Developing OERs for Teaching Database Systems[1]

A Two-Year Effort of Four Universities of Applied Sciences

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Abstract: In the project EILD.nrw, Open Educational Resources (OER) were developed for teaching database systems. Lecturers can use the tools and courses in a variety of learning scenarios. Students of computer science and application subjects can learn the complete lifecycle of databases. For this purpose, we developed and published quizzes, interactive tools, instructional videos, and courses for learning management systems, under a Creative Commons license. Find an overview of the developed OERs according to topic, description, teaching form, and format in this paper. Furthermore, we describe the implementation of licensing, sustainability, accessibility, contextualization, content description, and technical adaptability. The learning and teaching modules were used in ongoing classes and evaluated anonymously by students.

Keywords: database systems, open educational resources (OERs), higher education

1 Introduction

Using digital teaching and learning materials for teaching offers opportunities for design of new scenarios: *availability* anytime and anywhere, *customization*, especially with the individual speed of *reception*, automatable *review* of solutions, *traceability* of use as well as easy *reproducibility* [Ra21; RF19]. The content consists of presentations, scripts, and tasks. Activities can be forums and chats, surveys, and tests, enriched with gaming elements, all provided for learning management systems.

Overall, the EILD.nrw project developed about 80 open educational resources (OERs) for the life cycle of databases such as modelling, relational data model, SQL, and implementation

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of database management systems [EI22a; Ra22]. The project partners coming from four universities have many years of experience in teaching database systems with self-developed learning units. Every semester, about 1,000 students can acquire knowledge in supported self-study and work on practical tasks for the conception, creation, and programming of database systems.

The project was funded by the Ministry of Culture and Science (the Ministry) of the State of North Rhine-Westphalia (NRW) starting in the winter semester of 2020 as a cooperation project with the *Digitale Hochschule* of North Rhine-Westphalia (DH.NRW) The tools can be used for courses dedicated to studies in Informatics and Media, Business or Technical Informatics and applied to specific learning scenarios for blended learning. The content created in this as well as the other projects of the funding line OERContent.nrw are being made available under the CC BY-SA 4.0 license – sharing and editing with attribution and passing on under the same conditions [NN22]. Other included software and other material like logos are licensed as specified.

To our knowledge there is no recent initiative to develop such a huge amount of OERs for teaching database systems covering the main topics. We present the full scope of material and make it freely available to promote exchange in the database community and to improve teaching the database systems subject. Hence, some of the tools and courses developed in the project were presented at *LWDA'22* [Ra22].

We outline studies of OER usage of lecturers internationally, but mainly focus on German speaking countries' conditions of use for the database systems subject. We describe the requirements of OERs in general but also the requirements from the EILD.nrw project. The developed OER are listed respectively with their teaching form and their technical format. During development, we also focussed on quality assurance and compare our development with the findings published at project start [Ra21].

2 Related Work

The use and usability of OERs by lecturers were examined in many international studies with different focal points [BF21]. A study on how OERs must be designed so that lecturers can use them for the database systems subject is still pending. However, the results from existing, non-subject-specific studies already provide many clues that can be implemented for database systems related OERs. Numerous and frequently examined factors influence teachers in their decision to use an OER or not. Education, university policy and training can create the prerequisites for the use of OERs, such as such as knowledge and technical ability. [Pi16; WT17]. The nature of the OERs (content, technical, qualitative) including their metadata are crucial for findability and selection. There are solutions to improve metadata, ranging from cross-repository standardization [DD12] to subject-specific, ontology-based indexing (RJG14). Quality control and reusability are important for creation and provisioning. To ensure quality, one suggestion is to implement editorial processes [To19]. As a recent

initiative by lecturers, the *1st International Workshop on Data Systems Education* brought together case studies and experiences from the use of self-developed tools.

The usability of learning content and Open Educational Resources (OER) have been under discussion in Germany since 2000 [De16]. Slides, scripts, tasks, wikis, blogs, and video recordings are made available individually or as collections in online courses - the Massive Open Online Courses (MOOCs). Nevertheless, there is a great deal of helplessness as of how to integrate these offers into the curricula at German universities [De16].

At the 2008 autumn meeting in Düsseldorf, the German SIG Database Systems of the German Informatics Society (*GI-Fachgruppe Datenbanksysteme*) dealt with the topic "Quo Vadis: Forms of database training and further training"[Ra09]. A special issue of the journal *Datenbank-Spektrum* edited by the *GI-Fachgruppe Datenbanksysteme* was published introducing several digital and even one analog tool presented in the workshop [Ra09]. But it took a decade to address digital teaching agian prominently in the community. At a workshop of the database systems conference BTW 2019 both procedures for teaching the database systems subject – digital communication, portals, blended learning – and their handling considered from the learner's perspective were presented [RF19]. In 2021, two issues of *Datenbank-Spektrum* were dedicated to the digital lecture of database systems [STH21].

Our developments in the project EILD.nrw support the start done in 2019 by the German database community very well. We have extended our effort to make existing or newly developed tools available as OER. In our journal paper, we introduced the variables and their features for a good practical usage of OERs [Ra21]. The forms of licensing, sustainability, and accessibility, as well as the possibilities for contextualization and the content, the technical adaptability as well as compliance with data protection on platforms are the determining factors for exchanging digital content in teaching. In the project, we dedicated our efforts to make already existing or newly developed tools available as OER, and thereby fulfilling most of the requirements published.

3 Requirements for Database-related OERs

Are there any peculiarities in applying digital teaching to the database systems subject? – The use of databases is taught using descriptive SQL programming. The desired results are specified, but not the path to these results. Usually, programming is taught first with procedural or object-oriented concepts [**GI16**]. Hence, the methods in SQL seem unfamiliar and therefore require a special approach on how loops or intermediate results can be "bypassed".

In computer science, digital tools are used professionally. Teaching has long been conducted using these tools – commercial ones, open source or self-developed. But does computer science in general not involve any practical work since "everything" is possible using

computers? – Not necessarily, even if originally analogue working methods such as pair programming can be mapped to digital formats. But in application areas such as media technology with the use of photo and film cameras, as well as the green room, or in media design using sheets of paper, analogue work continues [He17; Wo19]. Nevertheless, in the EILD project we focus on the digital tools which is enough work to do.

The requirements for the exchange of OERs [Ra21] are classified with EILD specific marks (Tab 1). Decisions must be made which types to choose resp. how to fulfil them. In the project EILD.nrw, some were already set by the by the Ministry's call for proposals.

Requirement	**Types**			
Licensing	private	without license	commercial	open
Sustainability	permission to use	customizability	technical feasibility	privacy
Accessibility	style	layout	language	language level
Contextual-ization	vocational training	school	higher education	professional
Content description	knowledge	learning goals	competences	learning paths
Technical adaptability	customization	platform		

Tab. 1: Requirements for the Exchange of OERs [Ra21], EILD-specific marks are underlined (must, optional)

- **Licensing**: The licensing type was required to be Creative Commons with the variants *CC* for free at all, *CC-BY* with a mandatory credit for the original creation, and *CC-BY-SA* for the additional requirement using this licensing in case of further distribution for other versions [NN22]. In all variants, commercial use is allowed. We have chosen CC-BY-SA to be credited for our substantial work, and to encourage making changes – not only updates, as well as also language adaptations – available to the community.
- **Sustainability**: Permission to use is granted by licensing and cannot be withdrawn. Customizability and technical feasibility as required by the request are achieved by using open software and/or state of the art products. As in modular systems, the resources should be selected based on metadata and a guide for the lecturers explaining their properties. Privacy must comply with the European General Data Protection Regulation (GDPR). The given distribution platform ORCA.nrw is operated by a German institution; thus, the responsibility is on their side first [OR22]. If the OERs log privacy-related data, their usage should be described and optionally made available.

- **Accessibility**: Due to different teaching concepts synchronous digital media like interactive presentations, courses, and (programmable) tools as well as asynchronous digital media like instructional videos/ screencasts and tests are offered. Due to their intended use in basic courses first, the initial content is in German. Translating the content into other languages is intended, but as there are no funds available in the project for translation, the OER community will have to rely on voluntary work. However, for example, learning instructions for textbooks in German - which are provided in our OER courses - , can only be mapped into other language settings with a great effort.
- **Contextualization**: The OERs are provided with descriptions, learning outcomes, and metadata. Teachers notes contain the didactic concept used in introductional videos and courses, explained in terms of best practices. The funding line's purpose was to encourage the use of digital materials for universities and target the higher educational sector. A professional level is not intended to be addressed. However, vocational education and training (VET) and secondary school courses may use some of the OERs provided.
- **Technical adaptability**: Easy customization is requested by the lecturers. It can be achieved in different ways according to the teaching form of an OER – video, tutorial, software tool, course – of an OER. The ministry requests the installation of ORCA.nrw as distribution platform [OR22]. Also, the OERs must be useable for the two learning management systems ILIAS and Moodle, which are widely used in NRW.

4 EILD Educational Resources

Thematically, for database systems, the following topics are recommended [Ke15, Ku15, Fa07]: *conceptual design, relational data model, SQL programming and mapping from models, database-based application development*, and *internals of database management systems (DBMS)*. Learning modules building on those fundamentals being suitable for master's degree programs are *distributed databases*, mainly *NoSQL databases*, and *data analysis*. The learning units developed are modular. Competencies (skills) to be taught are described in the recommendations of the German Informatics Society (GI) for Informatics [**GI16**] as well as for application subjects in Business Informatics [**GI17**], Media Informatics [He17; Wo19], and Technical Computer Science [**GI18**]. The study regulations and module descriptions of specific degree programs implement such recommendations institution related.

The tools and courses can be selected and adapted to the respective requirements of the lecturers and the type of their courses based on included guides. Using the open environments HTML, JavaScript, SQLite, and Jupyter notebooks, ensures to meet these requirements. For most of the tools, you can download texts in JSON format and change them to your

own needs. Software versioning via GitHub provisioning [EI22b], inclusion of didactic descriptions and evaluation results within the courses are also available.

The learning content is currently available on the ORCA.nrw platform [OR22] and partly as a repository on GitHub as well as an executable version on GitHub Pages. You can run an OER yourself on ILIAS, Moodle, or similar platforms by uploading the files provided on the ORCA.nrw platform or in GitHub as a packed file and unpacking it within the LMS. Another option is to generate the application from the source code using the build script. The content is thus freely available and easily accessible.

The self-assessment tests provide direct feedback on what was answered correctly or incorrectly. Thus, no user-specific data is processed at any time and no dependencies on external servers are implemented. Alternatively, you can use the versions provided via GitHub Pages making changes available immediately. Note, that the GitHub servers are outside the scope of the GDPR.

Table 2 shows an aggregation of OERs we have developed. In each case, the *topic*, a *description* of the content, the *form* of material, and the available *formats* are indicated.

Topic	**Description**	**Form**	**Format**
Overlapping Concepts	1300 questions with solution hints	Multiple choice test	JavaScript Pages
			SQL Database
	Generation of crossword puzzles from 200 items	Interactive tool	JavaScript Pages
	Tutorial for the three-layer architecture	Instructional video	Video with subtitles
Conceptual Design	Modelling ER diagrams	Instructional video	Video with subtitles
		Interactive tool	JavaScript Pages
	Modelling UML class diagrams	Interactive presentation	H5P
			SCORM
Relational Data Model	Introduction to the relational data model and the normalization of relations	Instructional videos	Video with subtitles
		Interactive course	Moodle Course
		Interactive tool	JavaScript Pages
SQL Programming and Mapping from Models	SQL querying and creating databases	Interactive programmable tool	JavaScript Pages
			SQLite DBMS
	Practicing triggers, functions, and procedures in PL/SQL	Interactive programmable tool	SQL DBMS - Oracle® application

Tab 2, part 1: Overview of the Developed OERs

Topic	Description	Form	Format
	Use of Oracle SQLcl® [La21]	Instructional screencast	Video with subtitles
	Use of Oracle SQL Developer® for PL/SQL	Instructional screencast	Video with subtitles
	Mapping the ER-Model or UML-classes to SQL	Interactive presentations	JavaScript Pages
	Optimising databases	Interactive presentation	Video with subtitles
Applications	Object-relational mapping	Instructional videos	Video with subtitles
		Interactive presentation	H5P
			ILIAS module
			SCORM
Internals	The five-layer DBMS architecture	Instructional video	SCORM
	Introduction to transaction management	Instructional videos	Video with subtitles
	Exercises to synchronize transactions	Interactive tool	JavaScript Pages
	Creation of a B-tree index	Interactive tools	JavaScript Pages
Distributed Systems	Introduction to NoSQL databases	Instructional videos	Video with subtitles
	Distributed querying	Interactive course	Video with subtitles
	MongoDB	Interactive programmable tool	Jupyter Notebook
Data Analytics	Programming Apache SPARK with Python	Interactive programmable tool	Jupyter Notebook
	Text analyses	Interactive programmable tool	Jupyter Notebook
	Image analyses	Interactive programmable tool	Jupyter Notebook

Tab 2, part 2: Overview of the Developed OERs

5 Quality Assurance

All new and further developed tools were presented and discussed in regular meetings including all project members such as professors, scientific and student staff. Demonstrations take place once per quarter. After the presentation of the innovations, the used contents and concepts are discussed professionally for improvement and review. The discussion was complemented by the exchange about didactic concept, technical implementation, usability, and the need for actual use in teaching - with the associated difficulties.

The learning and teaching modules were used in ongoing classes and evaluated anonymously by students [**RF21**]. A mixture of quantitative and qualitative surveys has proven to be helpful. The evaluation results were documented in the learning units to provide students and lecturers with an aid for selection.

While the quantitative information only records the valuation by the students, specific suggestions and reasons for the valuation could be given in the free text. The free-text option was well received by the students, and the suggestions made for improvement could be evaluated in combination with the scaled answers and integrated into the modules accordingly. For example, the "*Podcast: Introduction to SQLcl from Oracle*"was rated as helpful according to quantitative questioning. In addition, criticism of the visibility of individual elements in some web browsers was also expressed in the free text. The screencast was therefore revised according to accessibility guidelines and the problem was solved with improved browser compatibility.

Students also wanted more helpful tips beyond the DBMS's error messages. For this purpose, all faulty SQL statements were logged and compared with the stored sample solution [FBS20]. Suggestions from student were not only related to the course content itself, but also to its integration into teaching [**RF21**]. There was also a desire to improve the instructions for using the tools, as well as suggestions for structuring the course.

In most cases, the peer discussions as well as student feedback have led to specific improvements in OER and will be continued.

6 Conclusions

With our developments in the project, we could verify our findings published at the beginning of the project in Datenbank-Spektrum [Ra21]: (1) *a mix of synchronous and asynchronous digital media*, (2) a *sustainable licensing*, (3) a clear *didactic concept*, (4) a low-threshold *student participation* (through reporting, voting, anonymous questionnaires, suggestion boxes, breakout, and question sessions, etc.), (5) the agreement *among the lecturers* of a degree program to limit the variety of tools and methods, and (6) the *use of interactive tools*.

We believe, there is not just one concept for successful teaching, but rather an interaction of several influencing factors will decide on the success. The EILD.nrw project has made a significant contribution to these finding.

Focusing on teaching as well as on the successful learning process allows a different view on the integration of OERs, which in this scenario serves to improve teaching [BF21]. More purposeful than the question of how teachers use or can use OER is the following question: How can OERs enhance teaching as well as the learning process? And what do teachers need for this?

In many projects we have developed predecessors of these OERs. We would like to thank the students who helped us to improve the content through their questions in lectures and practical courses. The students of our degree programs in the semesters starting in the winter semester 2020 up to the summer semester 2022 took thankfully part in the quality assurance surveys. Especially, we would like to thank the students who made the results of their student research work available to us: *Anne Giesen, Arabella Jackszis, Frederic Cieslik, Jonas Baur* and *Monika Joussen*. Together with the authors of this article, *Alexander Kosmehl, Björn Salgert, Christian Schindler* and *Melanie Beutel* worked on the EILD.nrw project. Our heartfelt thanks go to them all.

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