Open Science and Research Data Management: A FAIR European Postgraduate Programme

Horacio González–Vélez*, Ciprian Dobre†, Barbara Sánchez–Solis‡,
Giulia Antinucci§, Dave Feenan¶, Dana Gheorghe‖
*National College of Ireland, Ireland. †ICI București, Romania. ‡Technischen Universität Wien, Austria.
§Università degli Studi di Roma "La Sapienza", Italy. ¶Digital Technology Skills Ltd, Ireland.
‖Universitatea Politehnica din București, Romania

***Abstract*—Open Science is widely regarded as a culture that is characterised by the transparency and broad accessibility of scholarly work, where researchers share openly artefacts almost immediately and with a very wide audience. The overarching aim of this paper is to document the systematic development of a European postgraduate programme on Open Science and Research Data Management developed by the TRAINRDM project. TRAINRDM is a 30-month European Union funded project, which aims to develop a training network around Open Science and Research Data Management. We have applied a comprehensive survey collecting 239 responses from researchers across Europe, representative of 2.58 million individuals i.e. the total number of researchers employed in the EU-27 region. We then mapped out existing skills and offerings at different TRAINRDM partner institutions to produce a fully-online postgraduate programme with micro-credentials, fully distributed delivery, and compliance to FAIR principles to address academic and industrial research needs. The main outputs of the project are a training programme for Early Career Researchers delivered in Summer 2022, and a the postgraduate programme (Master degree) to be fully validated under the European Qualifications Framework at Level 7 and delivered in 2023. The TRAINRDM curricula, teaching materials, data, and software are openly released under CC BY 4.0 and GPL licenses.**

***Index Terms*—open science, open data, data management, open source, data carpentry, FAIR principles**

I. INTRODUCTION

Systematically defined as transparent and accessible knowledge that is shared and developed through collaborative networks [1], Open Science (OS) has opened up new ways in which research, education, and innovation are undertaken, archived, curated, and disseminated across the globe. Typically framed around the FAIR principles—Findability, Accessibility, Interoperability, and Reusability [2], Research Data Management (RDM) is designed to guide data producers and publishers when releasing formal scholarly digital research objects including datasets, algorithms, tools, and workflows.

OS and RDM are not dogmatic *per se*, but about greater efficiency and productivity, more transparency, and a better response to interdisciplinary research needs. They require a cultural change in academic institutions and research-intensive industrial organisations, to embrace the acquisition of new knowledge and skills for open access publishing, open source software, reproducible workflows, and research data sharing. Early career researchers (ECRs)—including MSc and PhD Students—have to arguably be harbingers of change within the traditional system of academic science and publishing. While OS and RDM can be key factors driving this change, it may take more time than expected unless fostered especially regarding practices. Therefore a favourable, rewarding environment is required where there are opportunities to acquire awareness and knowledge and develop OS relevant skills.

> TRAINRDM *aims to empower the Education and Skills dimension of OS and RDM by exploring innovative mechanisms and tools to develop a training network and an associated postgraduate programme with particular emphasis on FAIR principles.*

TRAINRDM is a 30-month project funded by the European Commission Erasmus+ Programme, designed to increase capacity and professionalism in OS and RDM at European level. The TRAINRDM Consortium is built on a 6-strong solid partnership composed of four Higher Education Institutions (HEIs) namely Universitatea Politehnica din București (UPB), Technischen Universität Wien (TUW), National College of Ireland (NCI), and Università degli Studi di Roma "La Sapienza" (SAPIENZA); ICI București (ICI), a national institute for research, development, and innovation in information and communications technology; and Digital Technology Skills Ltd (DTSL), an industrial organisation with proven expertise in the management and delivery of large skills projects.

This paper describes the development of the TRAINRDM postgraduate programme. We have analysed and map the skills and training needs for OS and RDM by applying a comprehensive survey across Europe collecting 239 responses from researchers across Europe, representative of a 2.58 million population—the total number of researchers employed in the EU-27 region. As part of the survey, we have also mapped out existing competencies and offerings at different TRAINRDM partner institutions to ultimately produce a fully-online postgraduate programme.

Based on four main pillars—Findability, Accessibility, Interoperability, and Reusability—the FAIR guiding principles are an inter-sectional attempt to ease the access, use, and reuse of digital resources by both humans and machines [2]. TRAINRDM has endeavoured to produce skills training in compli-

ance with FAIR principles. Validated at European level under the 1999 Bologna Agreement and delivered from September 2023, the proposed postgraduate programme features fully distributed online delivery via an open-source content management system and a federated identity service. Each module in the programme is also offered as a validated micro-credential. The TRAINRDM curricula, teaching materials, data, and software are expected to be openly released under CC BY 4.0 and GPL licenses. The Materials of Erasmus+ TRAINRDM Open Science "Early stage Researchers" Training Week held at Università degli Studi di Roma "La Sapienza" from 12th to 16th September 2022 are openly at the TUW repository [3].

It is duly noted that FAIR concepts are not only embedded in the curricula, but there is also a dedicated 15-credit module on FAIR Data Management developed by Technischen Universität Wien, the institution which hosts the FAIR Office Austria. The aim of this initiative is to connect stakeholders from research communities and service facilities and to jointly promote the implementation of the FAIR principles in Austria.

The remainder of the paper is organised as follows. In Section II we present a brief overview on OS and RDM and their relevance as a curricula. Section III outlines the common definitions of OS and RDM concepts and describes the TRAINRDM survey and its results. The curricula and technical set-up for delivery are described in Section IV. The paper closes with Section V which provides the main conclusion from this work and offers some possibilities for future work and defines a strategy to further develop the understanding and deployment of OS and RDM globally.

II. BACKGROUND

As a joint endeavour undertaken by professional computing societies worldwide, the Computing Curricula 2020 (CC2020) [4] "summarise and synthesise the current state of curricular guidelines for academic programs that grant baccalaureate-level degrees in computing as well as propose a vision for future curricular guidelines." From its early work and discussions [5], the CC2020 task force recognised the dynamics of computing education and the workplace and focused on competencies. The CC2020 has also expanded the main curricula to embrace data science as key discipline. Subsequently, the Computing Competencies for Undergraduate Data Science Curricula 2021 (CCDS 2021) has recognised data science as a truly interdisciplinary field where students need to learn about data collection, storage, integration, analysis, inference, communication, and ethics [6].

Under this educational context, it has been documented that OS and effective RDM have become a priority for organisations globally [7], since funding agencies and publishers now require scientists to share their data effectively. On the one hand, as it is widely recognised that OS comprises several interdisciplinary dimensions. On the other hand, RDM has long been recognised as an important area by information professionals [8], where the information is preserved at five levels:

1) Digital object: migration/emulation, experimentation, loss.
2) Collection: interoperability, metadata, standards
3) Repository: policies, procedures
4) Process: automation, workflows
5) Organisational: governance and sustainability

While the implementation of FAIR-compliant applications arguably addresses the five aforementioned levels and has rightly permeated different stakeholder communities, its consistency is not standardised. In fact, ensuring the convergence and interoperability of the implemented solutions worldwide, still requires significant harmonisation aligned with the FAIR guiding principles [9].

In their advice paper on OS and the role of HEIs [10], the League of European Research Universities (LERU) highlights the *Education and Skills* training of all people in the universities as key within the eight OS ambitions defined by the European Commission priority policy [1]:

> *All scientists in Europe should have the necessary skills and support to apply open science research routines and practices.*

Many HEIs have consequently developed and delivered their own training on OS and RDM e.g. leveraging the Open Science Framework [11], while others have worked with external providers. LERU states that OS skills training should be firmly embedded–in online progress tools or similar study management and supervisory systems–and should be acknowledged in professional development and career progression. Universities should therefore integrate OS concepts and their practical applications in educational and skills development programmes, analysing and mapping their needs for skills training and taking into account the different OS dimensions and the varying needs of different audiences, different disciplines, etc.

On the one hand, LERU identifies five essential dimensions for OS training [12]:

> *"Clearly, there is an evident need for skills training with regard to scholarly publishing and research data management; those are the areas of Open Science in which universities tend to invest most at the moment. Also, research integrity and ethics courses, and increasingly, citizen science courses, are important".*

The report insists that such training should be tailored to the specific needs, resources and requirements of the audience, including a large variety of formats such as in-person or distance, classroom, webinars, blended or not.

On the other hand, the European Commission working group [13] defines OS skills and expertise needs for researchers so that skilled talent can publish under open access,

[1] https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/open-science_en

manage (open) research data, conduct professional research (including research management, legal expertise, ethics and integrity) and engage with citizen science. The report recommends the introduction of open science education and training tailored for students and ECRs, to encompass an open research environment. " Institutions should offer and promote both traditional and/or online career-level appropriate Open Science training courses for researchers [...] All Open Science skills courses should have career level appropriate accreditation and could also be modularised [...] it should be mandatory for universities and research organisations to offer these as part of their training".

A. *The* TRAINRDM *Approach*

The TRAINRDM project aims to support the OS *Education and Skills* dimension and addresses the increasing need for skills training with regards to RDM focusing in the five aforementioned levels–Digital object, Collection, Repository, Process, and Organisational.

TRAINRDM is particularly relevant at a time where preserving and sharing data is key to generate effective Data Management Plans for funding agencies [14], [15]. In fact, the creation of a effective Plan is widely recognised as an integral part of the research practice [16].

OS and RDM skills training is arguably crucial for a variety of audiences at academic and industrial organisations [17]. In academia, they will include researchers at all career phases (from doctoral researchers to senior professors and students at the bachelor and masters' levels [18], while in industry they will be instructors, research management staff, data scientists, data stewards, copyright officers, librarians and citizen scientists. They will all benefit from OS and RDM training, which needs to be tailored to the needs of specific subgroups. Finally, supporting role models and training the trainers may need to be considered.

However, existing R&D units in Europe typically lack experts capable of dealing with such complex paradigms. The planned training activities within TRAINRDM involve training of new researchers in the RDM competences on a broad level using Carpentries concept meaning the organisation of Software Carpentries, Data Carpentries and so on [19], where trainers from our partners or from other institution can be invited to develop workshops sessions. These will be organised based on new setting up training concepts /module adjusted to various target groups as well as for those from industrial environments, by closely working with research-intensive companies in Europe. Moreover, the knowledge concerning the Open Access tools used for different management data systems (from RDM to DM System) will be involve during the training activities in order to enable European companies further increase their access to research data produced by research institutions and so to increase their competitiveness with respect to similar companies in USA and China.

III. SURVEY

As our primary objective has always been the creation of a relevant programme on OS and RDM, the TRAINRDM Consortium designed a survey to gather additional details from researchers in Europe. As respondents to the survey were expected to put forward their views on skills and training needs on OS and RDM, we included the below definitions at the start of the actual questionnaires. The intention was for the definitions to apply as widely as possible and set the context.

The survey did not gather any personal information and participation was on the basis of fully-informed, freely-given consent. All respondents were duly informed on the nature and purpose of the study and other aspects. The survey was deployed using SurveyMonkey, a widely-used survey software with proven GDPR compliance, with full ethical clearance from the National College of Ireland Ethics Committee.

- Knowledge: composition of facts and figures, concepts, ideas and theories which are already established and support the understanding of a certain area or subject.
- Skill: Ability to use one's knowledge effectively and readily in execution or performance.
- Competency: Important skill that is needed to do a job.
- Competence: Ability to do something well.
- Research Data: Qualitative, quantitative, or textual information upon which a novel investigation was conducted. Data can be "raw," meaning in the form it was collected, or "cleaned" or "prepared," meaning corrected for errors or transformed into a new form for analysis (e.g., preprocessing) or sharing (e.g., anonymisation).
- Scholarly work: A paper, article, book, report, research data, computer code, or other form of media artefacts communicating the outcome of academic research.
- Open: Content that is publicly available with minimal barriers to access, i.e. it can be viewed, licensed, and/or downloaded online without registration, payment, or approval.
- Open Science: Transparent and accessible knowledge that is shared and developed through collaborative networks
- Open Source: Software with source code that anyone can openly inspect, modify, and enhance.

From this perspective, our OS definition subscribes to the public and infrastructure schools as defined in [20] as TRAINRDM is focused on making science accessible to the public and improving research impact by improving available tools and applications.

We contend that this work should serve as the starting point for the identification of staff competencies and skills needs relevant to the development of similar programmes across the world.

As part of the TRAINRDM project, we have conducted a survey to analyse and map the skills training needs for OS and RDM taking into account the different OS dimensions, target groups, and level of existing knowledge. In addition to HEIs, the survey was distributed among research-intensive

Small and Mid-size Enterprises, Multinational Corporations, and research-intensive Startups.

In order to build upon previous work in the literature, we have reviewed the Swinburne Open Science Survey [21] and The Open Scholarship Survey [22]. In the TRAINRDM Survey, we have focused on two aspects:

- the current familiarity of concepts related to OS and RDM; and,
- the availability of training on OS and RDM topics at partner institutions.

Consequently, the Survey has been divided into the distinct parts:

- **Part 1. EVERYONE:** This was an exploratory exercise aimed at our four target groups: ECRs, Senior Researchers/Research Managers, Librarians, and Data Scientists from any (preferably European) institution. That is to say, this part was distributed, as wide as possible, by all TRAINRDM partners using their available European research and academic networks.
  It was expected that this part would take participants some 20 minutes to complete. There were no right or wrong answers and responses to all of the questions were absolutely confidential. All data was fully anonymised in compliance with GDPR regulations.
- **Part 2. PARTNERS ONLY:** This part built an inventory of available programmes, modules, and in general training on OS and discipline-specific Data Management practices at TRAINRDM partner institutions. That is to say, this Part was distributed within partner institutions and, depending on the institutional structure (departments, schools, faculties, etc), only a limited number of instances completed.

For Part 1, our ideal number of responses was 385, as this is the ideal sample size at a 95% confidence level given that there are 2.58 million researchers employed in the EU-27 region [2]. On the other hand, Part 2 was by design going to have a limited number of responses and would therefore require a careful distribution within TRAINRDM partner institutions. The survey was deployed during the Summer 2021.

A. Results

For Part 1 of the Survey, we have collected 239 responses which is roughly representative of the original intended population (2.58 million researchers in Europe) at 90% confidence with a 5% margin of error. As presented in Figure 1, 80% of the researchers work in academia while the remaining 20% split evenly between industry and public sector. There are no significant issues in term of gender equality or diversity.

As presented in Figure 3, research methods, report writing, and data collection are considered the most valuable training and education to be successful in Research. Of particular relevance to this work, 61% and 36% of the respondents considered extremely or somewhat important that datasets and/or code materials are Open Data and Open Source respectively (see Figure 2, and 76% have used other researchers' Open Data and/or Open Source materials in their own research.

When it comes to published data, 57% and 39% of respondents considered extremely or somewhat important that data from published research is openly available (see Figure 4). 63% and 54% have used Open Data from other sources (e.g., researchers, government, etc.) or in their own research respectively.

87% of the respondents had published some research in the previous five years, and 70% considered Open Access publishing the most commonly used OS practices. Half of the respondents use predominantly GitHub and/or their own institutional repository as the predominant OS resource. Finally, for 70% of the respondents, the dominant barrier for OS uptake was the lack of funding for open access publishing and their main resources to learn are found directly on Internet.

For Part 2, we have collected 11 responses from TRAINRDM Consortium partners. Based on the responses and partner meetings (online and face-to-face), Table I presents the Matrix of Competencies per Partner.

> *The complete set of results for both parts of the survey are included in the deliverable* "IO1: RDM & OS TRAINING METHODOLOGICAL TOOLKIT" *openly available from the* TRAINRDM *website at https://rdmtraininghub.eu/.*

The TRAINRDM project participants have indeed used the results of the survey to inform the instructional material development.

IV. RECOMMENDED PROGRAMME

Building upon the Survey results, i.e. the skills needed and suggested by the researchers and the competencies possessed by the different TRAINRDM partners, it is suggested to develop and, **eventually**, deliver a full pan-European programme in Open Science and Research Data Management. While the creation of such programme is a long-term aspiration, the TRAINRDM will endeavour to develop more training paths (e.g. summer schools) that could offer credits recognised under the European Credit Transfer and Accumulation System (ECTS) and/or other certificates such as open badges.

A proposal for a 90-credit *Master of Science in Research Data Management* is depicted in Figure 5, where the proposed programme is structured as four 15-credit online/blended modules with a capstone 30-credit top-up Research Project.

As detailed in the structure, the 15-credit modules are to be developed and delivered directly by the four HEIs in the TRAINRDM Consortium, namely UPB, NCI, TUW, and SAPIENZA, and also packed as micro-credentials with European validity. The 30-credit capstone project is linked to case studies under the supervision of ICI and DTSL with help from the TRAINRDM's HEIs. The entire programme will have

[2]Source: EU Eurostat https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Research_and_innovation_statistics_at_regional_level (Last Accessed: 12/Jan/2022).

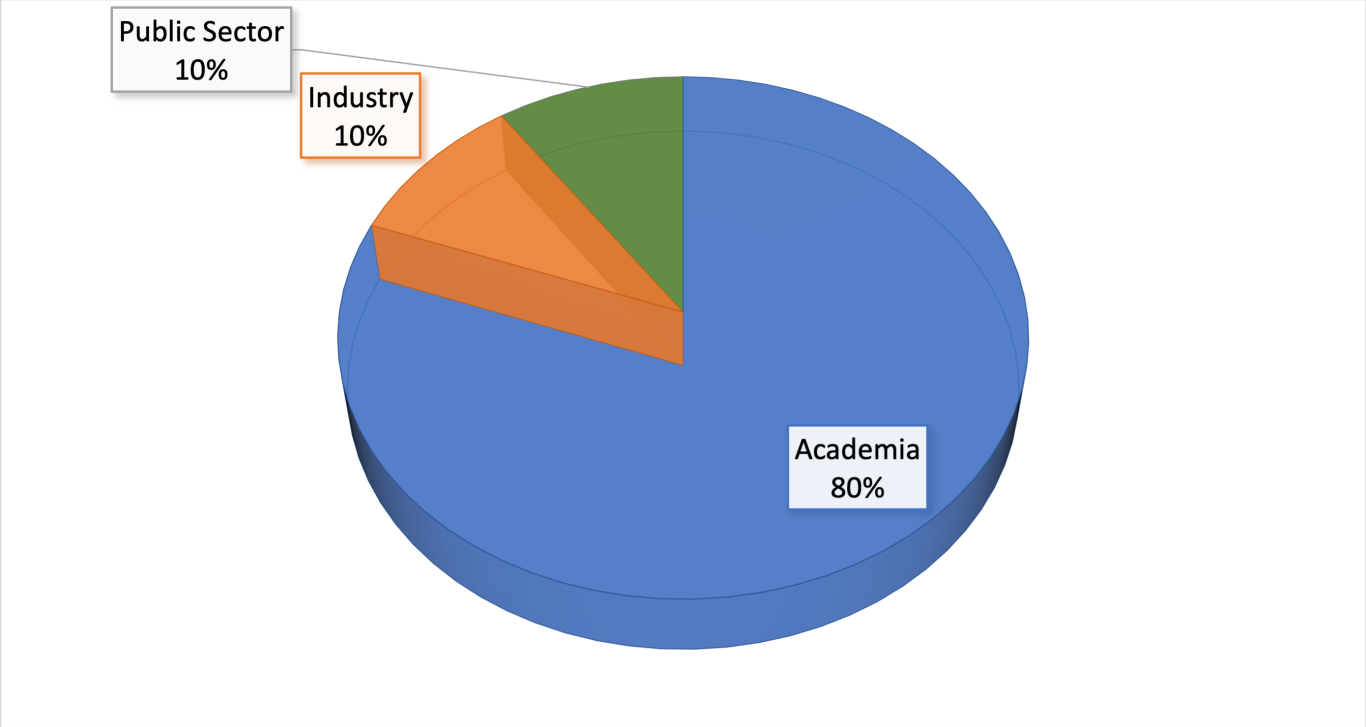

Fig. 1. Sectoral affiliations of the 239 researchers who responded the TRAINRDM survey.

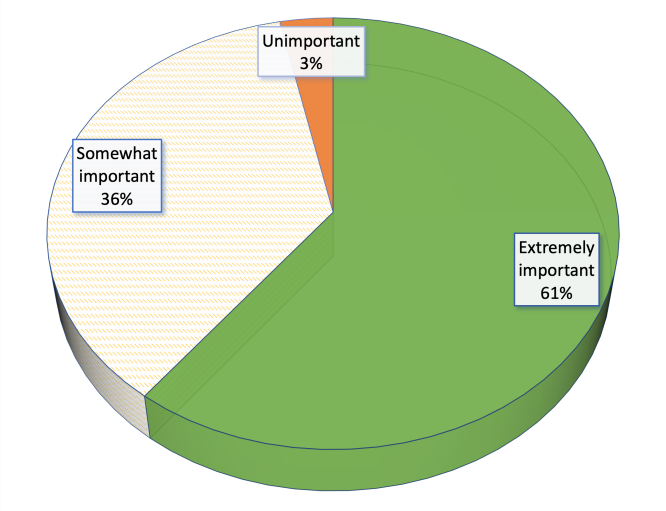

Fig. 2. How important is it that datasets and/or code materials are Open Data and Open Source respectively?.

a flexible route with joint delivery, leading to a single award recognised across Europe under the 1999 Bologna agreement. It is duly noted that in several European countries, MSc programmes have 120 credits as mentioned by SAPIENZA and UPB.

Upon completion of this MSc programme, graduates will be able to perform independent research that puts them into a position to make informed and critical decisions regarding requirements elicitation and analysis, implementation, evaluation and documentation in OS by using Research Data Management principles.

> *There will be two elective modules to cover the additional ECTS credits required (i.e. 90 and 120): "Text and Data Mining" (to be developed by* NCI*) and "Research workflows" (to be developed by* ICI*)*

The programme will run as online leading to a Level 7 degree in the European Qualifications Framework. Graduates of the programme will take up roles as Data Management Analyst, Clinical Research Coordinator, Clinical Data Manager, Data Governance Manager, Data Management Specialist, Data Management Clerk, and Data Management Specialist.

The proposed teaching and learning mode is online delivery via lectures, demonstrations, and tutorials. Underpinned by independent research and pre-reading, declarative and procedural learning will be addressed through activities such as formal lectures, case studies, scaffolding programming tasks, and coding tutorials. A pedagogy-centred approach will address functioning intended learning outcomes through peer collaborative learning, coding projects in novel and unfamiliar situations, systematic group work and presentations, web-enhanced learning, and research problems. Learners will also engage in a capstone research project, conducting appropriate research and undertaking the design and development of a OS case study proposed by the TRAINRDM industry partners.

A typical case study explained to students is built on the

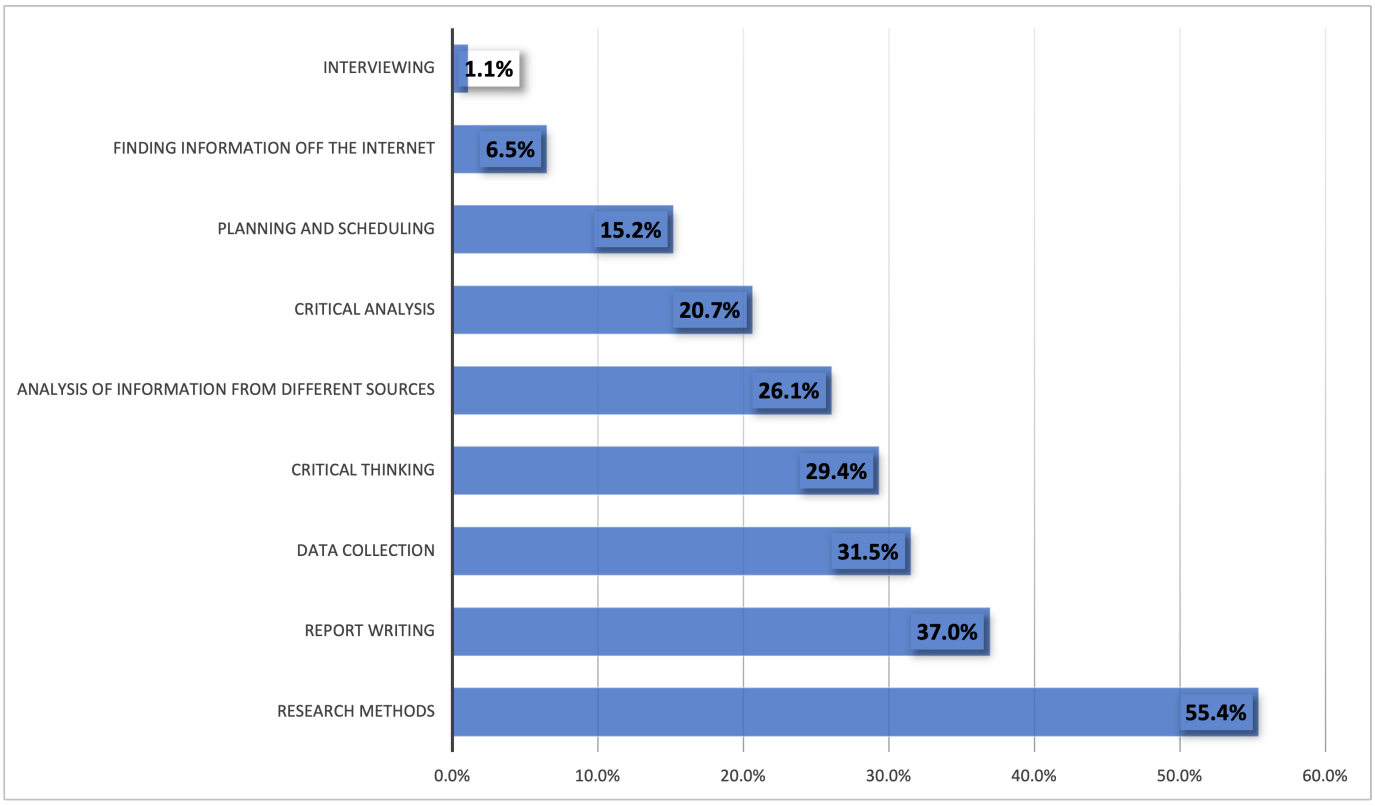

Fig. 3. Which of the following topic areas would you find most valuable for ongoing training and education for your organisation to be successful in Research?.

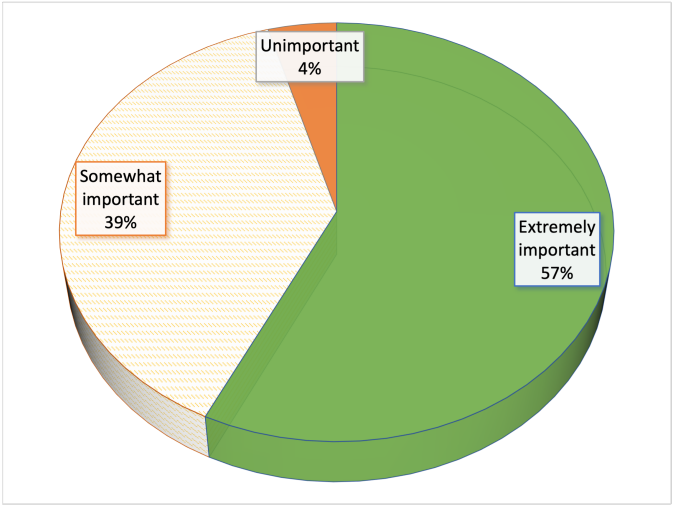

Fig. 4. How important is it for your research field that data from published research is openly available?

topic "**Steps To Share Your Data**" and is presented below.

Step 1: Select what data you want to share, i.e. not all data can be made openly available, due to ethical and commercial concerns, and you may decide that some of your intermediate data is too large to share. As such, you first need to decide which data you

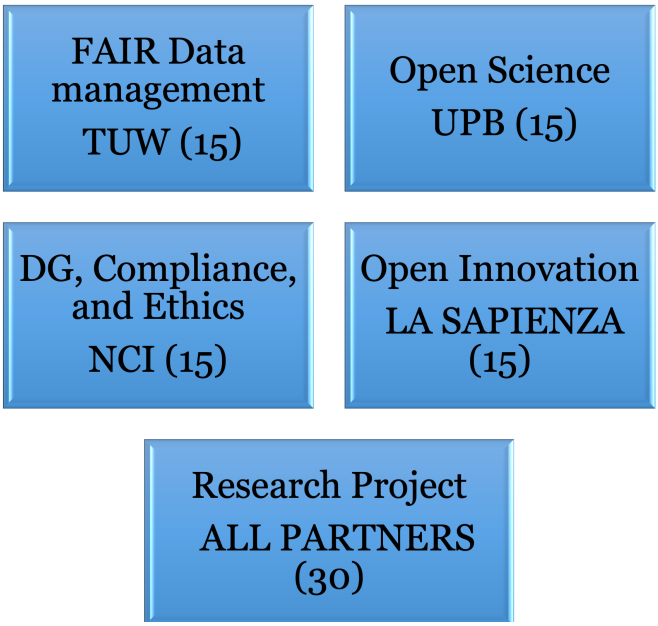

Fig. 5. 90-credit MSc in Open Science and Research Data Management: Proposed Structure

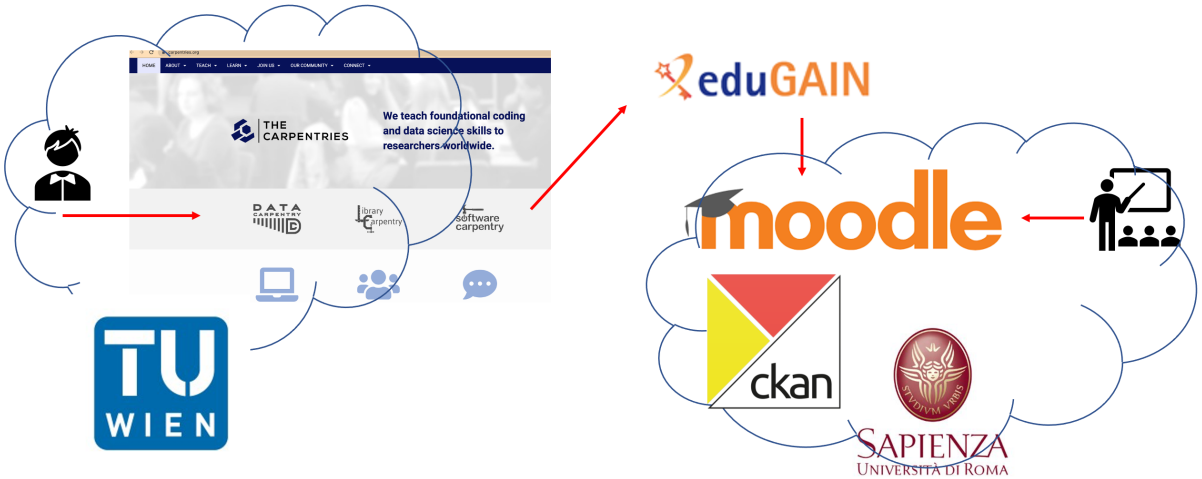

Fig. 6. Interaction on the TRAINRDM delivery platform between two given partners: one delivering a module, SAPIENZA, and another hosting an instance in Moodle TUW.

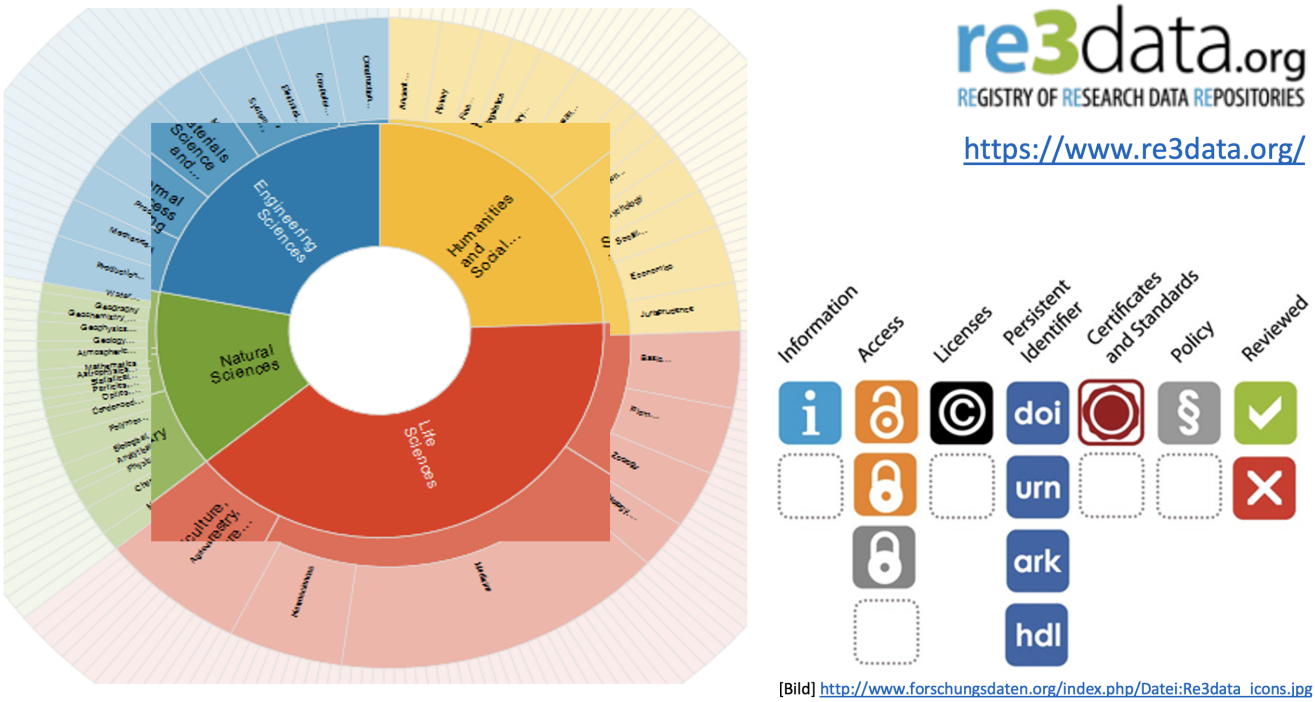

Fig. 7. Re3data: The Registry of Research Data Repositories

TABLE I
MATRIX OF COMPETENCIES PER TRAINRDM PARTNER

Competency	UPB	TUW	NCI	DTSL	SAPIENZA	ICI
Data Management Plan		✓				✓
Research Ethics		✓	✓		✓	
Data Stewardship		✓				✓
Data Protection		✓	✓			
IPR		✓		✓	✓	
FAIR	✓	✓	✓		✓	
Data Visualisation		✓				
Data Analytics	✓		✓			
Federated Content Management Systems	✓		✓			✓
GDPR	✓		✓			
Open Innovation				✓	✓	
Open Science	✓					✓
Open Source				✓		✓

need to share for others to be able to reproduce your research.

Step 2: Choose a data repository or other sharing platform. Data should be shared in a formal, open, and indexed data repository where possible so that it will be accessible in the long run. Suitable data repositories by subject, content type or location can be found at Re3data.org (see Figure 7), and in FAIRsharing where you can also see which standards (metadata and identifier) the repositories implement and which journal/publisher recommend them. If possible use a repository that assigns a DOI, a digital object identifier, to make it easier for others to cite your data.

Step 3: Choose a licence and link to your paper and code, so that others know what they can do with your data, you need to apply a licence to your data. The most commonly used licences are Creative Commons, Open Government Licence, or an Open Data Commons Attribution License. To get maximum value from data sharing, make sure that your paper and code both link to your data, and vice versa, to allow others understand your project better.

Step 4: Upload your data and documentation In line with the FAIR principles, upload the data in open formats as much as possible and include sufficient documentation and metadata so that someone else can understand your data. It is also essential to think about the file formats in which the information is provided. Data should be presented in structured and standardised formats to support interoperability, traceability, and effective reuse. In many cases, this will include providing data in multiple, standardised formats, so that it can be processed by computers

and used by people.

A. Delivery Platform

As an integral part of the project, we are developing a *Distributed Training Platform* to share online digital training materials with Students and Early Stage Researchers. The platform will :

1) host online training sessions and be able to seamlessly collect feedback; and,
2) be a Living Lab for fostering hands-on activities on OS domains, including working with open and accessible data.

Initially, we carried out an analysis of the requirements for the platform, with particularly emphasis on investigate the possibility of hosting at each institution an instance of the platform. We have also checked different standard methods for interconnection and authentication. After a comprehensive analysis involving different IT teams at the TRAINRDM partners we have selected a delivery platform based on of Moodle [23], an open-source course management system, and EduGAIN[3], the EU-funded inter-federation service interconnecting research and education identity federations in Europe and abroad.

Figure 6 presents the interactions between two partners, where SAPIENZA delivers a module and Technischen Universität Wien hosts an instance of the programme within the overall distributed platform.

V. CONCLUSIONS AND FUTURE WORK

Under the umbrella of the TRAINRDM project, we have put forward a case for the creation of training network on OS and RDM to foster a culture characterised by the transparency and broad accessibility of scholarly work where researchers share openly artefacts, almost immediately, in compliance with FAIR principles and with a wider audience.

As a key TRAINRDM deliverable, we have documented a European postgraduate programme on OS and RDM developed. Our 90-credit postgraduate programme structure is based on desk research and fully informed by a comprehensive survey collecting 239 responses from researchers across Europe, representative of a 2.58 million population—the total number of researchers employed in the EU-27 region. We have mapped out existing skills and offerings at different TRAINRDM partner institutions to produce a fully-online postgraduate programme with micro-credentials, fully distributed delivery, and compliance to FAIR principles to address academic and industrial research needs.

The programme is expected to be fully validated and admitting students across Europe from October 2023. Future work will entail a fully exchangeable micro-credential system with European coverage and a procedure to allow a student to assemble a module from different components offered by TRAINRDM partners but eventually by any authorised provider.

[3]https://edugain.org/

ACKNOWLEDGEMENTS

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