AGILE: GIScience Series, 5, 9, 2024. https://doi.org/10.5194/agile-giss-5-9-2024
Proceedings of the 27th AGILE Conference on Geographic Information Science, 4–7 Sept. 2024.
Editors: Alison Heppenstall, Mingshu Wang, Urska Demsar, Rob Lemmens, and Jing Yao.
This contribution underwent peer review based on a full paper submission.

OER4SDI: Open Educational Resources for Spatial Data Infrastructures

Carsten Keßler [1,2], Albert Remke [3], Henryk Hodam [4], Fabian Przybylak [1], and Andreas Rienow [4]

[1]Department of Geodesy, Bochum University of Applied Sciences, Bochum, Germany
[2]Department of Sustainability and Planning, Aalborg University, Copenhagen, Denmark
[3]Institute for Geoinformatics, University of Münster, Münster, Germany
[4]Department of Geography, Ruhr University Bochum, Bochum, Germany

Abstract. Education on spatial data infrastructures is an important building block of study programs focusing on spatial data. The focus is on equipping students with essential skills for future contributions to spatial data infrastructure development and application. Despite a wide range of available teaching materials, their reuse is hindered by a lack of harmonization and integration into learning modules. This paper reports on the activities in the "Open Educational Resources for Spatial Data Infrastructures" (OER4SDI) project, which addresses this gap by developing easily reusable teaching materials for spatial data infrastructures. OER4SDI strives to create high-quality, findable, accessible, interoperable, and easily reusable (FAIR) educational resources, fostering efficient knowledge exchange in the field of spatial data infrastructures. The project puts a special focus on the modularity of open educational resources to enable reuse in a wide variety of settings. We describe the workflows and technical setup we use to enable collaborative development of open educational resources and their continuous revision, which is vital in this rapidly evolving field. Three example open educational resources for spatial data infrastructures are given, dealing with the "AAA Data Catalog", "OGC Open API Features", and "Knowledge Graphs". We share the lessons learned from the project to foster the development of more high-quality open educational resources in our community.

Keywords. Open Educational Resources, Spatial Data Infrastructures, Education, Training

1 Introduction

The architecture, implementation, and use of spatial data infrastructures (SDIs) is a core component of GIScience study programs, such as geoinformatics, geodesy, or geomatics. The corresponding courses cover the conceptual, technical, and legal foundations of distributed SDIs as well as models for their development and management at regional, national, and international level. Students should develop the essential skills that will enable them to contribute to the development and valorization of SDIs in their future careers. They learn about the distributed nature of these socio-technical systems and their purpose to ensure the availability and usability of geographic information for specific purposes, such as supporting environmental policy, civil protection, or efficient science. To this end, students need to understand how these "systems of systems" are developed, operated and utilized by very large and heterogeneous interest groups at regional, national, or international level. A comprehensive understanding of this topic is essential for students studying geoinformation processing, as this knowledge is fundamental for their later activities, whether in research and teaching, management, development, or use of SDIs.

Even though a large number of teaching materials exist at the corresponding universities and many of the involved teachers are willing to share them, they are difficult to reuse as long as the content and didactic concepts are not harmonized and the materials are prepared in a way that hampers integration into learning modules. Aspects such as accessibility, the legally compliant use of sources and the regulation of further re-use by third parties are also important factors when it comes to publishing and using such materials. A search for existing so-called open educational resources (OER) revealed that although there is a wealth of source material, some of which is of very high quality (e.g. geo-train.eu by Geographical Information Systems International Group, 2020; smeSpire.eu by the smeSpire Consortium; or OpenGeoEdu by Bill et al.), there is no coherent collection of OER modules in the field of SDI that can easily be reused in a modular fashion, without adopting a whole course – which is hardly ever done, because teachers still need to adopt their courses to the overall curriculum, their students, and their own teaching style.

The project *Open Educational Resources for Spatial Data Infrastructures* (OER4SDI) was initiated to address this situation. It was triggered by the insight that while we teach concepts and best practices for sharing geospatial information resources, we ourselves lack concepts and best practices for effectively exchanging and sharing educational resources. In fact, we are more accustomed to developing SDI courses and materials in parallel over and over again, rather than joining forces and creating useful high quality learning materials that are findable, accessible, interoperable, and easily reusable.

OER4SDI therefore aims to develop easily reusable and editable teaching materials for this domain that can be applied both for in-person teaching as well as for online self-training. It covers examples such as the Infrastructure on Spatial Information in Europe (INSPIRE), the European Earth observation system Copernicus and the national spatial data infrastructure GDI-DE, but also information infrastructures that do not explicitly focus on geographical data, such as the National Research Data Infrastructure (NFDI) in Germany or the European Gaia-X initiative, as a large proportion of the data processed here also has a spatial and temporal reference.

This paper reports on the current state of the project, which is a joint effort by the University of Münster, Ruhr University Bochum, and Bochum University of Applied Sciences, with input from the Universities of Dresden and Twente, as well as 52°North. It is funded by the Ministry of Culture and Science of the German state of North Rhine-Westphalia under an effort to build a cross-disciplinary catalog of OERs on the ORCA.NRW portal. Based on a brief overview of related work (Section 2), we describe how we plan and conceptualize our OERs (Section 3) and provide insights about the technical infrastructure and tools we chose for the development of our materials (Section 4). We then provide an overview of some example OERs (Section 5), before discussing the evaluation of our materials (Section 6) and finishing the paper with concluding remarks (Section 7).

2 Related Work

Open Educational Resources (OER) are educational materials that are freely accessible and legally available to the public. They are typically in the public domain or licensed in a manner that permits copying, using, adapting, and redistribution by others (UNESCO, 2019; Sparks, 2017). This open licensing is a critical aspect of OERs, as it enables educators and learners to freely use, modify, and share these resources without infringing copyrights. These qualities make them ideal for use in educational settings, such as universities. For students, OERs help alleviate the financial burden of purchasing expensive educational materials. For university teachers, they provide opportunities to continually adapt and expand their curriculum, ensuring it aligns with the evolving realities of the professional fields their students aspire to excel in. Studies indicate that these benefits do not compromise their effectiveness (Hilton, 2016). The idea of offering free teaching resources and providing them online was formulated early on by the Massachusetts Institute of Technology (Goldberg, 2001). While finding and using OERs is becoming more and more common, concerns about the quality and a general lack of information about this form of knowledge distribution are still keeping some teachers and institutions to fully embrace the possibilities of OER content (Belikov and Bodily, 2016; Menzli et al., 2022). OERs are digital by definition and thereby inherit all the potential as well as the challenges that come with the production and distribution of digital teaching materials. Those challenges can often be specific to a certain target group or material. School teachers, for instance, encounter distinct challenges compared to university educators in implementing purely digital materials. The production of effective video content may require a different approach than more interactive teaching content. However, it has been demonstrated that these obstacles can be surmounted, and efficient workflows can be developed to create effective materials (Hodam et al., 2020, 2021). Technology-driven and quickly evolving fields like SDI have a particular requirement for the digital teaching materials and methods to adapt and evolve. This aspect has often been overlooked and requires more attention, as shown during the project *SPIDER: open SPatial data Infrastructure eDucation nEtwoRk* (Donker et al., 2022). The focus of the SPIDER project was on a conceptual mapping of the contents relevant for Open SDI education. The SPIDER toolkit[1] defines learning outcomes and proposes teaching activities and assessment questions. It therefore stays at a more abstract level than the concrete OERs developed here. The MOOC[2] developed at the end of SPIDER does constitute a form of OER, but it targets self-training, without the goal to be used in other forms of teaching.

While there is some overlap between SPIDER and OER4SDI – both in terms of the team and the project goals – OER4SDI has a stronger focus on the development, dissemination, and use of OER as an *open educational practice* (OEP). While OER is about the learning materials, OEP goes beyond and encompasses the entire set of strategies and approaches used to improve the effectiveness of teaching and learning by utilizing the paradigm of openness. It invites all stakeholders to share ideas, competencies and capacities that contribute to a high-quality learning experience (Ehlers, 2011; Mayrberger, 2020). In this sense, cooperation between universities in the creation of any teaching materials is already an OEP. The design of these teaching materials as OER creates further momentum by opening up the cooperation to other higher education institutions and further teachers and learners. In fact, OEP can be viewed as a strategy to address the issues of quality and acceptance that OERs face, which stem from

[1] See https://sdi-spider.github.io/toolkit/.
[2] See https://sdispider.eu/wp/open-sdi-mooc/.

their largely unmanaged lifecycle and the scattered nature of their dissemination platforms (Camilleri et al., 2014).

Although the definition of OERs is straightforward, they are available in a variety of forms, that are interlinked and also have an impact on their potential re-usability in light of good OEP. The definition of different learning objects and their aggregation levels is defined by the IEEE Standard for Learning Object Metadata (see Figure 1) and may act as a framework when planning the production of OERs (IEEE, 2020).

3 Planning and Conceptualizing OERs

Building on the concepts and best practices for OER and OEP as summarized in Section 2, this section describes the identification of project-specific requirements and objectives as well as the concepts and design decisions that were derived from them.

3.1 OER4SDI Stakeholders and Requirements

To this end, we first identified the relevant stakeholder groups and described profiles of virtual personas that are considered typical representatives. In several workshops, we compiled requirements for these personas in the form of user stories, prioritized them according to the MoSCoW (*M – Must have, S – Should have, C – Could have, W – Won't have*) scheme[3] and grouped them into epics. Acceptance criteria were defined for the user stories, clarifying how we want to consider the requirements in the OER implementations. Project workshops and open discussion formats in courses were used as input for the analysis, as a systematic survey using statistical methods was neither needed nor possible within the project.

The following stakeholder groups were identified: a) SDI students attending courses on SDI-related topics and using OERs as a supplement to classroom activities, b) SDI practitioners, e.g. employees of companies, research institutes or public authorities who want to deepen their SDI knowledge on selected topics, c) SDI teachers and trainers who offer courses on SDIs and are interested in reusing and adapting OERs, and d) OER clearinghouses such as ORCA.nrw who are interested in supporting OEP and facilitating access to high-quality OER offerings.

We discussed the use of OERs with 1–2 external individuals representing each of the groups to complement the experience within the project team, where all groups (except group d) are represented. The requirements that emerged clearly from this analysis and were assigned a high priority in the further course of the project are highlighted below:

[3] See https://www.agilebusiness.org/dsdm-project-framework/moscow-prioririsation.html.

(a) SDI student requirements

Students are increasingly supplementing the teaching materials provided in SDI courses with information from web-available resources such as tutorials, videos, blogs, community platforms or AI-supported text generators. In addition, the subject of "SDI" itself is embedded in the web and many courses will have continued in hybrid formats after the COVID-19 pandemic. The web and virtual space have become the classroom and the bar for the quality of SDI-related OER is already high. In light of these developments, a key requirement is the effectiveness of teaching materials, which is closely linked to the two criteria of "relevance", i.e. the immediate usefulness of the knowledge that can be acquired, and "time to knowledge", i.e. the time required to apply the learning material. A key advantage that students see in OER is the ability to control the intensity and timing of the learning activity themselves.

A frequently mentioned demand regarding the design of OER materials is that they should focus on clearly defined learning objectives and be easy to consume. The materials should not only present learning content, but also enable active practical engagement with the subject matter. The benefits and effort required to use the material should already be assessable from the material description (metadata). The students of the aforementioned courses expressed the wish that the materials should not replace interaction with teachers and other students in the (virtual) classroom, but rather supplement it.

b) Requirements of SDI teachers

For SDI teachers, the reusability of existing learning materials is particularly important, i.e. easy retrieval, accessibility, interoperability with existing technical infrastructures and efficiency. As far as the content of the learning materials is concerned, teachers primarily want the modules to be easy to embed in their SDI course context. The learning materials should not be too extensive and should be as free from dependencies on other learning materials as possible. There should be no legal or technical obstacles to their integration and use. It is explicitly requested that not only the learning modules as a whole, but also parts of them, such as images, diagrams, or individual chapters, are easily reusable and adaptable. If the naming of authors is desired for further use by third parties, they should be easily identifiable and citable.

c) Requirements of SDI practitioners

SDI practitioners are generally not interested in disassembling OER modules and reusing them in parts, but in using them very efficiently when spending their time on it at work or in their free time. The examples used in the learning materials should be closely related to practice so that the acquired knowledge can be easily transferred to the work context. The materials should be easy to find and

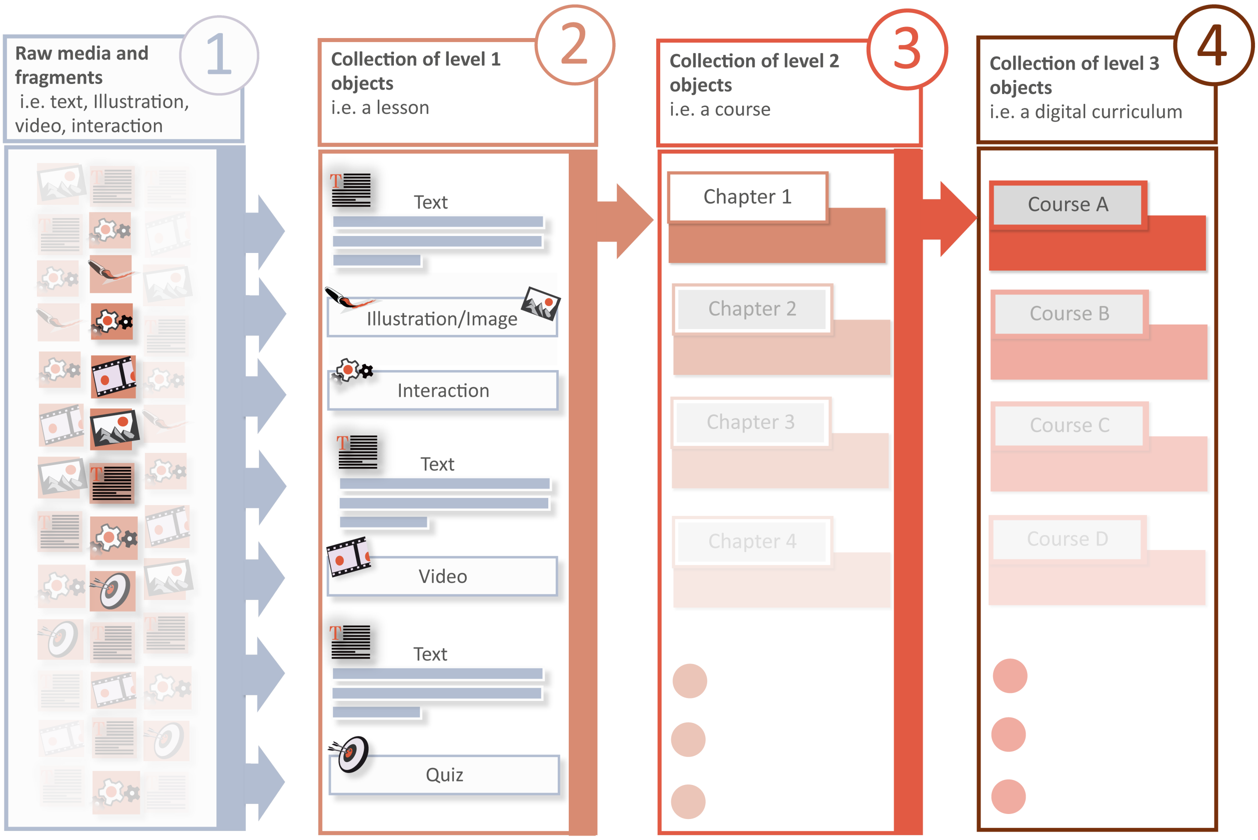

Figure 1. Aggregation levels of eLearning objects, based on IEEE 1484.12.1-2020.

simple to use so that the time required to acquire knowledge is minimal. The granularity of OER materials should be such that the use of individual OER materials takes around 10-30 minutes, but a maximum of 60-90 minutes, so that the materials can be used selectively according to their learning needs.

d) Requirements of the OER clearinghouses

For OER clearinghouses such as ORCA.nrw, it is also important that the materials meet the requirements of the users and thus offer high potential benefit to their user community. The materials should be professionally designed, easily accessible and integrable into existing learning management systems (LMS) such as MOODLE, ILIAS, or OpenEdX. They should be published under an open license and must not infringe any third-party rights. The OER should be usable and modifiable for later use without the need to pay for commercial software licenses. When publishing the OER, a complete metadata record should be created in accordance with the standards defined by the clearinghouse. The OER should have been tested and evaluated in practical use before publication.

3.2 Basic strategies and design decisions

Some of the above requirements are already served through OER by definition, such as openness and support for the FAIR principles. Other characteristics appear to be more specific, such as the requirements for the granularity of the OER or the support of technical experiments. In fact, we were able to derive a number of insights, strategies and design decisions for OER4SDI from the requirements analysis. A key finding from this analysis was that it is not the OER materials themselves, but the development and use of OEPs that are the main focus of interest for teachers and learners, in which the OER materials have a firm place. This led to three strategies and several project-specific design decisions for the implementation of OER in the OER4SDI project:

1. *Support cooperation between developers and users of OER materials*. The OER4SDI learning materials shall be developed and improved in an open collaboration process, similar to open source software or open data projects. The materials used in the OER will be made freely available in a versioning system such as Git, facilitating contributions and replications as well as communication and feedback between developers and users. Where technical experiments and tasks are part of the OER, these will be provided in

a portable runtime environment (e.g., a Docker container) for independent adaptation and use.

2. *Support blended learning*. The OER4SDI learning materials are designed in such a way that they do not replace social interaction in the (virtual) classroom, but can be integrated into courses as plug-ins. As a rule, they contain a summarized explanation of a knowledge context, supplemented by technical experiments and practical tasks that implement the principles of active learning and promoting problem-solving skills.

3. *Support self-paced learning*. The OER4SDI learning materials are designed to be usable both in the context of courses and beyond organized teaching. The learning effort is usually less than one hour. The OERs each deal with a topic conclusively without strong dependencies to other OERs. In terms of content, the materials are designed in such a way that they can be used by students with different levels of prior knowledge, for example to catch up on the group's level of knowledge or for more advanced participants to delve deeper into individual topics.

The requirements analysis was an important work step that made it possible to develop project-specific strategies and design principles and to leverage significant synergy potential within the project consortium.

4 Collaborative Development and Maintenance

Existing OERs for higher education are often conceptualized as whole courses, as this is typically their origin: The materials were developed for a university course, an online self-training course, or a tutorial-style workshop which has been planned according to a learning progression where subsequent units build upon subjects covered earlier in the course. In many cases, publishing the materials as OERs was an afterthought. This phenomenon is not exclusive to OERs on SDI, but can also be witnessed in many other domains. This is notable because it hampers the reusability of resources for the – very common – case that someone else wants to use resources outside of the context of the course they have been developed for. Examples include the slide deck of a whole 90-minute lecture as well as individual exercises or examples and even atomic elements such as individual figures. Such resources are often difficult to interpret outside of their original context and can be difficult to extract, e.g. when figures are wrapped in PDF files or an example is only available as part of a video lecture.

In OER4SDI, we therefore strive to make our resources as modular as possible and provide all parts as individual files in open formats. This not only requires careful planning of an OER, it also requires a technical infrastructure that supports this modularity, particularly when considering that the OERs are developed collaboratively in a team and should be easy to revise. We have chosen GitHub as a collaborative development platform for this purpose,[4] as it fulfills our functional requirements. A template repository built around a storyboard as a starting point ensures a certain level of standardization regarding the structure of a repository; however, the individual OERs deviate from this structure whenever the context requires it.

Besides Git as a versioning and collaboration tool, we make heavy use of other open languages and formats such as Markdown or the HTML- and JavaScript based H5P[5] containers for interactive materials. H5P is supported by all major LMS, so that these materials can also be imported into such a system in one go, while the individual parts (images, videos, quizzes, etc.) can still easily be extracted, as they are contained as separate files.

Openness also plays an important role when it comes to any software tools covered in the content of the OERs and particularly in any hands-on exercises. We use Free and Open Source Software (FOSS) whenever possible to enable any learner to follow those exercises, regardless of the availability of commercial software licenses. This includes typical tools widely used in the GIScience community – Geographic Information Systems (GIS) such as QGIS, spatially enabled database management systems such as PostGIS, but also GeoServer and Docker for more complex setups. The need to use Docker – and also introduce it with its own OER module – was recognized early in the project when a module on data steaming was developed. This module is based on a relatively complex software setup and asking learners to set up the required software would already have taken longer than the targeted time frame for the whole module, so that we quickly came to the conclusion that we need to provide the software setup in a way so that anyone, independent of their operating system, can just download the setup and have a running system for this module. Again, this is only possible because of the focus on FOSS tools.

5 Example OERs

This section will delve into the detailed description of three modules that have been developed in the context of the project, but which rely on different elements to most effectively convey the learning material. This exploration aims to provide an overview of the different characteristics of these OERs, highlighting variations based on factors such as target audience, study program, mode of delivery (face-to-face vs. online) and other relevant considerations. The selection discussed here deals with a range of different aspects of SDIs: the AAA Data Model (Section 5.1) introduces students to the data models used in German SDIs; OGC API Features (Section 5.2) deals with a new standard for accessing vector data; and the OER on Knowl-

[4]See https://github.com/oer4sdi for the project organisation on GitHub.

[5]See https://h5p.org.

edge Graphs (Section 5.3) covers approaches to proivde semantic data descriptions in SDIs.

5.1 AAA Data Model

The “AAA data model” provided by the state offices of surveying in Germany is pivotal for students of SDI in Germany, as it offers a direct insight into the country’s approach to geospatial data management. Understanding how to handle it is crucial for effectively engaging with Germany’s national spatial data infrastructure, which is integral to various applications ranging from urban planning to environmental management. Familiarity with the AAA (AFIS, ATKIS, ALKIS – the national information systems for survery markers, topographic-cartographic data, and the cadastre, respectively) systems enables students to appreciate the nuances of high-quality, standardized geospatial data collection, maintenance, and dissemination. Such expertise is invaluable in a landscape where accurate and accessible geospatial information is key to informed decision-making and efficient public service delivery. Moreover, this understanding fosters skills in interoperability and data integration in web or desktop GIS applications.

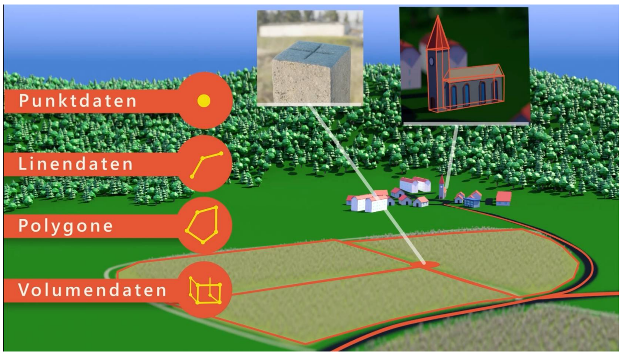

Figure 2. Screenshot from the explainer video “Introduction to the AAA Data Catalog” serving as an entrypoint to the course’.

The course materials[6] are primarily created with a focus on future dissemination. While the three videos comprising the course are interconnected, they are also designed to function as standalone learning resources. This is particularly true for the explainer video (see Figure 2), which is versatile enough to be utilized in various educational settings involving the use of basic geospatial data.

In a concise online course available on Moodle and the ORCA platforms, students are taught how to navigate the AAA catalogue in three succinct chapters. The course begins with an introductory explainer video, designed for learners with no previous background in the subject. This is followed by a practical lesson presented as a screencast, where students are guided through various techniques to access data in QGIS. The final chapter, also in screencast format, offers a hands-on application of the AAA Data. Here, students engage in a real-world spatial problem, learning to apply the data effectively for problem-solving. Following each chapter, a brief quiz is included to assist students in evaluating their understanding and knowledge acquisition.

[6]See https://github.com/oer4sdi/OER_AAA

5.2 OGC API Features

OGC API Features (OAPIF; Portele et al., 2019) is a specification developed by the Open Geospatial Consortium (OGC) for RESTful data services that support access to feature data. OAPIF is part of a series of specifications that take up the Spatial Data on the Web Best Practices defined by the W3C and OGC in 2017 (van den Brink et al., 2019). These include, for example, the use of URIs to identify and provide resources, the support of HTML and JSON encodings and the provision of lightweight "convenience APIs". It is expected that many implementations of classic OGC web services such as the Web Feature Service (WFS), Web Map Service (WMS) or Web Coverage Services (WCS) will be replaced by APIs of the new generation in the near future. However, both types of interfaces will continue to be relevant in SDI teaching for some years to come.

By using the OER, users should learn how to access these types of web services via browsers, via integrated software and via programming languages (here: Python and OWSlib; Gillies et al., 2018–2023). It should be recognized as an advantage of the OGC API interface series that the HTML representation of resources in service instances of this type allows people easy access to the content of the service. And it should be recognized as an advantage of standardization that any client system that implements the service interface can connect to the service instance in plug-and-play mode.

After downloading and installing the learning material, the main learning activities consist of reading a short textual summary of the concept of OGC API features, practicing workflows for accessing OGC API features via browsers, QGIS and Python, experimenting with the interface and solving simple tasks. The simple tasks are both a means of activating learning and an opportunity for formative self-assessment. Users receive immediate feedback on the success of their efforts to find a solution to the predefined tasks. In a course context, the learning material can be embedded in a more comprehensive theoretical discussion of API styles. The summary of the technical background provided in the learning material then only serves as a repetition. The hands-on experience with the technology supports students and SDI practitioners in deepening their knowledge on the subject matter.

The OER consists of a tutorial that is available both as an interactive H5P package and as a PDF file. The H5P package can be used directly in an LMS or independently on the desktop via the free LUMI software. The tutorial contains instructions for installing the technical components of the learning material, which are made available via the GitHub repository of the OER.[7]

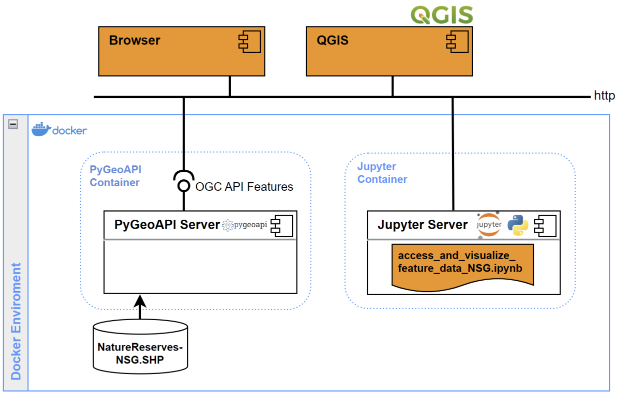

Figure 3. OAPIF OER – Docker configuration with PyGeoAPI and Jupyter Servers.

The repository can be cloned or downloaded as a zip file. It contains Docker files to create two Docker containers for a pyGeoAPI (pygeoapi development team, 2019–2024) server and a Jupyter server as well as data volumes with prepared datasets and a Python notebook (see Figure 3). A simple docker-compose command in a terminal downloads the software packages, builds the containers and executes them. The OGC-API service is then accessible via localhost both to the browser and to the Python notebook. All of the OER materials can be reused under the terms of open licenses.

5.3 Knowledge Graphs

In a dynamic data landscape, the intersection of knowledge graphs, the semantic web and linked data is emerging as a key paradigm that contributes to improved interoperability and knowledge representation. Knowledge graphs provide a structured framework for organizing and connecting information (Auer et al., 2014). The OER[8] provides a comprehensive insight into the field of Knowledge Graphs, as well as the concepts of the semantic web and linked data in the context of geospatial infrastructures and explores the symbiotic relationship between them (Shadbolt et al., 2006; Bizer et al., 2011). Users of the learning module gain an understanding of the concepts conveyed and get to grips with the technical implementation in practice. The module serves as an introduction to the topic and is intended to encourage users to delve deeper into the subject themselves through a high degree of interactivity. An optional quiz has been integrated to check the level of learning, which is intended as a motivating self-assessment and can be repeated as often as required (see Figure 4 for an example). In teaching, the OER can either be offered as a whole to supplement a course in order to deepen the knowledge acquired, or individual components can be integrated into the course as interactive elements.

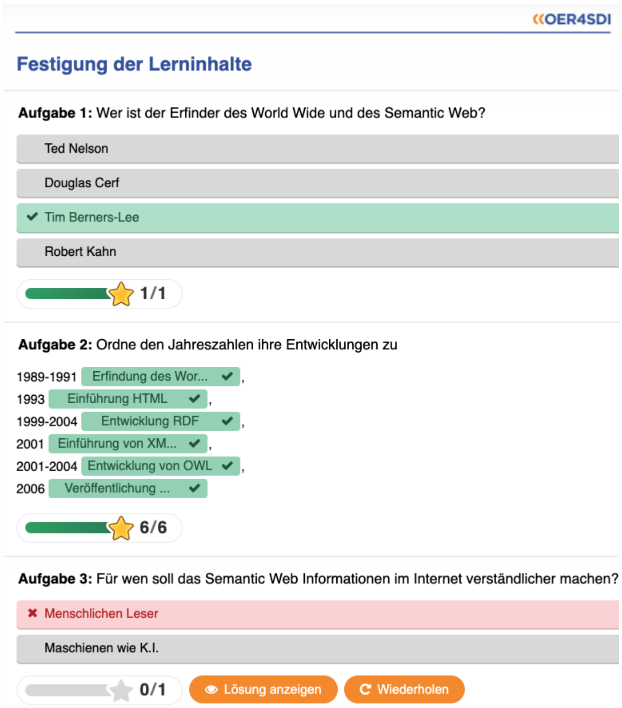

Figure 4. Example of a self assessment quiz embedded in an H5P module.

The OER is created as an H5P interactive book and is divided into several sections via chapters. The content is first summarized with a few key points in the "Overview" chapter. In addition, the metadata and a didactic and technical commentary are provided as text hidden behind an accordion function. In a brief introduction, an interactive timeline is used to summarize the historical development of the technology. Particularly relevant developments are highlighted through keyframes and explained in more detail in short texts. In the three sections on in-depth content, a comprehensive overview of the central concepts of knowledge graphs, semantic web and linked data is provided, with a focus on their applications in the field of SDI. The existing texts are particularly loosened up by the use of short sections and by highlighted examples, or by videos. The main part of the OER consists of exercises and guides, leading learners through two practical applications in a screencast format. The first exercise deals with the creation of ontologies using the web tool "WebVOWL" (Lohmann et al., 2015). The video provides detailed instructions on how to use WebVOWL, explains the main concepts of the Web Ontology Language and guides learners to create their own ontologies. The second exercise is dedicated to applying SPARQL queries to the WikiData semantic database. The accompanying video explains the Wikidata platform (Vrandečić and Krötzsch, 2014) and the structure of SPARQL queries, by guiding the learners through sample SPARQL queries. An optional quiz follows to consolidate the learning content concludes the active part of the

[7]See https://github.com/oer4sdi/OER-DataAccessVia-OGC-API-Features

[8]See https://github.com/oer4sdi/OER-KnowledgeGraph.

OER and tests the knowledge acquired on a cross-section of the content taught. Interactive multiple choice and drag-the-word questions are asked, which provide direct feedback by displaying star ratings. The summary highlights key points of the OER, provides recommendations for further learning resources and lead to a feedback form, inviting learners to participate in improving the materials via GitHub.

6 Evaluation

The ongoing evaluation focuses on the question of how learners and teachers experience the OER4SDI teaching materials. Currently, 12 learning modules are under development, most of them containing additional elements such as videos or notebooks that can also be used as stand-alone learning materials. Six of these modules are in the beta release stage. Two first learning videos were published a few weeks ago on ORCA.nrw[9]. The completion and publication of further modules is planned for the first half of 2024.

Due to the early stage of development, a broader systematic evaluation of the results is still pending. In particular, there is still no empirical data on the use of the modules by learners or teachers outside of the project partners' teaching activities. However, individual modules, or parts thereof, have been used in SDI courses and feedback has been gained from students, which is now being used to optimize the modules. A total of three learning materials (with several components) were tested in four SDI-related courses. Between 20 and 30 students took part in each of the courses. At Bochum University of Applied Sciences, feedback was obtained by asking additional questions during the general teaching evaluation of the course. The results were discussed with the students. At Ruhr University Bochum and the University of Münster, specific questionnaires with predominantly open questions were used to obtain concrete information on problems or potential improvements.

The overall feedback from the students was very positive in all tests. In particular, the practical relevance of the materials and being supported in actively engaging with the technical aspects of the teaching topic were emphasized very positively in the feedback: What did you like best? Answer: "The combination of explanatory videos, self-tests and practical exercises". There were also valuable comments on weaknesses and areas for improvement, e.g. the provision of additional help at certain points in the learning material or the suggestion to make it clearer how the use of the learning material contributes to the preparation for the final examination of the course.

Six lecturers at the partner universities are involved in the implementation of the OER4SDI teaching modules, who also rate their previous experiences with the development and use of OER modules very positively. In particular, it is emphasized that the collaboration on creating OER has led to a very valuable exchange of experience, in which all participants benefit from the skills and creativity of their colleagues and support each other with suggestions and feedback.

At the same time, it can be observed that despite the common overarching theme of SDI, the requirements for the design of the OER modules differ significantly between the three partners, e.g. in terms of language, focus of the topic, level of abstraction to be selected, etc.. This indicates once again that the subsequent use of OER in teaching situations other than those for which they were developed will typically focus on individual components or require more extensive adaptations. The reason for this is that only in rare cases teachers will be willing and able to adapt their specific requirements and teaching concepts to existing teaching materials. It is therefore extremely important to make all components of the teaching material accessible and modifiable and to reach as many potential users of a learning material as possible (learners and teachers) through the effective publication of OER.

7 Discussion and Conclusions

Throughout the development of this project, we have been in a constant exchange with the community involved in SDI education and led many fruitful discussions. One such discussion was held at the AGILE 2023 workshop on *Geospatial Education 5.0: New Paradigms for Geospatial Training and Education* in Delft, where several common concerns about the publication and use of OERs were raised. Workshop participants mentioned that many educators do not want to share their teaching resources because they think the materials are "not in shape" for publication and would need too much additional work to bring them to a publishable state. This situation is currently being addressed by several initiatives, such as at the OERContent.nrw program that has funded this work; micro funds for "polishing" existing educational materials for publication[10]; or efforts at EU level that specifically target the production of open materials for capacity building, e.g., in the projects targeting FAIR and open research on the European Open Science Cloud.[11]

Another common concern is that materials are not self-explanatory, as many educators develop their slides to illustrate their lectures and they do not want their materials to be used out of context. While this can potentially be fixed and supported by funding instruments such as the ones mentioned above, other materials cannot be shared publicly in full because they consist of lab exercises that students need to complete. Sharing them in a public repository with the corresponding solution would indeed render

[9] See https://orca.nrw

[10] See https://nfdi4earth.de/?view=article&id=375&catid=15, for example.

[11] See https://aquainfra.eu/work-packages/community-engagement-and-capacity-building, for example.

the exercise useless, as students would certainly find the solution in the repository as soon as it is indexed by search engines. Solving this dilemma would require a user management for the repository where only authorized users identified as teaching staff would be allowed to access the solutions. We are not aware of any repository that offers such functionality at this point.

Regarding the technical setup we have chosen for OER4SDI, it has to be noted that a platform such as GitHub – which most of the OER4SDI team members were already familiar with from their software development projects – can have a steep learning curve, particularly for teachers who do not come from a technical background. Such platforms are therefore most likely not a generic solution for OER development. The editing tools within LMS are more user friendly, but strongly linked to the corresponding platform and not ideally suited for open, cross-platform development. Collaborative development is particularly challenging on those platforms.

Finally, metadata and an explicitly open license are requirements for retrieval and safe reuse. Concerning the license, OER4SDI uses a CC-BY-SA 4.0 Creative Commons license that ensures that materials can be reused without restrictions, as long as credit to the original author is given and derivative materials are shared under the same license. Regarding retrieval, it is important that materials are provided in a way that permits indexing by search engines, so that they can also be found without going through the portal or repository where they are hosted. To ensure this, we have created a small metadata profile[12] that is compatible with schema.org and emerging standards such as the Learning Resource Metadata Initiative (LRMI; Barker and Campbell, 2015).

As the discussion in this final section shows, the development of good OERs still comes with various challenges. Having said that, new developments regarding the platforms, formats, standards, metadata, funding, and – most importantly – an increasing openness to sharing their materials on the teachers' side are slowly increasing the popularity of OERs in our field. In this spirit, we will close this article with a suggestion for 5 ★OERs, an adaptation of Tim Berners-Lee's 5 ★Open Data (Berners-Lee, 2015):

★make your educational resource available on the Web (whatever format) under an open license
★★make it available in an editable format (e.g., PowerPoint instead of a video of your slides)
★★★make it available in a non-proprietary open format (e.g., HTML instead of PowerPoint)
★★★★link it to prerequisites, learning outcomes, metadata, and other OERs
★★★★★enable collaborative and continuous development of the resource (e.g., use Git instead of a plain download).

[12] See https://github.com/oer4sdi/Metadata-Model.

Data and Software Availability

The developed Open Educational Resources, including the data and code used in the provided examples and exercises, are published under a permissive CC-BY-SA 4.0 license and available at https://github.com/oer4sdi/ and on the companion website https://oer4sdi.github.io/.

Acknowledgments

OER4SDI – Open Educational Resources for Spatial Data Infrastructures is supported by the Ministry of Culture and Science of North Rhine-Westphalia through the OER-Content.nrw program under grant agreement no. 214-76.01.08-25-1824.

References

Auer, S., Ngomo, A.-C., Lehmann, J., and Zaveri, A.: Introduction to linked data and its lifecycle on the web, Reasoning Web. Reasoning on the Web in the Big Data Era: 10th International Summer School 2014, Athens, Greece, September 8-13, 2014. Proceedings 10, pp. 1–99, 2014.

Barker, P. and Campbell, L. M.: LRMI, Learning resource metadata on the web, in: Proceedings of the 24th International Conference on World Wide Web, pp. 687–687, 2015.

Belikov, O. and Bodily, R.: Incentives and barriers to OER adoption: A qualitative analysis of faculty perceptions, Open praxis, 8, 235–246, 2016.

Berners-Lee, T.: 5 Star Open Data, https://5stardata.info/, 2015.

Bill, R., Lorenzen-Zabel, A., and Hinz, M.: Offene Daten für Lehre und Forschung in raumbezogenen Studiengängen–OpenGeoEdu, gis. Science, 1, 32–44, 2018.

Bizer, C., Heath, T., and Berners-Lee, T.: Linked data: The story so far, in: Semantic services, interoperability and web applications: emerging concepts, pp. 205–227, IGI global, 2011.

Camilleri, A., Ehlers, U., and Pawlowski, J.: IState of the Art Review of Quality Issues Related to Open Educational Resources (OER), Publications Office of the European Union, on-line access: https://publications.jrc.ec.europa.eu/repository/handle/JRC88304, 2014.

Donker, F., van Loenen, B., Keßler, C., Küppers, N., Panek, M., Mansourian, A., Zhao, P., Vancauwenberghe, G., Tomić, H., and Kević, K.: Showcase of Active Learning and Teaching Practices in Spatial Data Infrastructure (SDI) Education, in: 25th AGILE Conference on Geographic Information Science "Artificial Intelligence in the service of Geospatial Technologies", Association of Geographic Information Laboratories for Europe (AGILE), 2022.

Ehlers, U.-D.: Extending the territory: From open educational resources to open educational practices, Journal of open, flexible and distance learning, 15, 1–10, 2011.

Geographical Information Systems International Group: Geospatial Knowledge Base (GKB) Training Platform, https://www.geo-train.eu, [Online; accessed 20-Dec-2023], 2020.

Gillies, S., Anguenot, J., Lautaportti, K., Lowe, D., Walsh, J., Kralidis, T., Cepicky, J., Cinquini, L., Hards, B., Ledermann, C., Cowan, S., Wilcox, K., and Tzotsos, A.: OWSLib: OGC Open Web Services (OGC OWS) client-side implementation using Python programming language., https://www.osgeo.org/projects/owslib/, 2018–2023.

Goldberg, C.: Auditing classes at M.I.T., on the web and free., http://web.mit.edu/ocwcom/MITOCW/Media/NYTimes_040301_MITOCW.pdf, [online; Accessed 20-Dec-2023], 2001.

Hilton, J.: Open educational resources and college textbook choices: a review of research on efficacy and perceptions, Educational Technology Research and Development, pp. 573–590, https://doi.org/10.1007/s11423-016-9434-9, 2016.

Hodam, H., Rienow, A., and Jürgens, C.: Bringing earth observation to schools with digital integrated learning environments, Remote Sensing, 12, 345, 2020.

Hodam, H., Rienow, A., and Jürgens, C.: Creating and testing explainer videos for earth observation, Remote Sensing, 13, 4178, 2021.

IEEE: Standard for Learning Object Metadata, IEEE Std 1484.12.1-2020, pp. 1–50, https://doi.org/10.1109/IEEESTD.2020.9262118, 2020.

Lohmann, S., Link, V., Marbach, E., and Negru, S.: WebVOWL: Web-based visualization of ontologies, in: Knowledge Engineering and Knowledge Management: EKAW 2014 Satellite Events, VISUAL, EKM1, and ARCOE-Logic, Linköping, Sweden, November 24-28, 2014. Revised Selected Papers. 19, pp. 154–158, Springer, 2015.

Mayrberger, K.: Open Educational Practices (OEP) in Higher Education, pp. 1–7, Springer Singapore, Singapore, https://doi.org/10.1007/978-981-287-532-7_710-3, 2020.

Menzli, L., Smirani, L., Boulahia, J., and Hadjouni, M.: Investigation of open educational resources adoption in higher education using Rogers' diffusion of innovation theory, Heliyon, 8, 2022.

Portele, C., Vretanos, P., and Heazel, C.: OGC API Features—Part 1: Core, Open Geospatial Consortium Inc., Wayland, MA, USA, OpenGIS® Implementation Specification OGC, 2019.

pygeoapi development team: pygeoapi, https://pygeoapi.io, 2019–2024.

Shadbolt, N., Berners-Lee, T., and Hall, W.: The semantic web revisited, IEEE intelligent systems, 21, 96–101, 2006.

smeSpire Consortium: smeSpire Training Platform, http://www.smespire.eu/training/, [Online; accessed 20-Dec-2023].

Sparks, S.: Open Educational Resources (OER): Overview and Definition, Education Week, pp. 96–101, on-line access: https://www.edweek.org/teaching-learning/open-educational-resources-oer-overview-and-definition/2017/04, 2017.

UNESCO: The 2019 UNESCO Recommendation on Open Educational Resources (OER): supporting universal access to information through quality open learning materials, on-line access: https://unesdoc.unesco.org/ark:/48223/pf0000383205.locale=en, 2019.

van den Brink, L., Barnaghi, P., Tandy, J., Atemezing, G., Atkinson, R., Cochrane, B., Fathy, Y., García Castro, R., Haller, A., Harth, A., et al.: Best practices for publishing, retrieving, and using spatial data on the web, Semantic Web, 10, 95–114, 2019.

Vrandečić, D. and Krötzsch, M.: Wikidata: a free collaborative knowledgebase, Communications of the ACM, 57, 78–85, 2014.