

A Modular and Community-Driven FAIR Teaching and Training Handbook for Higher Education Institutions

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Abstract

The FAIR principles have had a transformative effect on research data management. Based on this, there is a growing need to increase awareness, understanding and adoption of this topic in higher education at all levels and to provide guidance on how to teach it in bachelor's, master's and doctoral degree programmes. This article discusses a collaborative, co-creative approach to construct a body of knowledge and a set of tools addressing this gap, that have been summarised in a teaching and training handbook. We outline how the handbook was written using a large community of volunteers working together remotely. We then discuss the overall content of the handbook, including lesson plans, guidance on how to develop appropriate lessons, a detailed overview of FAIR-related competencies and learning outcomes, and guidelines on how to implement FAIR within an institution. Finally, we discuss the uptake of the handbook, and examples of how the handbook has or could be used in a variety of different training settings.

Keywords: FAIR principles; research data management; teaching; training; higher education institutions

1. Introduction

Since the release of the FAIR data principles (Wilkinson et al., 2016), libraries have assumed a wide range of roles in their implementation ranging from

promoting the FAIR principles, incorporating them into data management plans and institutional policies, and evaluating and enhancing data repository infrastructures, to the development of workshops and courses targeting students, researchers and staff (e.g. LIBER Research Data Management Working Group, 2020; Martinez et al., 2019; Rocca-Serra et al., 2022). The FAIR principles spell out four core goals when it comes to the management and sharing of research data: making data findable, accessible, interoperable and reusable (FAIR). Higher education institutions across Europe and in other parts of the world recognise that good data management is key in an era of collaborative science which – in an ideal world – should be as open as possible (and closed when necessary), trusted and digitally enabled. This requires that research outputs should be made FAIR and related data services should be made available and interoperable with wider ecosystems, e.g. via the European Open Science Cloud (European Commission Expert Group on FAIR Data, 2018). However, to fully reach the potential of these developments, a key challenge is to create and roll out teaching and training programmes at the institutional level. Although awareness of the FAIR principles among researchers has been on the rise, there are still many doubts as they may have heard of the term but are still not familiar with the details of FAIR’s implementation (Goodey, 2022). This gap might be best addressed at various stages in teaching and training but also in the context of research processes and policies.

In spite of universities and other research institutions having developed a wide range of training materials on research data management (RDM), a landscape survey undertaken in 2019 (Stoy et al., 2020) indicated that there is a need to raise the coverage of RDM- and FAIR-related topics in higher education at all levels. This is accompanied by a lack of guidelines and lesson plans for universities to integrate RDM and FAIR-related content and exercises into bachelor’s, master’s and doctoral degree programmes.

2. Methodology

2.1. Background

The handbook “How to be FAIR with your data” was developed in the context of the EU-funded project Fostering FAIR Data Practices in Europe

(FAIRsFAIR),¹ which ran between March 2019 and February 2022. The project aimed to develop and supply practical solutions to support the implementation and use of the FAIR data principles throughout the research data life-cycle. In particular, the handbook resulted from the efforts of FAIRsFAIR in fostering the uptake of FAIR data skills in higher education institutions. To this end, a body of knowledge was constructed which was specifically tailored to the context and needs of university teaching and translated into a set of tools that higher education staff can use to put teaching and training on FAIR into practice.

Work started in 2019 with a landscape analysis of the state of play of FAIR data education in Europe (Stoy et al., 2020) and desk research of resources and initiatives addressing FAIR data teaching and training (Principe et al., 2020). The definition of the FAIR Competence Framework for Higher Education – Data Stewardship Professional Framework (Demchenko et al., 2021) and its corresponding Body of Knowledge was the foundation of this handbook and provided the basis for the creation of the competence profiles. This work re-used methodology and core definitions of competences and knowledge areas/units provided in the EDISON Data Science Framework (EDSF) (EDISON Community, 2022). The handbook was complemented by a good practice report, highlighting case studies of successful implementation of FAIR data teaching and training in higher education institutions (Garbuglia et al., 2021).

The analysis and results presented in those documents provided a reference point for the development of the handbook as a practical tool for universities and their staff. Understanding more about the landscape of FAIR data education and the expectations of universities ensured that the handbook would be designed to address several challenges encountered by the universities surveyed in the project. These challenges included the lack of FAIR skills and training at the institutional level, the lack of awareness among students, researchers and university leadership, and the need for practical guidance on how to apply the FAIR data principles in different domains and disciplines (Stoy et al., 2020). Furthermore, the handbook represents an implementable translation of the FAIR Competence Framework for Higher Education, offering ready-to-use materials for institutions interested in creating new, dedicated courses, or in integrating FAIR data teaching and training into existing programmes.

While the scope of the activities during the FAIRsFAIR project mainly addressed FAIR data skills and training at the bachelor, master and doctoral levels, the resulting handbook also provides resources for upskilling university staff responsible for (FAIR) research data management and data stewardship. A recent study conducted by the European University Association showed how RDM responsibilities still largely fall on the shoulders of existing members of staff, such as librarians, IT experts, and research administrators (Garbuglia et al., 2022). In the absence of adequate upskilling and reskilling opportunities, including knowledge of the FAIR principles and how to implement them, they might not be able to offer researchers the right support and guidance. In addition to recommending that universities create dedicated research data support services and hire staff for specific data support roles, such as data stewards and research data managers, institutional strategies should be in place to ensure that the existing staff have the skills and capacity to meet the growing demand for FAIR RDM support services (ibid.).

This handbook can serve as a reference point for university practitioners who are navigating this complex and diverse background. It does so by providing practical tools such as competence profiles, learning outcomes, and lesson plans that foster the development of the next generation of data professionals and address the shortage of data-skilled professionals at the institutional level.

2.2. Collaborative Creation

The approach taken had to be able to deliver a number of requirements. As mentioned above, there were existing resources, knowledge and concepts that we could draw on. From these, relevant parts had to be selected, assembled and elaborated further; gaps had to be filled. FAIR-related knowledge and competencies cover a wide range of topics. In addition, pedagogical aspects like lesson and curriculum planning had to be considered. A co-creation process providing the opportunity to include a broad spectrum of experts with diverse backgrounds both from within and beyond the project's core team was considered a promising approach to address these needs and requirements. Since book sprints (Zennaro et al., 2007) had been successfully used before in similar endeavours (Bezjak et al., 2019; Clare et al., 2019; Martinez

et al., 2019; Rocca-Serra et al., 2022; The Turing Way, n.d.), the decision was made to use this type of co-creative effort to develop a handbook incorporating a set of different types of resources that can be used in a flexible way. Other approaches involving face to face seminars and workshops, e.g. the Dahlem Workshop methodology (Altmann, 1985), have proven to be successful but would have been very expensive to run for a team of authors as large as this. Also, the sprint methodology favours remote meetings which were a necessity during the Covid pandemic.

The handbook was co-created by a team of 42 individuals from 16 countries² with a variety of disciplinary backgrounds,³ affiliations,⁴ and job roles.⁵ A core team (9) were members of the FAIRsFAIR consortium which contributed to the development of the handbook as a deliverable. The other creators were recruited on a voluntary basis.

The book sprint approach follows the principles behind scrum-based agile software development (Rubin, 2012) that employs a cross-disciplinary team to carry out a series of discrete tasks to progress the project. Book sprints are a knowledge creation and community process where the contributors take collective responsibility for the whole book, complementing and correcting each other in the writing and editing phases. The methodology also goes beyond the traditional production cycle of textbooks as the result is commonly released under an open licence and based on software that allows release in various formats (Fahrenkrog et al., 2023).

The creation of the book was kicked off by six three-hour virtual meetings⁶ which were held over June 2021. The first of those meetings was used to introduce the approach, reflect on the needs and expectations of the handbook's audience (using personas), and discuss the overall structure before getting onto the writing of text. Four subsequent meetings were dedicated to the collaborative writing process which took place in breakout sessions. Smaller teams developed the individual chapters and lesson plans in parallel, with each team working on a separate section of the main document or an individual document. The last meeting wrapped up the previous sessions and outlined the subsequent editorial process.

Collaborative tools used included a collaborative writing environment (Google Docs), a video conferencing service (Zoom), a virtual whiteboard

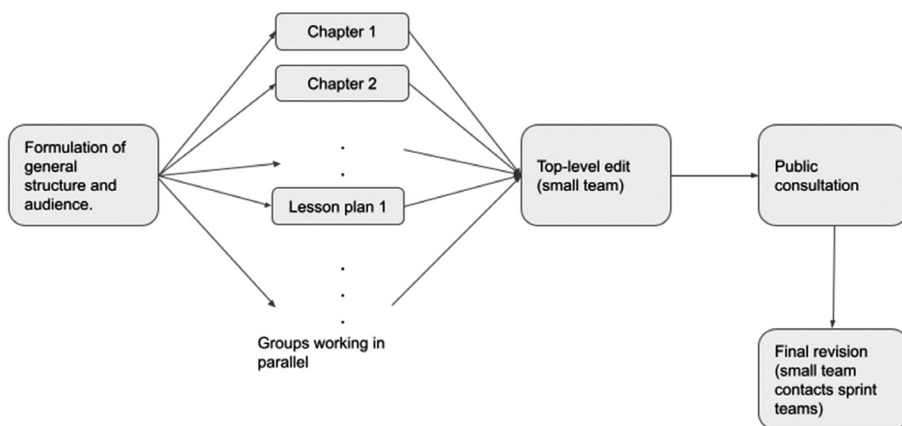
(Mural), and a messenger service (Slack). The use of a version control tool, e.g. Git (Chacon & Straub, 2014), at the stage of writing was rejected as having too steep a learning curve.

At the end of the six book sprint meetings, the bulk of the content had been created, but still needed further editing, revision and refinement. The subsequent editorial process took about nine months in total and was led by an editorial team. It included the finalisation of all sections by the writing teams, a review by the editorial team, and the release of a draft version for community review (from mid-July to mid-September 2021). The revised version was presented at a community workshop for a last round of feedback in October 2021 and wrapped up with a final internal review by the editorial team.

The stages of the writing and editing process are summarised in Figure 1.

The final document was used for creating the project deliverable and archived for a pre-release (Engelhardt et al., 2021) in December 2021. The document was submitted to Göttingen University Press for typesetting and publication as an electronic and printed book (Engelhardt et al., 2022). In addition, a GitBook Version⁷ was created based on the version released by Göttingen University Press. In terms of sustainability, this means that suggestions and

Fig. 1: Diagram of book sprint development.



corrections from the user community can be made on a rolling basis, and the editorial team can judge whether to accept such changes or not.

After the release of the handbook, it was widely promoted through mailing lists and at various events targeting data management experts, librarians, educators, and teaching support staff at higher education institutions. These efforts are still ongoing, and first examples of the use of the handbook are described in Section 4.

3. Handbook Content and Use Cases

With promoting and upskilling the use of FAIR data principles in higher education institutions in mind, the handbook provides practical content that can be readily used in day-to-day training opportunities, such as lesson plans (Chapter 5) and training programme development (Chapter 4). Enabling FAIR practices is not a task for one individual. It requires efforts and resources from multiple stakeholders. Chapter 6 highlights the important collaborative efforts from multiple stakeholders, administrative units, and service provision units to support FAIR practices and initiatives within the higher education ecosystem. The following sections (3.1 to 3.4) outline a variety of potential use cases for the handbook.

3.1. Using Lesson Plans to Run Successful Workshops

The handbook can be read cover to cover, but readers are invited to jump into a section that suits their needs. The predominant use case we had in mind while writing was the planning of courses, workshops, and training sessions around FAIR concepts and practices. The heart of the book is therefore Chapter 5 “FAIR lesson plans”. Each of the existing 16 theme-based lesson plans in the handbook provides suggestions on what to include, what to aim for, and where to find resources for a successful lesson.

All lesson plans follow the same structure:

- FAIR elements (that are relevant to the topic of the lesson)
- Learning outcomes

- Summary of tasks/actions
- Material/equipment needed
- References (with links to helpful resources)
- Take-home tasks

Each lesson works as a standalone document but they are also linked to each other and the wider context. The use of a template for lesson plans gives consistency and aids ease of use, and will also enable the updating of content and the addition of new lessons in the future.

The lesson plans in the handbook are not considered an exhaustive or complete list. It is also not intended or suggested to run a series of these 16 lessons in their entirety. The idea is more of a menu that allows one to pick and choose, to adapt and remix, and to inspire new lessons and approaches.

3.2. Creative use of Lesson Plans in Various Training Contexts

The lesson plans are designed to give a wealth of information on a specific topic in a brief form, to get the reader quickly started with planning and conducting their lessons and workshops. There are however use cases, where a lesson plan is insufficient for the reader to successfully plan and deliver a lesson. This could be either due to a lack of teaching experience, the intention to teach different topics, or to merge and upgrade materials with other resources. A deeper look at designing successful lessons is provided in Chapter 4 “Teaching and training designs for FAIR”, where a primer of didactical approaches and elaboration on the steps of lesson design is provided:

- 1) Identifying learning outcomes
- 2) Selecting or developing learning experiences
- 3) Selecting or developing content
- 4) Identifying or developing assessments
- 5) Evaluation

Readers with little or no teaching experience can use Chapter 4 as a guide in conjunction with the lesson plans in Chapter 5 to plan their lessons. More experienced teachers can use Chapter 4 as a guide or reminder when planning lessons for other topics or when merging and adopting a variety of

resources. This chapter will also be useful for upgrading existing lesson plans and informing the creation of further lesson plans.

3.3. Designing a Training Programme

Individual lessons on topics relevant for FAIR are generally not taught in isolation, but form part of a curriculum. Readers who want to plan a string of workshops or rework an existing curriculum will benefit from reading Chapter 3 “FAIR skills and competences”. The chapter considers what knowledge, competencies and skills students at different educational levels should acquire and suggests concrete learning outcomes.

3.4. Supporting Institutional Transformation

FAIR training programmes are one element of institutional support services for the implementation of FAIR data management. Institutional support is crucial to ensure a successful application of FAIR principles in training programmes within the higher education ecosystem. Administrators and research support staff in libraries, research offices and IT departments need to work with researchers in implementing policies, infrastructure, and services in support of FAIR. Chapter 6 “Implementing FAIR” highlights potential stakeholders and allies within a typical academic system to develop and implement policies and services necessary to enable FAIR. Moving towards an institutional perspective, Chapter 6 is also a great resource for institutional leadership to better understand the nuances and complexity of implementing FAIR research practices within an academic institution.

4. Awareness and Use of the Book

This section provides a range of examples of how the handbook could be – and has already been – used. An overview of the use cases presented in this section is provided in the table below:

Name of use case	User	Type of activity	Target group(s)	Motivation	Feedback on application of materials*
Developing a Research Essentials course (4.2)	Research Data Service, UCC Library, University College Cork, IE	Creation of training materials and activities for in-person workshops on FAIR, Research Data Management and Metadata	PhD students Postdoctoral researchers Research support staff	Research community identified the need for longer, more hands-on classes or workshops addressing data-related topics. Strong demand for general practical knowledge on RDM, however, adapted to specific domains.	The handbook helped prepare materials in a systematic and structured way, ensuring critical topics were covered. It also helped ensure that the materials were pitched at the appropriate level for the cohort of learners. The handbook is used to rework and restructure the existing course.
Research Data Management Foundations and best practices (4.3)	University of Amsterdam, National Technical University of Ukraine "Kyiv Polytechnic Institute"	Tutorial and part of the course on Big Data Infrastructure Technologies, taught regularly 3 times a year. Often delivered as a 2–4 hours tutorial at conferences, summer schools, project meetings. Training future trainers.	Master students, PhD students, researchers, practitioners		
Enterprise Data Management (based on DAMA DMBOK2) (4.3)	University of Amsterdam, National Technical University of Ukraine "Kyiv Polytechnic Institute", Vodafone Ukraine Data Science Academy	Training for practitioners and as a part of the course on Big Data Infrastructure Technologies. Training for MATES project (maritime industry) in 2020–2022	Master students, PhD students, researchers, practitioners	Strong demand for data literacy and general practical knowledge on data management from industry.	The handbook is used to rework and restructure the existing course.

Name of use case	User	Type of activity	Target group(s)	Motivation	Feedback on application of materials*
FAIR lesson plans in and beyond the context of ELIXIR (4.4)	ELIXIR Nodes, i.e., the Netherlands, Germany, UK, and Sweden	Hackathons to develop lesson plans as framework to advance FAIR skills	Trainers, support staff, data stewards, researchers	Struggle with training on how to implement FAIR in practice	Reuse of the handbook's lesson plan template in an adapted version. Template was conceived as very useful. It was used to extend the handbook's first 16 lesson plans to a bigger collection. The matrix of learning objectives in this handbook formed the starting point for our activities and was very helpful.
Development of a learning objectives matrix on RDM topics (4.5)	DINI/nestor AG Forschungsdaten (UAG Schulungen/ Fortbildungen)	Development of a learning objectives matrix on RDM topics (for the German-speaking region)	Lecturers, trainers, curriculum managers	Missing or ambiguous description of the complex topic RDM. Strong demand for guidance on relevant aspects related to the topic.	

* Which parts of the handbook did you use? How useful/helpful were these? Suggestions for improvement?

4.1. Survey

In order to gauge the awareness and interest in the use of the handbook, a short, non-representative survey was run in mid-2022. This was carried out when the book was announced. Overall, 34 responses were collated. Two thirds of the respondents indicated that they would use it for future training. Of those 23 respondents who already heard of the handbook, 9 had used the handbook in their teaching and training.

A variety of optional written comments in addition to the quantitative data gathered above were also provided. Many of these responses focussed on describing the type of training they would provide and how new this topic was. Two typical examples were as follows:

- 1) “At the moment looking at how [to] formalize or make our training offer more systematic by identifying learning outcomes and linking them to our institution goals/requirements (e.g. Open Science KPIs by our government). Will also use the learning for more formal description of our training sessions. Draw inspiration from the FAIR lesson plans.”
- 2) “For PhD students, but also for myself, as a Librarian on a steep learning curve to know FAIR data training. I love the many references and the many lesson plans, very useful for teaching colleagues a better understanding of the ‘new normal’ in future training of researchers and PhD students. I even believe the ‘data literacy topics’ integrated in the text/material will be useful.”

Given the small sample size, only limited conclusions can be drawn from the survey. Nonetheless, it served as a first indicator of interest in the handbook. Respondents shared their aims with regard to using it for training development, which included a broad range of topics covered in the handbook rather than very specific aspects of the text.

Moreover, general community interest in the topic of FAIR teaching and training is reflected in the views and downloads of the handbook since its release in December 2021. At the time of editing this article based on peer review (August 2024), there have been a total of over 24,000 views, comprising of almost 17,400 views (all versions) via Zenodo, about 5,100 views via Göttingen University Press and about 1,500 views via the OAPEN Library.

4.2. Developing a Research Essentials Course at University College Cork

In 2022, the Research Data Service in University College Cork (UCC) Library began a review of RDM and FAIR training. At that point, regular hour-long introductory classes were offered either in person or online giving an overview of FAIR and RDM, as well as longer or tailored classes on request for groups or modules. The feedback received was that there was interest and a need for longer, more hands-on classes or workshops, which addressed specific topics in relation to data sharing in more detail. With the progressive return to in-person on-campus activities and an increase in capacity with the addition of a Research Data Steward (Dr Deborah Thorpe) to the Research Data Service, the timing was right for the service to redevelop the training.

New classes and workshops needed to go beyond the introductory content and give participants confidence to apply the knowledge they gained. To do this, the aim was to present participants with practical information and give an opportunity to apply some of that knowledge within the classroom setting. Based on feedback, existing expertise, and capacity, a series of six workshops on a range of topics were developed: the Research Essentials series. The workshops directly informed by the handbook were “Being FAIR with your Data”, “Research Data Management” and “Metadata for Researchers – Lego for Reproducibility”.

The first step in developing the series was using the skills and competencies from Chapter 3 of the handbook to review existing materials, to ensure that content was delivered at the right level for the intended audience, and to help identify any gaps. For potential workshop attendees who are ready to move beyond the basic introductory content, pre-workshop materials in the form of short explainer videos and pre-reads are provided. The aim is that, once at the workshops, participants are ready to ask questions specific to their needs, and use the exercises presented to help them understand how to apply data sharing practices to their own work.

The next step in developing the new workshops involved outlining learning outcomes for each workshop. Again, at this stage, the handbook was a useful reference point and resource. Using the existing materials as a starting point, and the handbook for the next level, learning outcomes for each workshop were articulated. It was useful that in Chapter 3, the learning outcomes are broken down into basic, intermediate, and advanced. It allowed the

application of a consistent approach and descriptions of learning outcomes across the three workshops.

The final step involved developing the teaching materials. The lesson plans and materials do not follow those in the handbook, since existing materials worked well in the context of UCC, and a significant amount of practical, hands-on activities such as the Lego Metadata for Reproducibility workshop and exercises developed for the FAIR and RDM workshops were added (Donaldson & Mahon, 2019).

The Research Essentials series was first delivered during October and November 2022 and was attended by 56 researchers from across all disciplines. Participants included PhD students, postdoctoral researchers, research support personnel, and other staff from various areas. The feedback from all workshops was positive with participants commenting that “it was a very informative and enjoyable way of expanding my knowledge on the subject” and the strengths being described as “examples used, the exercises and an accessible format where I could ask many questions” (comments by participants of the “Being FAIR with your Data” workshop). The series is now part of a regular offering of UCC Library Research Services. The handbook provided useful reference resources in the development of the workshops and consistency of approach across a wide range of content. It will be used in the future to develop further RDM and FAIR data training at UCC.

4.3. Data Management in Computer Science Programmes at the University of Amsterdam and the Igor Sikorski National Technical University of Ukraine

One of the questions with regard to teaching research data management and the FAIR principles is the timing of introducing the concepts to students. The Data Science programmes at the University of Amsterdam (UvA) introduce elements of project management and related data management skills in the mandatory bachelor programme course on basic academic skills (PAV – Practicum Academische Vaardigheden; Universiteit van Amsterdam, n.d.). The students are introduced to the basic data management principles constituting the foundation of the FAIR principles, they are required to apply good file naming conventions to their reporting documents, and to provide the necessary metadata in their project deliverables.

Introducing research data management at the master level is a more common approach and should align with students embarking on their initial research practice. The experience of teaching the course Big Data Infrastructure Technologies for Data Analytics (BDIT4DA) in the Data Science master programme at Igor Sikorski National Technical University of Ukraine (Igor Sikorsky Kyiv Polytechnic Institute, n.d.) shows that the students are more interested in general and enterprise data management than in research data management. Taking this observation into account, the students are provided with lectures on (1) general data management knowledge, primarily for business and industry applications as recommended by the Data Management Body of Knowledge (DMBOK; DAMA International, 2017), and (2) Open Science, research data management and stewardship, FAIR data principles and metadata management.

Both courses will be reworked with content and guidance from the handbook enriched with local data management experience and demand. Key issues that will be addressed in this process are:

- 1) Low knowledge, understanding and acceptance of the principles of Open Science and FAIR data management among teachers. Despite many decisions and adoption programmes, there is still low acceptance at the level of researchers (both junior and senior), teachers and teaching assistants;
- 2) Due to the complexity and pace of computer and information technologies development, university programmes are highly overloaded; the majority of the students' educational work, such as assignments and essays, does not require complex data management principles.

The handbook will be instrumental in providing input into the restructuring of the above courses.

4.4. FAIR Lesson Plans in and Beyond the Context of ELIXIR

Co-led by ELIXIR-Netherlands, ELIXIR-Sweden, and as part of the ELIXIR-CONVERGE Training Work Package (ELIXIR, n.d.a), hackathons have been organised from June 2022 onwards to build on the lesson plans of the

handbook. Although initiated in the context of ELIXIR (ELIXIR, n.d.b), an intergovernmental organisation bringing together life science resources (open access databases, software tools, training materials, cloud storage, and supercomputers) from across Europe, the hackathons are open to participants outside ELIXIR, making it a cross-domain effort consistent with the handbook.

The events targeted people with an interest in research data management in the life sciences (trainers, data stewards, researchers, etc.) and offered the opportunity to jointly create additional lesson plans to help research organisations advance their data stewards' and researchers' FAIR skills (how do you go/do FAIR). These lesson plans include links to existing materials (e.g. knowledge clips, guidelines, etc.) that organisations may use in their training programmes, but also identify gaps and make suggestions for additional material to be developed.

Using an adapted lesson plan template based on the handbook and building upon its existing lessons, an adapted curriculum of seven units was created:

- 1) FAIR generics
- 2) Findable data
- 3) Accessible data
- 4) Interoperable data
- 5) Reusable data
- 6) FAIR software
- 7) Data repositories

The first subset of lesson plans has been published via the ELIXIR GitHub.⁸ The GitHub web page targets trainers looking for materials on teaching researchers or peers (trainers, data stewards, policy makers) on FAIR data, and offers guidance on integrating these topics into an organisation's curriculum. It builds on existing ELIXIR resources such as the RDMkit (<https://rdmkit.elixir-europe.org>), the ELIXIR/NPOS Data Stewards Competency Framework (NPOS/ELIXIR, n.d.) and the FAIR Cookbook (Rocca-Serra et al., 2022). ELIXIR Nodes (ELIXIR, n.d.c) such as the Netherlands, Germany, UK, and Sweden are encouraged to use the lesson plans in their teaching on FAIR.

4.5. Developing a Matrix of RDM Learning Outcomes

Based on the competence profiles and the learning outcomes provided as part of the handbook, the German-speaking DINI/nestor working group on RDM training and further education⁹ developed a matrix of learning outcomes with regard to RDM for the bachelor, master and PhD levels as well as data stewards (Petersen et al., 2025).

The aim was to provide a standardised set of RDM-relevant topic areas and corresponding learning outcomes in German (an English version is also available) that can be used as a tool that provides orientation when designing and planning courses, workshops, and other teaching formats in higher education programmes as well as with regard to the education and training of data stewards and related support staff.

The matrix gives a structured overview of the relevant topics associated with RDM. For every topic, it suggests learning outcomes tailored to four levels – bachelor, master, PhD students, and data stewards. The topics and learning outcomes can either be used directly as they are or serve as a starting point for context-specific adaptations.

The starting point for developing the matrix was Appendix E of the handbook – the table that combines the knowledge units and corresponding learning outcomes for the bachelor, master and PhD levels. Drawing on teaching content and learning outcomes from a number of projects and established concepts (Biernacka et al., 2021; Blümm et al., 2022; Christian-Albrechts-Universität zu Kiel, 2022; Hörner et al., 2021; RWTH Aachen University, 2023; Universität Bielefeld, n.d.; FAIR Data Austria [<https://forschungsdaten.at/fda/>]), the table was revised and extended by members of the DINI/nestor working group and teaching staff of Kiel University in several iterations. The authors harmonised the wording for topics and added a “Data Steward” column as well as respective learning outcomes. Compiled learning outcomes were operationalised based on the taxonomies by Bloom/Andersen & Krathwohl and harmonised with regard to their wording. In addition, competence areas that are strengthened with the achievement of the learning objectives were assigned to all learning objectives.

The matrix is intended to be a living document that can be adapted, extended, and continually improved. It was deliberately developed as a proposal or

starting point for further design by the consortia of the National Research Data Infrastructure Germany (Nationale Forschungsdaten-Infrastruktur e.V. [NFDI], n.d.a) and the work of the NFDI Section EduTrain (NFDI, n.d.b).

At a session at the Research Data Alliance (RDA) Germany conference in February 2023 (Petersen & Slowig, 2023), the matrix of learning outcomes was presented and several use cases at German institutions were discussed. One such case is the revision of the certificate course “Research Data Management” (Technology Arts Sciences TH Köln, n.d.). In this context, the matrix provided a beneficial instrument for comparing the current curriculum to a common understanding of RDM and for quality assurance, which also supports accreditation or re-accreditation processes. Another example was reported by the project `fdm@studium.nrw` (Digitale Hochschule NRW, n.d.) which used the matrix as a framework for the evaluation and selection of content and learning objectives for a self-study RDM online course. Also, the operationalised learning outcome formulations helped with the design of quizzes and assessments within this course. At Kiel University, the matrix is discussed with participants as part of a Train-the-Lecturer workshop on RDM and is used both to compare ideas on relevant topics and as guidance for lecturers who are interested in including RDM topics into their lectures.

According to the community feedback so far, the matrix appears to be suitable and helpful in its current form as a starting point and orientation aid for the development and revision of generically designed teaching and learning materials for the area of RDM. However, users also stated that especially for the target group of students, more subject-specific designs of a learning outcome matrix are necessary. The matrix as a whole is very comprehensive and can seem overwhelming. Topic aspects and learning objectives should be selected or filtered from a subject-specific perspective, and learning objective formulations as well as assignments for the qualification levels of bachelor and master should be adapted to the requirements of the respective subject. Several working groups of different consortia of the NFDI are currently working on subject-specific adaptations and extensions of the matrix.

5. Conclusions and Outlook

The take-up of RDM across higher education institutions and research institutions in the recent past demonstrates a need for relevant training materials.

This is particularly true for the FAIR data principles. There is a need to move beyond generalised discussion of the principles and provide implementable advice. With this in mind, there was a need to develop the FAIR data handbook. An approach of knowledge construction, developed by a thriving community of trainers, was used to address this. The challenges associated with doing so are multi-faceted depending on factors such as discipline, institutional context, drivers for change, and so forth. This paper outlines how this was carried out.

The development of the handbook followed a sprint-based approach to collate material and to develop the overall structure with a team of editors to guide corrections. This method is generic and could be applied widely to quickly build up further related materials. The approach does have its challenges. Sprint sessions need to be managed carefully by the editors. Developing the overall structure was time-consuming and an editorial team would be advised in the future to have a clear idea of the overall structure beforehand. Likewise, at the end of the process there was difficulty in ensuring that all corrections and updates were completed even when deadlines were set.

The handbook provides a lightweight, adaptable, and accessible source from which educators can start by picking and choosing based on their own needs and requirements. There are 16 theme-based lesson plans to help those who wish to design a lesson, workshop or course on one or more FAIR-related topics. A chapter on “Teaching and training designs for FAIR” guides readers with less teaching experience step-by-step through the process of course design. Competence profiles indicating the knowledge and skills required at different educational levels and suggesting associated learning outcomes can inform the development or revision of a curriculum or programme in terms of FAIR-related aspects. Finally, a chapter on “Implementing FAIR” expands on the different facets of building a FAIR-enabling institutional environment.

Although the handbook has filled a gap and created a resource for those who engage in teaching and training, complementary approaches are necessary to strengthen FAIR and data literacy more generally. Due to the timing of the creation of the handbook and limited resources in the FAIRsFAIR project, the handbook was not followed-up by a series of workshops or pilot courses to test and refine the suggested lesson plans. The handbook can also inform and complement more specialised handbooks and guides, e.g. for teaching data

management in informatics (e.g. Biernacka & Schulz, 2022) or FAIR implementation guidance for the Life Sciences (Rocca-Serra et al., 2023).

As a first step towards exploring the uptake and impact of the handbook, the case studies described in section 4 of this paper illustrate how the tools provided by the handbook can be employed in diverse contexts and to different ends. They also show that the handbook can serve as a starting point for further developments in various communities and settings, such as the lesson plans for the life sciences created in the ELIXIR hackathon series or the extended matrix of learning outcomes that was developed based on handbook material.

To ensure its sustainability and relevance in the long-term, the handbook was designed to be modular. It is a living document that belongs to the RDM community and will be actively maintained by it. It has been formatted into a GitBook¹⁰ and communities such as the Community of Practice of Open Science Training Coordinators and Research Data Alliance have been approached to ask for their assistance in its upkeep going forward. Scheduled book sprints, much in the same way as was done in the initial writing of the handbook, would be a possible option for gathering input in the future, with an established editorial team overseeing the overall process.

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Notes

¹ More information about the FAIRsFAIR project is available at <https://www.fairsfair.eu>.

² Germany, Netherlands, United Kingdom, Canada, France, Republic of Ireland, United States of America, Austria, Belgium, Denmark, Finland, Norway, Portugal, Spain, Sweden, Switzerland (ranked according to frequency from highest to lowest).

³ The Life Sciences were slightly overrepresented followed by the Natural Sciences, the Humanities and the Social Sciences (with a nearly equal distribution among the latter three). Library and information science as well as computer science were also well represented. There was one participant with an engineering background.

⁴ The vast majority of participants were affiliated to universities and research performing organisations, but research infrastructures, research funding organisations and national agencies, and large enterprises were also represented.

⁵ The group of authors included lecturers, professors, librarians, research/RDM support staff, trainers, developers of training and training/teaching materials, courses and curricula, managers/coordinators, one national research council member, and one person providing didactic support of lecturers.

⁶ At the time the idea to use a book sprint approach for this task was borne, this was envisioned to be an in-person event. Due to the Covid-19 pandemic going on during the whole of 2021, it was changed to a completely virtual event.

⁷ The GitBook version is available at: <https://fairsfair.gitbook.io/fair-teaching-handbook/> (associated GitHub repository: <https://github.com/FAIRsFAIR/FAIRteachinghandbook>).

⁸ ELIXIR Training GitHub: <https://github.com/elixir-europe-training/>, FAIR lesson plans: <https://elixir-europe-training.github.io/ELIXIR-TrP-FAIR-Converge/>.

⁹ DINI/nestor UAG Schulungen/Fortbildungen: Working group on training and education on RDM in the German-speaking countries (Forschungsdaten.org, n.d.).

¹⁰ <https://fairsfair.gitbook.io/fair-teaching-handbook>.