too large. The cover must include the objective of the resource and the final product or result.

  The content must not present any ideological bias but must be entirely objective. It must also be consistent with the didactic objectives and the purpose of the appeal. In addition, its presentation should be very clear and understandable, with the most relevant or key ideas standing out and clear instructions in the activities.

  Fundamental to the content is that it is presented to students in an innovative and attractive way, with options to capture their interest, where, in addition, the information connects with the students' interests and social reality. Moreover, the content of the OER must be adapted to the prior knowledge specified at the beginning, and it can be used regardless of teaching and learning methods.
- *Title.* The title of the OER should be motivating and encouraging the student. It must be clear and suggestive in order to invite the reader to identify the content and to use the OER.
- *Quality*. According to UNE 71362:2020, the presentation of the content, the adequacy to the level of knowledge of the student, the coherence of the objectives, the absence of ideological bias, the veracity of the information, the degree of updating of the contents and respect for copyright are the main ingredients for a good quality standard.
- *Adaptability* is when the resource can be easily adjusted to specific contexts and slightly different aims.

4.2.2. KPI-2: Didactics (D)

This dimension values whether the didactic objectives (what you want to teach with the digital educational material), the recipients (to whom it is addressed), and the skills to develop (what skills or competence abilities) have been defined and are coherent, and whether it includes suggestions for didactical exploitation (use instructions with respect to the most appropriate didactic methodology, mode of use, and educational context) for the teacher and/or the student (UNE 71362, 2020).

- *Motivation*. It evaluates the ability to attract and maintain the student's interest in learning. Characteristics of content that facilitate motivation will be valued as if the

content fosters the feeling of autonomy of the student, if it is presented in an attractive and innovative way, if the student perceives that what he/she learns is relevant, among other things (UNE-71362, 2020).

- *Consistency*. That means that a clear, cohesive structure, and internally homogeneous terminology should be used (Santos-Hermosa and Abadal, 2020).
- *Active methodologies*. It promotes active participation and also it stimulates reflection and criticism; that is the questioning of one's own ideas and the integration of new information with pre-existing knowledge (Morales et al., 2008).
- *Ability to generate learning.* This feature values if the digital educational material seeks to stimulate reflection, critical capacity and the ability of the student to relate concepts, as well as the creation of new ideas, procedures and competences (UNE-71362, 2020).

4.2.3. KPI-3: Technical Characteristics (TC)

According to the National Centre for Curricular Development in Non-Proprietary Systems (CEDEC), the used technology must fulfil some requirements.

- *Robustness.* It does not fail during the operation or use of the resource and it is not affected by user's errors.
- *Portability***.** UNE-71362 (2020) evaluates whether a material can be used in multiple environments and computer systems (*e-learning platforms* or personal computers). The portability can be evaluated in an inductive way, simply by verifying that it is possible to visualize/execute the material in various computer environments of general use or, more recommended, that it conforms to the format standards of digital content and digital educational content.
- *Usability***.** OER should ensure easily consultable web interfaces and content to promote learning, for example, avoiding distortion of images, graphics and any other visualization function that may distract or confuse the user (Santos-Hermosa and Abadal, 2020).

  Usability is a broad concept that measures the degree of efficiency, effectiveness, and satisfaction that a user experiences when interacting with a learning object to achieve its goals (International Standards Organisation, 1998). In other words, usability refers to the discipline that studies the interaction between people and computers in order to make the exchange of information that occurs between them more efficient, trying to minimize errors, increase user satisfaction, decrease frustration, and ultimately, make more productive the tasks that involve people and computers (Manchón, 2003).

  Usability appears as a discipline within the field of person-computer interaction known as HCI and is the approach that, in a widespread way, analyses and values electronic educational resources, as well as information and communication technologies based educational platforms. The concept of usability has been

expanded over the years, adapting to the context and needs of the user (Preece et al., 2002).

When usability is applied within virtual learning, quality requirements include specific characteristics derived from teaching and learning processes (Pinto et al., 2012). The usability of the electronic resource can be treated in a more technical or pedagogical way.

- *Metadata.* The OER should contain descriptions of its main characteristics (labeling) in accordance with international standards to facilitate search and retrieval by automated search systems (Santos-Hermosa and Abadal, 2022).

4.2.4. KPI-4: Accessibility (A)

Accessibility is the ability that a digital resource has to be used by anyone with visual or auditory disabilities (Santos-Hermosa and Abadal, 2022). OER must comply with the international guidelines on accessibility set out in the Web Accessibility Initiative.[53]

The accessibility criteria of OER are not only a mandatory requirement but also a guarantee of the didactic and technological effectiveness of the OER. This is because an accessible OER, in addition to being used by a wide range of people, reduces the effort of receiving, understanding, and assimilating its contents. In this sense, UNE-71362:2020 integrates the accessibility guidelines for OER elaborated by the Spanish National Organisation of the Blind, the standards UNE 139802:2009, Accessibility Requirements of Software; UNE 1389803:2012, Accessibility Requirements for Contents on the Web, by collecting specifications of accessibility and quality in digital environments.

In summary, accessibility measures whether text content is perceptible, operable, understandable, and robust (UNE 139803, 2012).

- *Text accessibility* is perceptible, operable, understandable and robust. It also evaluates that it does not present difficulties for people with some disabilities of the visual, auditory, motor, intellectual, ASD, ADHD, overdoing or learning difficulty (UNE 139803, 2012).
- *Visual accessibility* measures whether visual content is perceptible, operable, understandable and robust. As in the previous point, it also evaluates that it does not present difficulties for people with some disabilities of visual, auditory, motor, intellectual, ASD, ADHD, overdoing and learning difficulty (UNE 139803, 2012).
- *Flexibility,* according to Díaz (2002), refers to the practice in which the learner has the possibility to choose or select the form, place (space), and time of their learning according to their interests, needs and possibilities.

[53] www.w3.org/WAI/standards-guidelines/wcag/es

4.2.5. KPI-5: Inclusive communication (IC)

Inclusive communication means selecting and drafting content from the perspective of gender, equality, and non-discrimination, avoiding the generic masculine, eliminating stereotypes, and using inclusive words and images with gender parity, which serve as a reference to students. The iconic language as well as the written language must tend to be inclusive. People with different physical traits must be represented and the content must resemble the reality of the student.

As a final remark, it is noticeable that when preparing an OER assessment rubric, all the mentioned KPIs, as well as its respective features, must be taken into consideration by designing specific questions or items that address the efficient learning aim.

4.3. OER-AM Comparative Analysis

The main aim of this section is to compare the OER-AMs introduced in Section 4.1. The comparative analysis will be based on the KPIs introduced in Section 4.2.

Annex A summarizes the assessment strategy and locates whether or not each OER-AM takes into account each one of the features introduced in Section 4.2. Those AMs that best address each of the features are highlighted in green. In the lower part of the table in Appendix A, information on the proposed rubric is reported, such as number of dimensions, total number of questions and scoring system.

This Section is organised by KPIs in terms of comparing how the assessment requirements are treated or incorporated along the different OER-AMs. Emphasis will be focused on those dealing with the features in a more accurate and comprehensive manner.

The comparative analysis will be carried out according to the UNE 71362 norm recommendations, as a reference document on the quality of digital educational materials. In its most up-to-date version, it provides a basic, proven quality model that facilitates the creation, selection, and verification of such materials. In turn, it helps to improve those existing digital educational materials by creating new ones and adapting them to new needs. The elements listed in the UNE 71362 standard are easily understandable, with short but very precise definitions that indicate exactly what should be valued.

4.3.1. KPI-1: Content

In the comparative OER assessment methodologies table, we have divided this field into four features, where the first feature is the cover and the second is the title.

The cover is treated only by three of the OER-AMs under analysis, as well as the second element, which is the title. However, CEDEC and HEODAR give it a lot of importance because they are the first interaction of the resource with the user.

The third feature is the quality. The quality of OER is treated by everyone. In general, it is expected that the content is accurate, truthful, that the ideas are balanced with an adequate

level of detail on the subject being addressed, and, of course, that it does not present errors or omissions that could confuse or mislead the interpretation of the content.

The quality of the contents is addressed by all OER-AMs, however, there are different nuances. For example, UNE 71362 does not speak to who the content is aimed at, while IQOER highlights the importance of the recipients to whom it is addressed in addition to a prior description that is necessary for them to properly follow the development of the resource.

On the other hand, ECOBA proposes practical and application elements in addition to diagnostic and evaluation exercises. CEDEC is the only one that mentions that there must be a relationship between what is learned and the student's life environment, where the information connects with the student's interests and the social reality of the student.

The last feature to comment on is adaptability. Content adaptability is the vertebrate axis and is common to almost all sources. TEMOA and BC Campus OER do not consider adaptability, while the rest are treated more specifically and more generically.

For example, generically, ECOBA does not explain much of its use; it only defines the concept as the ease with which the resource adapts to different recipients. In contrast, #IE_RED nuances that the materials can also be used regardless of the teaching-learning method.

HEODAR does not mention the term "adaptability" of the resource, but in its exposure of the psychopedagogy category and its didactic-curricular category, it addresses it from the point of view of the student's feedback through exercises and self-evaluations. It does not give details on how to adapt this concept for the user.

CREA con DUA does not mention the word adaptability as such, but the assessment methodology promotes the resource to provide multiple forms of action and expression, offering students different ways to be able to organize and plan.

4.3.2. KPI-2: Didactics (D)

The second key performance indicator (KPI) that we are going to evaluate is didactics. Therefore, we will address the comparative analysis of five features.

The first characteristic is motivation. We see that it is not considered in all OER-AMs but in most of them, but not in the same way. To highlight the most significant ones, TEMOA generates motivation through content based on reality and for this, it uses multimedia resources, games that stimulate the student, humor, drama, etc. The UNE standard, on the other hand, evaluates motivation by promoting the independent learning of the student, as the feeling of self-learning can stimulate the capacity for motivation through activities that can self-correct. HEODAR evaluates the term motivation with attractive and original presentations that capture the attention of students.

EVAluator is the only one that evaluates the emotions that help to foster learning, as they can stimulate the activity of the neural networks, all the rest do not consider them, although it can be assumed that emotions are implicit in the content.

As for consistency as a third feature, we should comment that BC Campus OER and TEMOA do not evaluate this concept. The rest, such as IQOER, for example, includes different activities that promote student responsibility and autonomy and tasks that cover previously established learning goals.

The next feature within the content is the active methodology. The active methodology is a common denominator in all of them. Active methodologies are those that seek meaningful learning, which is achieved when the student takes action. Instead of being a passive subject, you become the protagonist of learning through your activity. Therefore, active methodologies place the student at the center of the teaching-learning process, and therefore, all of them treat the student fairly and equally.

#IE_RED evaluates in detail even by promoting and improving activities in digital and analog format so that the student can express themselves much better and can even promote individual but also collective learning

CEDEC offers the student different possibilities so that they can express themselves throughout the resource tasks. These can be of different types: textual, visual, graphic, interactive, musical, etc., while ECOBA evaluates fostering individual work by having students present activities for feedback through cooperative work. LORI evaluates it more generically to suit the learning objectives.

4.3.3. KPI-3: Technical Characteristics (TC)

This dimension has been divided into four features that have been considered the most appropriate to describe technical characteristics. The first is robustness. MERLOT evaluates the material as easy to use if an application runs effectively without the Internet without adding any other type of nuance to it. CEDEC provides information that the resource, in addition to not failing during its operation, is not affected by user errors. The feature responds quickly, and it is also interesting to note that it offers help options that can be used with or without connection, allowing you to export it to standard formats at the educational level. LORI, TEMOA, CoDA, EVALUAREED, CREA con DUA, and BC Campus do not evaluate robustness.

UNE 71362:2020 standard assesses whether portability can be visualised/executed in various computer environments in general. #IE_RED provides, unlike others, information to the user from where he is at each moment, avoiding the user being exposed to repetitive content elements. ECOBA only comments on compatibility with different browsers without specifying anything else about it.

The technical and pedagogical usability of EVALUAREED is detailed very specifically in the form of short questions: Is the resource easily navigable? Is it intuitive? Does it use a search engine?

and others. It details it from a technical point of view, but not so pedagogically. Similar approach is done in CEDEC.

In #IE_OER evaluates from a more pedagogical point of view, fostering the participation of the student during the reading, visualization or interaction of resources. It is also expected that the student can manage their own learning.

CoDA evaluates usability based on several requirements, such as the ease of navigating within the resource to quickly find the concepts. The instructions must be clear and accurate, as well as the links within the resource. HEODAR evaluates usability for learning objects, from the interface design to the navigation design.

To evaluate the feature of portability, HEODAR does it from the interface design and navigation design perspective, and it evaluates different items to obtain a high level of accuracy. UNE 71362 evaluates portability taking into account that all file types are standard. It is worth noting that this standard evaluates metadata within portability. #IE_RED evaluates portability in a broad manner without specifying particular requirements.

Concerning metadata, ECOBA and IQOER only ask if metadata is standardised, while LORI requires that metadata be sufficient and be available. CoDA requires that metadata be standard and be exportable to a compressed file. LORI-AD asks if the metadata matches the standard specifications in each of the nine indicators the method deals with. Within the technical characteristics, we highlight that IQOER focus on whether the resource offers assistance and technical support to the user for any technical incident that may arise.

4.3.4. KPI-4: Accessibility (A)

Accessibility is assessed in all the methods, as a basic characteristic of OER. It can be assessed by the flexibility of the text and also by the audiovisual format. CEDEC, for example, evaluates in more detail accessibility in text format designed from an open and inclusive perspective to facilitate student understanding. The texts are easy to read, and the audiovisual content has a text description.

LORI requires the information to be also designed for people with disabilities able to use mobile devices. TEMOA evaluates, similar to LORI, if the resource is also designed for people with disabilities, but with specific mention to users with special needs, that is, motor and sensory disabilities.

MERLOT evaluates textual accessibility in a concrete way and does little or nothing with audiovisual accessibility. Contrarily, TEMOA, LORI-AD, BC Campus OER, UNE, and CEDEC do not consider accessibility features.

#IE_OER evaluates if new materials can be created, and created with free formats and standards to use.

After addressing accessibility, we will now deal with flexibility. The flexibility is assessed by #IE_RED generally does not explain too much the place or time of learning where the student

wants to use the resource, but if it evaluates free, majority or standard formats according to the interests of the student, which allows a certain flexibility to the student. ECOBA evaluates flexibility in a very generic way without adding any relevant nuance to highlight. CEDEC does not evaluate flexibility.

On the other hand, MERLOT assesses flexibility in different situations, without specifying what these situations are. However, it evaluates the interactivity of the material and its use on different platforms (mobile, etc.), considering the possibilities of the student.

4.3.5. KPI-5: Inclusive Communication (IC)

The only OER-AM that deals with inclusive communication is CEDEC, by addressing the topics of inclusive communication in content, iconic and inclusive language, and stereotypes.

When applying a particular OER-AM to some specific OER, a radial plot can properly illustrate the figures in each of the dimensions or KPIs. As an example, Figure 7, shows the behavior of two different assessment methodologies, denoted AM-1 and AM-2. The similarity in three KPIs (Content, Didactics and Technical Characteristics) and the fully opposite evaluation in the other two KPIs (Accessibility and Inclusive Communication) can be directly concluded.

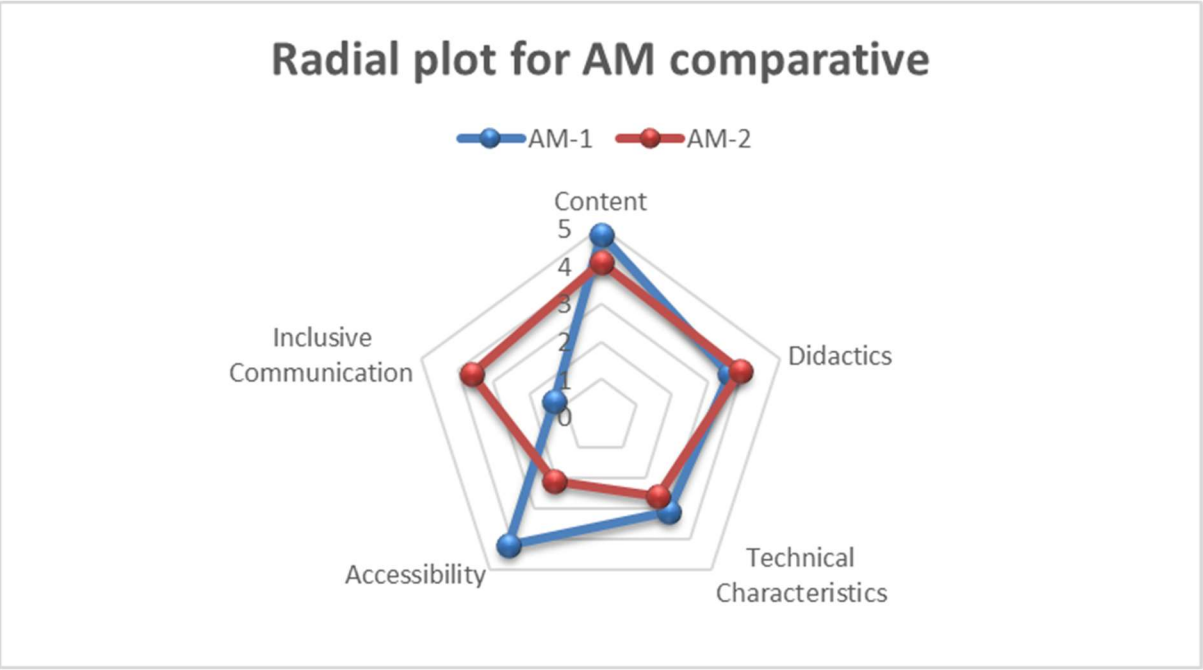

Figure 7. Illustrative example of the comparison between two assessment methodologies (AM-1 and AM-2) through a radial plot.

In summary, it has been identified that no one of the existing OER-AMs fulfills the overall KPIs requirements. As a consequence, it is strongly necessary to define a new OER-AM or rubric that becomes optimal under this perspective aiming for a general use in the high education community.

4.4. A New OER-AM Rubric Proposal

With the aim of proposing a broad spectrum OER-AM Rubric as flexible as possible, in this section we propose a weighted 2-step OER-AM Rubric that can be easily adapted to the users' specific requirements. As the name suggests, the proposal is organised in two steps in order to be able to carry out the evaluation in the most efficient way possible. Details on each one of the steps will be introduced later.

Each of the items or questions and KPI included in the rubric must meet:

- The item is subject to a weight defined by the user or institution according to the basic principles of the required performance criteria. For illustrative purposes, initial weights will be proposed by the authors (as an example, in a non-uniform manner among KPIs, and a uniform way among questions). Discussing how to decide the weights is not the purpose of this output.
- The weight is conditioned on the type, aims and target users of the OER. This includes the possibility of not being taken into consideration (in other terms, be weighted as a zero).

Due to efficiency reasons we propose a Rubric organised in two steps as follows.

- STEP I consists of a Checklist acting as a preliminary quality filter of the OER. After the particular setup, based on type, aims and users, the OER under assessment must satisfy all the items included in the checklist. If so, then the OER under assessment can be scored in accordance with the Rubric -which is supposed to be more time demanding-, otherwise the authors must redesign the OER.
- STEP II is the Rubric itself integrated by a list of a total of 63 questions distributed along the five KPIs introduced in Section 4.2.

4.4.1. STEP I: Checklist

After the analysis carried out in the previous sections we see that there are many characteristics that should be accurately analysed to affirm that a resource is of quality. As a consequence, the assessment process by itself can be time demanding. Therefore, it is necessary to choose some essential minimum characteristics in order to discard those resources that do not meet them.

Given a resource, we propose first of all to check, in a broad manner, basic features concerning four approaches: Open Licence, Accessibility, Layout Quality and Content. Details of the proposal are given in Table 3. Technical specifications or characteristics are not included in the Checklist because we are assuming that a preliminary technical filter has been already applied. Items in the Checklist can be narrowed or extended depending on the type, aims and target users of the OER.

Table 3. Checklist for STEP I in the proposed OER-AM.

OPEN LICENCE
☐ Does the licence allow for educational reuse of the materials?
☐ Does the licence allow modifications or adaptations of the materials?
ACCESSIBILITY
☐ Is the resource available for different mobile devices?
☐ Is it accessible to people with special abilities or needs?
LAYOUT QUALITY
☐ Is the layout and interface easy to navigate?
☐ Do the design features enhance learning?
☐ For multimedia resources, is the audio/video quality high?
CONTENT
☐ Grammatically correct
☐ Is the content true?
☐ Is the information clear and understandable?

4.4.2. STEP II: Comprehensive Rubric

Annex B contains our OER-AM rubric proposal. The rubric is made up of the mentioned five weighted KPIs, and different features that will be evaluated with a 1-to-5 Likert-style scale. As stated in the introduction to this section, this rubric is intended for generic and flexible use. In order to a better understanding of each feature, descriptions of the minimum (1), medium (3) and maximum (5) requirements for scoring are given. Setting the weights of each KPI and each feature within it, as well as statistics to be used, allows the rubric to be customised to the particular needs of teaching/learning agents. As an example, and initial proposal could be 30%, 25%, 20%, 15% and 10% for the KPIs, respectively, and uniformly among the features within each KPI. For the final summary of the scores average or median could be used.

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5. OER movements and OER developing groups

The OER movement is a global initiative aimed at providing free access to high-quality educational materials to learners around the world. In the last two decades, a rapidly growing amount of OER has been developed in all fields of education over the world (Clements et al., 2015). The OER movement seeks to democratize education by making educational resources available to everyone, regardless of their socio-economic status or geographical location. The movement also aims to promote collaboration and sharing among educators and institutions, and to reduce the cost of education by providing free or low-cost alternatives to traditional textbooks and other learning materials.

Several international organisations such as UNESCO, OECD, The WorldBank and The Commonwealth of Learning have supported this movement (Hylen, 2006; Taylor, 2007; Annand et al., 2017). Already in the early stages, more than 2,500 open access courses from more than 200 universities were available. These were educational institutions from countries such as Australia, Brazil, Canada, Cuba, France, Hungary, India, Iran, Ireland, the Netherlands, Portugal, Russia, South Africa, Spain, Thailand, the United Kingdom, the United States, and Vietnam (OECD, 2007). The OER movement has gained momentum in recent years, with a growing number of institutions, governments, and organisations embracing the concept of open education.

As a result of events related to the COVID-19 outbreak and educational crisis, OER for various subjects is becoming increasingly popular. Many universities and colleges are now incorporating OER into their curricula, and several governments have launched initiatives to promote the use of OER in their educational systems (Stevens et al., 2017).

5.1. Europe (with subsections also devoted to the Gate2Math partners)

As stated in the literature (Santos-Hermosa et al. 2017) most of the OER repositories were created in Europe. The European countries that created the highest rates were the United Kingdom, Spain, and France. The success of these countries may be due to both the significant funding of OER projects and the presence of the largest number of OER publications (Zancanaro et al., 2015) as well as the number of their respective language speakers (English - 1.456 millions; Spanish - 559,1 millions; French - 309,8 millions) .

Until April 29, 2022, the OER world map continuously tracked the global development of OER and promoted interaction and collaboration through the collection and exchange of open data on participants and activities related to OER. In 2021, more than 6,000 higher education institutions, companies, repositories, government agencies, services, events and individuals took initiatives and projects in the field of OER in Europe (see Figure 8).

Figure 8. European Countries on the OER World Map (ENCORE+ project). [54, 55]

A new beginning of the OER movement is the Gate2Math project. Its goal is to develop a platform for open digital educational resources in mathematics and put into operation for the international educational community an effective intellectual library Gate2Math for the optimal selection of open and multilingual educational resources in the field of teaching mathematics, covering the content of algebra, calculus, geometry, statistics and probabilities and their applications in STEM education.

The Gate2Math project consortium includes six higher education institutions from five different European countries, namely: Tallinn University of Applied Sciences/TTK UAS (Estonia), Porto Polytechnic Institute/P.PORTO (Portugal), Universitat Politècnica de Catalunya-BarcelonaTECH/UPC (Spain), Technical University of Cluj-Napoca/UTC (Romania), University of Applied Sciences CAMPUS 02/CAMPUS02 (Austria) and Tallinn University/TLU (Estonia). All partners are experienced in implementing ICT and innovative open practices in mathematical education.

5.1.1. Austria

The development of the open source *Geogebra* software for dynamic geometry and algebra can be seen as the start of the OER movement in Austria (Hohenwarter, 2002). This rapidly evolving software now integrates not only geometry and algebra, but also spreadsheets, graphs, statistics, and calculus into one easy-to-use format. In addition to software and applications, there are many resources available for GeoGebra, including the ability to create virtual/digital books on specific topics, including explanations and assignments. At the moment, around 130 "GeoGebra

[54] https://encoreproject.eu/, https://iet.open.ac.uk/projects/encore

[55] oerworldmap.org

Institutes" have already been created around the world with millions of users located in just about every country (Geogebra, 2023). The next steps towards open educational content were settling an international conference on OER and the first European Open eLearning Content Observatory Services project dedicated to OER developed in 2007 (OLCOS, 2023). Another well-known OER project in Austria is the *Catrobat* project[56] initiated in 2010. The goal of the project is to develop free software for children and young people, with which they can transform from passive users into creative developers using Pocket Code applications and its visual programming language. Over the past 15 years, interest in OER has increased in Austria.

Universities show a lot of interest in the use of OER in higher education compared to other educational sectors (such as primary, secondary, and adult education). Many modern teachers are sent to prepare their own study materials. Through the efforts of several Austrian universities, the Open Education Austria platform[57] has been created, which contributes to the development of a national OER infrastructure and the free use of educational content within open practices (open access, open data). On the platform, within the framework of the digitization project "Open Education Austria Advanced" (the University of Vienna, Graz University of Technology, the University of Graz, and the University of Innsbruck), the OERhub search engine has been created, which allows you to search for OER material on a topic in local archive systems with faceted search in the Austrian higher education sector. The technical implementation of the integration of all cooperation partners and other interested universities takes place by connecting local infrastructures (archive systems or repositories) to OERhub. All developed plugins are available as open source developments, state of the art, and use international interface standards. At the present, there are four OER repositories connected to the OERhub: the University of Vienna (PHAIDRA), the Graz University of Technology, the University of Graz (OER-Portal), the University of Innsbruck (OER Repositorium) and Austria's first and so far only MOOC platform iMooX[58], founded in December 2013 by the University of Graz and the Graz University of Technology. All materials are licenced under Creative Commons licences and available for free. The platforms offer several OER from the field of higher mathematical education in German and English languages.

Currently, they are even part of the official strategy of the Austrian Federal Ministry of Education, Science, and Research (BMB, 2022). Within the latter program, among other contexts of existing courses and research, as well as newly created curricula offering many opportunities for personalization, OER materials (Massive Open Online Courses are also offered when needed) should also be made available for use by teachers and students, as well as by all stakeholders.

[56] https://catrobat.org

[57] https://www.openeducation.at

[58] https://imoox.at

5.1.2. Estonia

Digital educational resources are a priority of the Estonian educational policy coordinated by the Ministry of Education and Research (MER) in accordance with the Lifelong Learning Strategy for 2014-2020 (MER, 2014) and, continuing it, the Estonian Education Strategy 2021-2035 (MER, 2021). The three strategic goals of the latter are:

(1) diverse and accessible learning opportunities, and the education system ensures a smooth transition between levels and types of education;

(2) competent and motivated teachers and directors, a diverse learning environment and a student-centered approach to learning and teaching;

(3) the relevance of training options to the needs of the development of society and the labor market. It should be noted that openness is not the main reason for focusing on digital educational resources.

The OER infrastructure in Estonia consists of educational object repositories (LOR), educational resource development tools, evaluation platforms, virtual learning environments (VLE) and auxiliary systems such as metadata application profile and single sign-on (SSO) (Põldoja & Laanpere, 2020). The concept of learning objects arose in Estonia in connection with e-learning support programs BeSt program (for universities, lasted from 2008-2013), VANKeR (for vocational education institutions and universities of applied sciences, lasted from 2008-2013), e-Jump, e-VÕTI and Primus[59] (lasted from 2008-2015, financed from Europe structural funds and implemented by the Archimedes Foundation). A learning object is defined as a complete digital resource that can be reused in different learning contexts and support learning, but changing them may not be possible (but not necessary) due to copyright or design considerations. The most common types of e-learning objects in Estonia are: animations, audio lectures, presentations, exercises (tasks), training videos, simulators, content packages (short courses), dictionaries, tests, video lectures/multimedia synopsis. Thus, the idea of learning objects (LO) is similar in nature to the idea of OER. Both LO and OER are types of digital educational resources that have associated metadata, including digital rights and learning design information such as learning goals and context. Between 2001 and 2016, the Koolielu portal[60] was used as the main repository for general education. Over the years, teachers have published more than 5,700 learning resources, over 3,300 of which are under a Creative Commons licence. After the launch by the Ministry of Education and Research (MER) of a new platform for early childhood education, basic education, secondary education, vocational education, and non-formal

[59] The goal of the program was to support the quality of higher education and increase the competitiveness of graduates, and to fulfill the goals, we work closely with 23 partners, which include 19 higher education institutions.

[60] https://web.archive.org/web/20190418143749/https://koolielu.ee/waramu/index

education - e-Koolikott[61] (e-Schoolbag), metadata of most high-quality resources from Koolielu were transferred to e-Koolikott. Currently, the repository contains more than 18,700 educational resources. These include OER, resources without an open license, and some commercial content from publishers. Teachers can create collections of content that contain existing resources in the repository and upload their own resources to the repository. Most of the materials on the platform were created using H5P interactive templates as part of the national OER development project "Digital Learning Property" („DigiÕppeVaramu", 2017-2018). The project was funded by the MED, the development of more than 10,000 interactive educational objects was coordinated by Tallinn University, all produced educational materials underwent a strict quality control procedure, and 20% of the resources were tested by teachers in 30 schools in the spring of 2018. These resources are published in Estonian under a Creative Commons Attribution licence, and available for use and editing by all teachers and students on the e-Koolikott platform (Põldoja & Laanpere, 2020). Learning objects can be commented on and recommended to other users or combined into simple shared collections with optional sign-in using Estonian national authentication methods or accounts. MER, together with the European Social Fund, has funded several projects to develop digital OER targeted at students with special needs[62]. The main attention was paid to the preparation of simplified teaching aids, workbooks, worksheets, various pedagogical materials and to promote their digitalization. For primary and lower secondary core subjects, MER preferred to purchase licences for commercially published digital textbooks compiled on an online platform called Opiq[63]. Two platforms eKool[64] and Stuudium[65] are used as educational information systems for primary and secondary schools. These systems started out as a digital gradebook and a tool for communicating with parents. However, both systems now also provide simple tools for managing assignments and learning content. School teachers themselves mainly use standard office software and Web 2.0 tools to create OER. The general strategy is to use Weebly, Blogger, WordPress, or Google Sites as a simple content management system and in combination with built-in resources from external services such as YouTube, SlideShare, LearningApps.org and others.

In higher and professional education, the repository of educational object operated by the Foundation for Information Technology for Education (HITSA) went live in 2009[66]. The repository contains over 4,600 learning resources, all under licences Creative Commons. To search for educational material, two types of search are used: by material metadata or by word cloud. Each

[61] https://e-koolikott.ee

[62] "Training of developers of HEV curriculum" (2005-2007), "Development of educational materials for students with special educational needs" (2008-2014), "Digital revolution" (2017–2020).

[63] https://www.opiq.ee/

[64] https://www.ekool.eu/

[65] https://stuudium.com/

[66] https://web.archive.org/web/20190528221650/http://www.e-ope.ee/repositoorium/

material can be evaluated, commented, and the use of the material can also be noted. The main purpose of this repository was to store resources that were developed in various content development projects funded by the European Social Fund. After the end of financial support for content development, the growth of the repository has decreased significantly. As a result of the reorganisation of tasks between foundations operating in the educational field, the repository of the HITSA Innovation Center has not been available to users since July 1, 2020. All materials in the eLearning repository will be archived until the end of 2025. Now, in the field of higher education, there are currently no initiatives at the state level to support the development and implementation of OER. Materials created for higher education are now stored in institutional repositories. The digital archive DSpace[67] is mostly used as repositories, which contains educational material, learning objects and educational videos prepared by the teaching staff of HI. Access to the content of the digital archive is guaranteed to all interested parties through the user interface and API (Application Programming Interface) standards. DSpace content is publicly available for both download and reuse, except in exceptional cases where the work is closed, restricted, or embargoed. All file formats are accepted for the preservation of publications and databases. The amount of data that can be stored in DSpace is unlimited.

The University of Tartu has created its own learning content creation platform based on OpenScholar. Some websites developed on this platform are published as OER. There have been several experiments with the Xerte Online Toolkit at Tallinn University, but it has not been widely adopted. The LePlanner online platform (Pata et al., 2017) allows teachers to create visual lesson plans that link teacher and student activities to the resources used in those activities. Learning scenarios can combine both OER and other content, making it easy to share a set of related resources with students. All training scenarios created in LePlanner are published under the CC BY licence. The main VLE used in vocational and higher education in Estonia is Moodle, which also stores OER created during various projects. For example, materials created within the international project "EngiMath - Mathematics on-line learning model in Engineering education" (2018-2021, 2018-1-EE01-KA203-047098). Some projects and communities have created their own open source repositories. For example, KAE Kool, inspired by Khan Academy, contains over 150 educational videos licenced under CC BY-NC-SA. Also, a physics themed repository created in cooperation between the project Tiger Leap, the University of Tartu, the Institute of Physics of the University of Tartu and MER[68].

MOOC courses are gaining more and more popularity in Estonian universities. Tallinn University has developed their own VLE named eDidaktikum, which is used mostly in teacher training programs. It also uses cMOOCs where all students use their personal blogs. The University of Tartu develops MOOC courses, which are usually conducted in the Moodle learning environment,

[67] www.dspace.ut.ee, https://dspace.emu.ee/, https://dspace.tktk.ee/

[68] https://opik.fyysika.ee/index.php/book/index

and all information - study materials, task descriptions, study guide and other things a student needs - is easily accessible. Course structure may vary. In some cases, the student must work on the course each week, while other courses provide more flexibility. In most cases, the learner must read study materials, watch videos, listen to interviews, and solve problems or take tests based on them, and there is also the opportunity to discuss on the forum and ask questions or help in case of problems. By actively participating in the forum, you can systematize your knowledge and learn from others. Part of the MOOC courses is conducted on European platforms such as Coursera, edX, and FutureLearn.

5.1.3. Portugal

In Portugal, a number of repositories containing diverse educational materials can be found, including national repositories (Nobre, 2020).

- RCAPP - OPEN ACCESS SCIENTIFIC REPOSITORY OF PORTUGAL[69]

This repository was established in Portugal in July 2000 with the objective of creating a national meta-repository and hosting service for new repositories. It integrates Portuguese repositories, including those affiliated with higher education institutions, hospitals, research and development institutions, public administration, and non-profit organisations. The RCAAP portal serves as a unique point for searching, discovering, locating, and accessing a wide range of scientific and academic documents, such as journal articles, scientific papers, conference proceedings, theses, and dissertations. The portal aims to collect, aggregate, and index scientific content in open access from various repositories associated with national educational institutions and other research and development organisations. Additionally, the RCAAP research portal facilitates research integration with Portuguese and Brazilian repositories, and provides a dedicated website[70] with comprehensive information, including multimedia tutorials for consultation and student learning. The repository also offers support resources, such as tutorials and self-training modules in Portuguese, and promotes the creation and self-archiving of OER.

- R UAb - OPEN REPOSITORY OF THE OPEN UNIVERSITY[71]

This open access scientific repository allows users to search for articles, theses, and other materials based on themes, keywords, sources, and dates. Its primary goal is to store, preserve, disseminate, and provide access to the intellectual production of the Open University in digital format, thereby making knowledge accessible to all. The repository offers a user-friendly interface with straightforward navigation and ease of comprehension.

[69] http://www.rcaap.pt/

[70] http://project.rcaap.pt

[71] https://repositorioaberto.uab.pt

- IAVE - Item Bank[72]

Under the responsibility of the Ministry of Education in Portugal, this repository encompasses several subject areas, including biology, chemistry, physics, geology, Portuguese language, economics, and geography. Teachers are permitted to create various forms of classroom exercises, such as replacements and homework, using the items available in the repository. Additionally, the repository contains exams, tests, assessment criteria, and grading grids for different disciplines, which are widely used. It provides OER specifically adapted to the educational context in Portugal, covering various subjects in primary education (1st cycle, 2nd cycle, and 3rd cycle) and secondary education.

Working with repositories and their content is generally practical and straightforward for users, regardless of their level of expertise in Internet tools. In some cases, repositories even offer additional tools to facilitate the production and dissemination of OER, as well as encourage open educational practices (OAPs), particularly at the institutional level.

- Open Repository of the University of Porto[73]

This repository collects, preserves, and publishes the intellectual and scientific production of the academic community at the University of Porto. It ensures open and free access to full-text documents, provided authorization is granted by the authors. The repository is organised into Communities and Collections, where the former represents organic entities within the University of Porto (including Porto Business School, I3S, CIIMAR, and ISPUP), and the latter comprises various document types, such as articles, books, book chapters, master's and doctoral theses, posters, reports, and others.

At the international level, a multitude of OER are generated through collaborative European projects. For instance, the DrIVE-MATH project, titled "Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees" (Erasmus project: 2017-1-PT01-KA203-035866, 2017-2020), aimed to devise a groundbreaking and comprehensive framework for imparting mathematical instruction in engineering programs at the university level. Its primary objective revolved around the implementation of innovative pedagogical approaches to actively engage students and foster their motivation to learn (Pinto et al., 2019). Another notable endeavor is the, already mentioned, EngiMath project – "Mathematics on-line learning model in Engineering education" (Erasmus+ project 2018-1-EE01-KA203-047098, 2018-2021). This initiative entailed collaboration among higher education institutions spanning six European countries, with the participation of over twenty educators representing diverse fields of knowledge. Together, they developed an online instructional model specifically tailored to

[72] http://iave.pt/

[73] https://repositorio-aberto.up.pt/

teaching mathematics within the context of engineering education. Subsequently, the shared English-language resource was translated into the languages of the partner countries (Soares et al., 2021).

5.1.4. Romania

Romania appears active in the OER movement mainly through institutions/groups or individuals engaged in specific initiatives, projects, or programs, but also through some proposals of policies at the governmental level that can become driving forces[74]. The initial stage of Romania's participation in the OER movement is considered to be the implementation of the strategic national project "Knowledge Economy Project" (KEP, 2005-2013), implemented by the Ministry of Communication and Information Society in cooperation with the Ministry of Education, Research, Youth and Sport is a partner in this program, and founded by the World Bank.

The Romanian Coalition for OER[75] was established in October 2013 and brings together people and organisations that support and promote the concepts of open access and OER. The coalition has published guidelines, organised several workshops and national conferences on open education, and formulated concrete proposals for the government related to Open Education[76]. Also, the Romanian Coalition for OER organizes scientific events related to open education: national conferences (since 2014, the eLSE International Conference[77] has a special section dedicated to OER and MOOCs); workshops within the Open Education Week (2014 and 2015).

The usage of OER and Web 2.0 in formal and life-long learning education as strategic lines of development for ICT in education is considered from February 2015 as a fundamental topic of the National Strategy on Digital Agenda for Romania 2020[78]. The reform carried out in Romania in 2017-2018 led to a large number of studies related to OER (Wang et al., 2017). The government programme also mentions the implementation of an e-learning platform and online repositories[79]. A project to implement online directories for OER was launched at the level of the counties inspectorates and at the end of 2018, almost all County School Inspectorates (40 out of the 42) had OER sections on their official websites and have implemented procedures to collect and publish OER from teachers (Grosseck et al., 2020).

The national OER repository in Romania is not implemented yet. There are several directories and projects for open resources maintained by online communities or private companies, most

[74] http://poerup.refereata.com/wiki/Romania

[75] http://educatiedeschisa.ro

[76] http://www.inorepublica.ro/educatie-deschisa-romania

[77] http://elseconference.eu

[78] https://www.comunicatii.gov.ro/agendadigitala-pentru-romania-2020

[79] http://mrp.gov.ro/web/programul-de-guvernare-2017-2020/

of them providing open access to digital resources for the pre-university level, and several without clearly specifying open licences (see Table 4).

Table 4. Directories with open resources in Romania (Hugyecz, 2018; Grosseck et al., 2020).

Initiatives	Websites
the community of pre-university teachers and the largest portal of educational resources	https://didactic.ro
online community developing good practices facilitated by the project CRED	https://creatorideeducatie.ro
portal of OER created by teachers, a project supported by the Institution of Educational Sciences	https://digitaledu.ro
educational online community of the Mures, County	https://educatie.inmures.ro
online community addressed to primary education sector	https://kidibot.ro
digital education program funded by Orange	https://digitaliada.ro
education through technology portal	https://dacobots.com
platform for publishing educational digital textbooks	https://livresq.com
community for Mathematics contests	https://infoarena.ro http://math-pdr.com
digital resources projects funded by Vodafone	https://www.scoaladinvaliza.ro, https://civiclabs.ro
open educational journals (e.g. iTeach platform)	https://iteach.ro/experientedidactice
e-learning Romania platform	https://www.elearning.ro
New Projects	https://revista.newprojects.org

Under the CRED[80] (Relevant Curriculum, Open Education for all, 2017–2021) project, 47,662 primary and secondary school teachers completed continuing education courses in various subjects (including Mathematics) to tailor teaching and learning processes to the specific needs of students, including students at risk of dropout. It was planned to create teaching aids in educational areas covering all disciplines provided for in the new framework plans for primary and secondary education, respectively, 7200 OER in all disciplines, which are equally available to

[80] https://educred.ro

students and teachers of OER centers, but also on online e-learning platform. In September 2019, the OER Digital Platform - Virtual Library - was launched, the purpose of which was OER, mainly for the gymnasium education cycle.

Training and courses related to open educational pedagogies for continuing professional development of teachers have been offered by KEP, Moodle Romania, Didatec, iTeach, Sloop2desc, The Centre for Innovation in Education[81] (TEHNE Romania), ActiveWatch Media Monitoring (Holotescu & Pepler, 2014; Holotescu & Grosseck, 2018).

The most of the open resources in public catalogs correspond to the pre-university level. There are far fewer concepts of open education or the creation or use of OER in higher education due to the generally conservative attitude of academic staff towards copyright issues. In addition, universities enjoy wide autonomy so that central national policies are not directly enforced unless they are aligned. Most universities run their courses on e-learning platforms, mainly Moodle or other open source environments for MOOCs at the university level and for continuing education. Platforms and MOOCs implemented by academic institutions, according to (Grosseck et al., 2020):

- UniCampus[82] started in April 2014 by University Politehnica Timisoara, Unicampus offers MOOCs on a version of Moodle platform based on cMOOCs.
- NOVAMOOC[83] is a project for development and innovative implementation of MOOCs in Higher Education, run by West University of Timisoara (WUT) during 2015–2017. The following MOOCs were developed: Practicing English with Technology, Teaching with OER, Fake news, and Digital storytelling[84].
- UniBuc Virtual[85] by Credis (Department of Distance Learning from Bucharest University) developed and ran three MOOCs for teachers training on a Google Apps-based platform.
- "Critical Thinking MOOC" was developed and ran in 2014 by the Maastricht School of Management Romania on Iversity[86].
- University "Babes-Bolyai" Cluj-Napoca developed in the eLIADA[87] project materials for four MOOCs.

[81] http://www.tehne.ro

[82] https://unicampus.ro

[83] https://novamooc.uvt.ro

[84] https://west-university-timisoara.teachable.com

[85] https://www.unibuc-virtual.net

[86] https://iversity.org/en/courses/critical-thinking-for-business

[87] https://eliada.granturi.ubbcluj.ro

In the framework of the NOVAMOOC project, in 2017, an international conference "New Trends and Prospects in Open Education" was held, which became the first event organised by a higher education institution on the topic of open education (Grosseck et al., 2020).

5.1.5. Spain

In Spain, there has been a growing interest in OER among universities, and many institutions have started to develop and share OER. The Spanish government has also encouraged the use of OER through various initiatives, such as the creation of a national repository for OER (Recursos educativos en abierto, or REA) and the establishment of a national plan for open science.

Several universities in Spain have also developed their own OER initiatives. For example, the Universidad Nacional de Educación a Distancia (UNED) has created a repository of OER that includes a wide range of materials, including textbooks, videos, and interactive learning activities. The Universitat de Barcelona (UB) has also developed a platform for sharing OER, which includes materials created by both faculty members and students.

The digital platform MDX[88] (*Materials Docents en Xarxa, in catalan*) created by the local Government of Catalonia in 2001 to provide OER to teachers, students, and the general public includes tools for educators to create and share their own OER. It offers a wide range of OER in Catalan, Spanish, and English, including textbooks, multimedia resources, and interactive activities. The materials cover a variety of subjects and levels, from primary school to higher education. The MDX platform has been widely used by educators in Catalonia and has received several awards for its innovation and impact. The platform has also been recognised as a best practice in open education by the European Commission and has been used as a model for similar initiatives in other regions of Spain and Europe.

Another open educational initiative is the UniMOOC project (Pedreño et al. 2013), launched in 2012 in Spain to provide free online courses on entrepreneurship, digital skills and innovation. UniMOOC was developed by the Universidad de Alicante in collaboration with a number of other institutions and organisations. UniMOOC offers a range of courses that aim to promote entrepreneurship and digital skills in Spain and bridge the gap between the academic world and the business community. Courses are designed to provide students with practical skills and knowledge that they can apply in their own business or career. The initiative has also received several awards and recognitions for innovation and impact, including the European Entrepreneurship Promotion Award and the Open Education Awards for Excellence.

In addition to these initiatives, there are also various organisations in Spain that promote the use of OER and provide resources and support for educators. For example, several universities and

[88] https://www.mdx.cat/

organisation participate in the Open Education Consortium[89], the global network for open education, and work together to promote the use of OER in education.

UPC has its institutional repository UPCommons[90] that collects, manages, disseminates, and preserves the teaching and research output of the members of the university community in open access: journal articles, research reports, conference papers, final theses, bachelor's theses, doctoral theses, teaching materials and other academic documents and educational resources. The UPCommons' aims are aligned with the ones in this project. UPCommons is managed by the Libraries, Publications, and Archives Service. It uses mainly DSpace, an open-source program developed by the Massachusetts Institute of Technology (MIT) and Hewlett Packard (HP). UPCommons guarantees perpetual access and preservation of its content through storage on secure servers of the University. It also meets the technical requirements to ensure interoperability with other information systems. The metadata records stored in UPCommons are served under a CC-by 3.0 Creative Commons CC-by 3.0 ES, which authorizes to share (copy and redistribute in any format) and to adapt (remix, transform, and build upon the material or any purpose, even commercially) as long as the authorship is acknowledged. Some current figures of the deposits contained in UPCommons: research (90,000+ files), teaching resources (100,000+ documents), and heritage collections (23,000+ documents).

5.2. Outside Europe

Not only Europe has been committed and engaged in the promotion and development of the OER movement, that, as mentioned before, has witnessed substantial growth on a global scale over the past decade. This expansion is attributed to the active involvement of numerous esteemed entities, including specialised OER organisations, governmental bodies, universities, scientific institutions, and cultural organisations[91]. These stakeholders are committed to the advocacy, policy development, funding, utilization, and augmentation of OER. Notable organisations such as COL, UNESCO, Creative Commons, OpenLearn, OER Africa, and several other credible proponents and pioneers of OER have played a pivotal role in establishing fundamental guidelines, benchmarks, frameworks, and professional development modules for OER, a trajectory that should be sustained (UNESCO & COL, 2011).

To facilitate the search for open resources spanning various disciplines and international repositories, George Mason University has developed an OER meta-crawler called the "Mason OER Metafinder" (MOM)[92] (Brown et al., 2020). The Mason OER Metafinder enables individuals to conduct comprehensive searches across 22 distinct sources of open educational materials

[89] https://www.oeconsortium.org/

[90] https://upcommons.upc.edu/?locale-attribute=en

[91] https://en.wikibooks.org/wiki/Open_Education_Handbook/OER_communities_and_interest_groups

[92] https://mom.gmu.edu

simultaneously. These sources encompass renowned OER repositories like OpenStax, OER Commons, and MERLOT, as well as platforms such as HathiTrust, DPLA, Internet Archive, and NYPL Digital Collections. These latter platforms often harbor valuable educational resources that are frequently overlooked and can be classified as "open" in nature (see Figure 9).

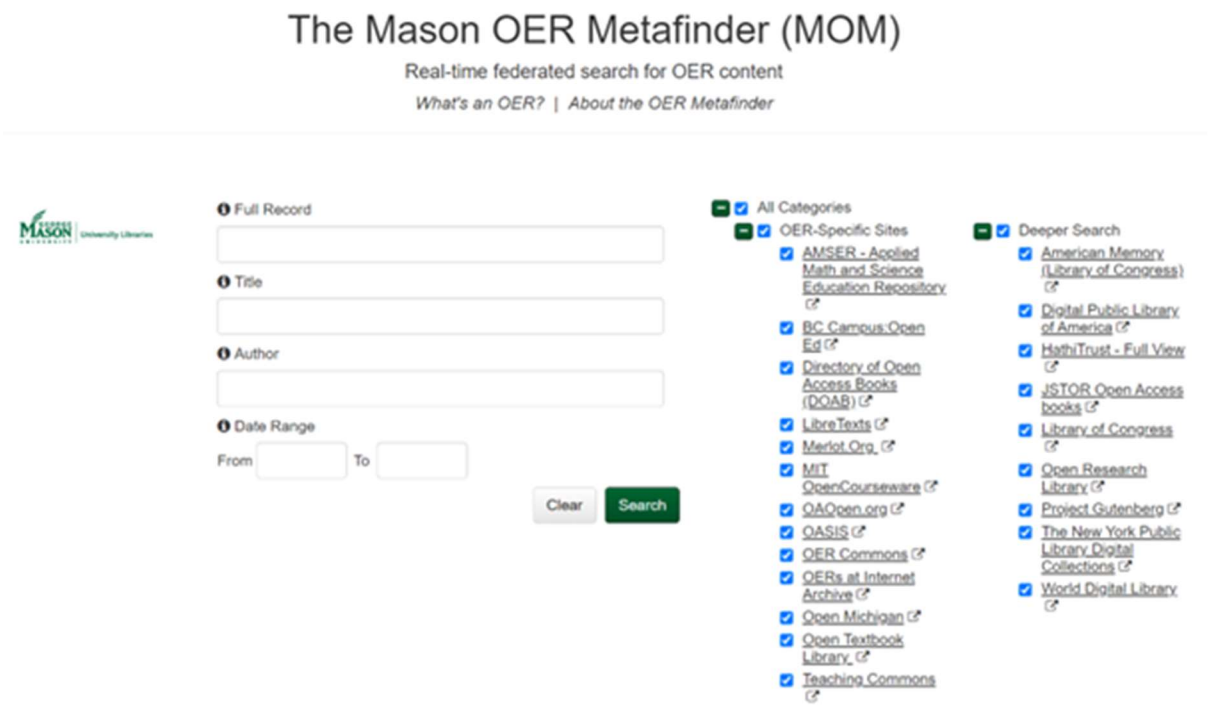

Figure 9. MOM's repositories and search sites.

Within the realm of mathematics, a wide array of topics can be explored, including Mathematics Education, Statistics, Computer Science, Discrete Mathematics, Mathematical Modeling, Differential Equations, Number Theory, Linear Algebra, and Contemporary Mathematics, among others. The comprehensive scope of mathematical subjects encompasses various domains of study.

One valuable resource for open courses with "zero textbook cost" is Lumen Learning[93]. Lumen Learning offers interactive content encompassing text, images, videos, assessments, directed feedback, and practice questions. Furthermore, their OER courses incorporate an online homework (OHM) system that provides students with numerous options for machine-based assessment, fostering immediate feedback and facilitating the study and mastery of mathematics topics such as Algebra, Calculus, and Statistics.

[93] https://lumenlearning.com

Massive open online courses (MOOCs) represent a significant aspect of the OER movement within the educational landscape. Prominent platforms such as Coursera[94] and edX[95] offer a diverse range of educational courses, often instructed by esteemed professors and subject-matter experts. These platforms enable students to acquire new knowledge, develop skills, and broaden their professional perspectives. The courses offer typically encompass recorded video lectures, auto-graded and peer-reviewed assignments, and community discussion forums, covering subjects such as introduction to algebra, geometry, trigonometry, pre-calculus, and calculus.

Educational platforms that provide digital support, such as Academic Earth[96], offer access to open courses, journals/trade magazines, grants and scholarships, internships, and student and professional memberships. These platforms serve as comprehensive hubs for supporting the academic growth and development of students.

In addition to textbooks, numerous projects and resources within the OER movement incorporate cutting-edge open content utilizing simulations, mobile apps, virtual reality (VR), and augmented reality (AR). For instance, the PhET Interactive Simulations project[97] offers a collection of free interactive science simulations, including those focused on mathematical concepts, enriching the learning experience for students.

Furthermore, there are dedicated repositories and platforms that exclusively provide OER materials for mathematics courses at either no cost or low cost for higher education. Some notable examples include MyOpenMath[98], Khan Academy Collection[99], Ximera open-source platform[100], Paul's Online Math Notes[101], and Desmos Classroom Activity[102]. Research has indicated that courses incorporating OER materials yield either superior or equivalent outcomes compared to courses that do not utilize OER (Khoule et al., 2021; Ryan & Nawalaniec, 2022; Muggli & Westermann, 2019). These studies underscore the positive impact of OER on educational effectiveness and student performance within the realm of mathematics.

[94] https://www.coursera.org/

[95] https://www.edx.org/learn/math

[96] https://academicearth.org/mathematics/

[97] https://phet.colorado.edu/

[98] http://myopenmath.com

[99] https://www.khanacademy.org

[100] https://ximera.osu.edu/

[101] https://math.lamar.edu/

[102] https://desmos.com

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Conclusive Remarks

The research work done by the Gate2Math consortium, until the moment of preparing this report, has allowed

a) a uniform among partners understanding of the OER definition and types of OER,
b) a better knowledge of standards, regulations, support, and active developing groups in Europe and across the world,
c) to review and compare the existing OER assessment methodologies, and
d) to define a new comprehensive rubric able to be adapted or personalized to the particular OER types and to institutional or teacher specific requirements.

These benefits and production are fully aligned with the expected results of the activity WP3/A2, and allow to define the specific scope of the project previous to the OER generation. Additionally, these results were also needed for an appropriate implementation of the validation criteria and protocol, as well the interface, for selecting, validating and uploading new OER to the Gate2Math smart library platform.

Annex A. A comparative of OER assessment methodologies (external pdf file)

Annex B. Rubric for OER quality assessment (external pdf file)

Table of figures

Table of tables