



# Digital skills for FAIR and open science

Report from the  
EOSC Executive  
Board Skills and  
Training Working  
Group

Independent  
Expert  
Report

EOSC Executive Board  
WG Skills and Training  
February 2021

Research and  
Innovation

## Digital skills for FAIR and open science

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# **Digital skills for FAIR and open science**

## ***Report from the EOSC Executive Board Skills and Training Working Group***

Edited by: the EOSC Executive Board

February 2021

Editors

Michelle Barker, Natalia Manola, Vinciane Gaillard, Iryna Kuchma, Emma Lazzeri and  
Lennart Stoy



### *A note from the chairs*

Science is reinventing itself more than ever and we have gone a long way towards building the knowledge society. As an example, it took only 50 years to evolve from a slow-paced “ivory tower” model where individual (almost exclusively male) scholars read and wrote paper books, commentaries and articles to a high-speed “carousel” model where groups of (more and more diverse) knowledge makers collaborate in multi- or even interdisciplinary teams to tackle big societal challenges, read and write e-books, tweets and blogposts and e-articles. In the ivory tower model, scholars produced a limited amount of data and the data were usually not shared. In the carousel model, the increasingly huge flow of data produced and shared is one of the main drivers of new research workflows.

The critical need to equip the carousel knowledge makers with appropriate competences and skills is at the heart of this report. Digital skills for FAIR and open science are a key enabler for the implementation of the new European Research Area, enhancing collaboration that will in turn accelerate research and innovation, as well as increase trust in science to be conducted with and for society. The EOSC Skills and Training Working Group has given us the opportunity to bring experts from around a diverse European landscape to better understand where we stand now and to recognise the many challenges EOSC will face in the next years. Coherence, alignment, continuity and permanence were in our thinking and are reflected throughout this report.

Passing the baton to the EOSC Association, we would like to give our sincere thanks to all group members for their contribution to the process, participating in numerous discussions and debates with enthusiasm and dedication. Our short 10-month period, which coincided with the start of the COVID-19 pandemic, shows a vibrant and persistent community which is set out to make EOSC a success.

## List of members of the EOSC Skills and Training Working Group

Co-chaired by Natalia Manola (OpenAIRE) and Vinciane Gaillard (European University Association), the WG included experts nominated by Member States and Associate Countries and EOSC projects.

*The full list of EOSC Skills and Training WG members is provided below.*

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<b>Angus Whyte</b>	Digital Curation Centre (DCC)

## List of abbreviations

<b>AC</b>	Associate Countries
<b>AI</b>	Artificial Intelligence
<b>API</b>	Application Programming Interface
<b>Athena RC</b>	Athena Research Centre
<b>BCUL</b>	Bibliothèque Cantonale et Universitaire Lausanne
<b>CARE</b>	Collective benefit, Authority to control, Responsibility, Ethics
<b>CERTH</b>	Centre for Research and Technology Hellas
<b>CERIF</b>	Common European Research Information Format
<b>CESSDA</b>	Consortium of European Social Science Data Archives
<b>CLARIN</b>	Common Language Resources and Technology Infrastructure
<b>CSIC</b>	Consejo Superior de Investigaciones Científicas
<b>DARIAH</b>	Digital Research Infrastructure for the Arts and Humanities
<b>DCMI</b>	Dublin Core Metadata Initiative
<b>DMP</b>	Data Management Plan
<b>EIF</b>	EOSC Interoperability Framework
<b>EOSC</b>	European Open Science Cloud
<b>ERIC</b>	European Research Infrastructure Consortium
<b>ESFRI</b>	European Strategy Forum on Research Infrastructures
<b>EU</b>	European Union
<b>ETHRD IG</b>	Education and Training on handling of research data Interest Group, Research Data Alliance
<b>FAIR</b>	Findable, Accessible, Interoperable, Reusable
<b>GDPR</b>	General Data Protection Regulation
<b>IARLA</b>	International Alliance of Research Library Associations
<b>ICDI</b>	Italian Computing and Data Infrastructure
<b>ICT</b>	Information and Communications Technology
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>LIBER</b>	Ligue des Bibliothèques Européennes de Recherche – Association of European Research Libraries
<b>LiDA</b>	Lithuanian Archive for Social Sciences and Humanities
<b>LOM</b>	Learning Object Metadata
<b>LRMI</b>	Learning Resource Metadata Initiative
<b>MVE</b>	Minimum Viable EOSC
<b>MS</b>	Member States
<b>OER</b>	Open Educational Resources
<b>RDA</b>	Research Data Alliance
<b>RDM</b>	Research data management
<b>SCORM</b>	Shareable Content Object Reference Model
<b>SPARC</b>	Scholarly Publishing and Academic Resources Coalition
<b>SRIA</b>	Strategic Research and Innovation Agenda
<b>UPV</b>	Universitat Politècnica de València
<b>WG</b>	Working Group

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## EXECUTIVE SUMMARY

Digital skills for FAIR<sup>1</sup> and open science are a cornerstone of the European Open Science Cloud (EOSC)'s operations and future. An EOSC network of skilled professionals is essential to bring a culture change for sharing research outcomes, and to empower individuals and institutions to develop and maintain EOSC competences, skills and capabilities.

The EOSC Skills and Training Working Group (WG) was formed in 2020 to identify a framework for building competence and capabilities for EOSC. The WG focused on four priority areas that form the major sections of this report:

- 1. Developing the next generation of FAIR and open science professionals:** Presents a framework of all the EOSC actors (roles) in the EOSC ecosystem for whom skills and training is relevant.
- 2. Collaborating to enhance digital skills for FAIR and open science in Europe:** Reviews organisational approaches to implement training activities and programmes, through the concept of competence centres.
- 3. Building a trusted and long-lasting and trusted knowledge hub of learning and training resources and related tools:** Provides insights for an EOSC federated training catalogue as part of a sustainable training infrastructure that supports EOSC actors.
- 4. Influencing national open science policy for skills by supporting strategic leaders:** Analyses the framing of digital skills required in EOSC in the wider European agenda for skills, to provide recommendations for Member States and Associated Countries on how to support EOSC in national skills policies and strategies.

Gap analysis completed by the WG demonstrates that significant work is still needed by a wide variety of stakeholders to not only achieve the vision of EOSC, but to maximise research impact internationally. Whilst this report identifies the next steps to overcome barriers and leverage opportunities to maximise vital skills and training development, a major focus is needed to continue to advance this area in the future. The WG's recommendations on next steps are as follows:

### Main Recommendations

1. Utilise the Framework of Actors in the EOSC Ecosystem (Figure 3) in the development of initiatives, skills, training, reward and recognition frameworks and career paths necessary to support further development and mainstreaming of FAIR and open science.
2. Coordinate and align relevant skills curricula and training frameworks by generating a consensus on a core European higher education curriculum to deliver FAIR and open science skills at university level.
3. Encourage and support the competence centres approach as a framework for increasing coordinated provision of aligned training to support FAIR and open science.
4. Facilitate increased integration of FAIR and open science courses with university qualifications.
5. Build a learning and training catalogue utilising the specifications for development recommended by this WG to maximise interoperability.
6. Include learning and training resources in the EOSC Interoperability Framework (EIF).
7. Develop an EOSC Skills and Training Leadership Programme to:
  - Increase coordination of European and national policies, programmes and networks supporting the skills elements of FAIR and open science.

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<sup>1</sup> FAIR stands for Findable, Accessible, Interoperable and Reusable ((Wilkinson et al. 2016)



- Develop and promote an EOSC Skills and Training Ambassadors programme to advise national decision-makers.
- Advocate for the inclusion of skills and training of FAIR and open science into major European and national funding instruments.

## 1 INTRODUCTION

A comprehensive skills and education strategy is needed to translate the vision of a strong European Open Science Cloud (EOSC) research data ecosystem into reality. Skills and training are essential for mainstreaming FAIR and open science practices, to spark innovation that ultimately provides societal benefits. However, there are significant challenges to creating and maintaining the digitally skilled workforce needed to ensure realisation of the EOSC vision, and for ensuring that Europe maintains its leading position in open science.

To realise the vision of a strong research ecosystem with data and software at its core, EOSC has an important role to play in ensuring recognition of digitally skilled professionals, propagating opportunities to acquire FAIR and open science skills, enabling access to relevant learning and training resources and influencing strategic agendas at the national and European levels.

### Box 1 - Definitions<sup>2</sup>

**Competence or competency:** An element (topic) of theory or practice e.g., 'workflow set-up and management', combined with an expertise level to indicate whether someone has an awareness of the area, or an ability to do it, or expert knowledge of it. [individual level]

**Capability:** Competence applied at a research team or organisational level, with a defined level of expertise and responsibility, to perform a service role or work in the EOSC environment. [organisational level]

**Skill:** A competence or capability acquired or applied in a specific context, e.g., producing a research output or deploying a service. A skill may be specified in a 'skills user story'. A badge or certificate may provide evidence that a skill has been acquired, and a publication, personal profile, portfolio or CV may provide evidence that a skill has been applied.

The EOSC Skills and Training Working Group (WG) was formed in 2020 to identify a framework for building competence and capabilities for EOSC. The WG focused on four priority areas that form the basis for this report:

1. Developing the next generation of FAIR and open science professionals.
2. Collaborating to enhance digital skills for FAIR and open science in Europe.
3. Building a trusted and long-lasting federated knowledge hub of learning and training resources and related tools.
4. Influencing national open science policy for skills by supporting strategic leaders.

This report concludes with policy and implementation recommendations for a range of stakeholders to facilitate advancement in this area.

To enable easy reading of areas of specific relevance to various stakeholders, the following reading guide provides different stakeholders with an overview of what relevant information they can obtain by reading each section.

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<sup>2</sup> [https://www.eoscpilot.eu/sites/default/files/fair4s\\_eoscpilot\\_skills\\_framework.pdf](https://www.eoscpilot.eu/sites/default/files/fair4s_eoscpilot_skills_framework.pdf)

## Digital skills for FAIR and open science

<i>Report section</i>	Policy makers & funders	Universities & research organisations	Competence centres	EOSC Association	EOSC projects
<b>2</b>	Understand the importance of addressing gaps in provision of digital skills for FAIR and open science				
<b>3</b>	Identify actors/roles that need to be supported in the EOSC ecosystem	Consider diversity of employment and training needs of staff	Identify knowledge to be taught and skills to be learned	Understand range of roles that initiatives must address	Ensure projects consider appropriate roles for both their staff and users
<b>4</b>	Consider how to support competence centres and encourage collaboration	Consider how to establish competence centres	Learn about governance, business models and alignment approaches of other competence centres	Consider how to encourage and support competence centres approach	Ensure projects consider FAIR and open science training
<b>5</b>	Recognise the need for investment in hubs for training resources	Know how to provide and access learning and training resources	Learn how to maximise interoperability, FAIRness and usage of learning and training resources	Facilitate interoperability and discovery of learning and training resources	Identify and engage key stakeholders, and build learning and training catalogues according to their goals and actions
<b>6</b>	Identify actions to advance national policies on FAIR and open science	Consider how to encourage and/or implement national approaches	Understand the importance of aligning with national programmes and policies	Identify ways to increase international alignment	Not relevant
<b>7</b>	Consider all recommendations				

## 2 EOSC STRATEGIC OBJECTIVES: FOCUS ON SKILLS

EOSC is a trusted digital platform for the scientific community, providing seamless access to data and interoperable services that address the whole research data cycle, from discovery and mining to storage, management, analysis and reuse across borders and scientific disciplines. This section explains the broader EOSC vision and the importance of skills, and how the work of this WG contributes to this, including the gap analysis undertaken by the WG.

In recognition of the importance of skills and to align with the New Digital Skills Europe objective (European Commission 2020d), EOSC sets out to develop a large digital talent pool across a wide range of profiles. EOSC is expected to facilitate and constitute an open research labour force of data scientists who have expertise in analytics, statistics, machine learning, data mining and data management; data stewards who have strong domain knowledge and the ability to apply this know-how within organisations to create value; research software engineers who are able to develop and maintain research tools, software and workflows; research support staff who can provide their expertise on sharing research in an open, FAIR way, while taking care of legal, intellectual property and ethical aspects.

A comprehensive skills and education strategy for EOSC allows important spill-over effects with other strategic objectives, such as Artificial Intelligence (AI) (European Commission 2020b) or the New Skills Agenda for Europe (European Commission 2020a), and funding programmes including Digital Europe, Erasmus+ and Horizon Europe. Skills development for EOSC will also facilitate the development of the workforce in industry, e.g., to build up pan-European Data Spaces as envisaged in the European Strategy for Data (European Commission 2020c), and extending the data value chain to citizens and the public.

### 2.1 *EOSC vision*

The Strategic Research and Innovation Agenda (SRIA, forthcoming) developed by EOSC features a synthetic presentation of the problems, barriers, objectives and benefits to achieve the EOSC vision. The SRIA is based on the EOSC Objectives Tree (Figure 1), which structures the aims of EOSC in terms of people, data and infrastructures. The strategic objective related to people envisions that open science practices and skills are rewarded and taught, becoming the 'new normal'. However, the absence of incentives, rewards and skills that enable open science is identified as a key barrier.

### European Open Science Cloud Objectives Tree

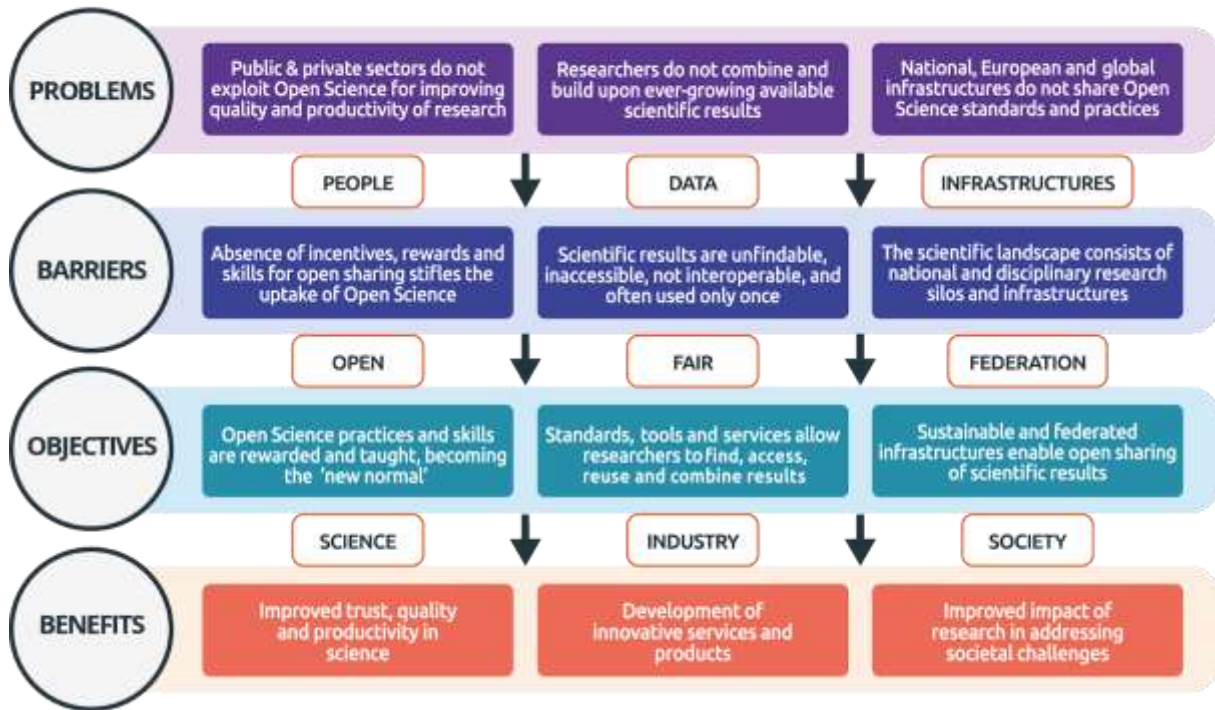


Figure 1. EOSC Objectives Tree

EOSC consultation on the EOSC SRIA further identified the development of open science training and professionalisation of associated roles to be a priority, as shown in Figure 2 (EOSC Secretariat n.d.). More than 50% of the 216 respondents indicated that the responsibility for this implementation lays mainly at the European level, with the remaining responses seeing the implementation mainly at the national (25%) or institutional (20%). In other words, the community feedback on the SRIA indicates that the SRIA priority related to open science training and professionalisation of associated roles needs to involve a wider range of organisations at multiple levels than other SRIA priorities.

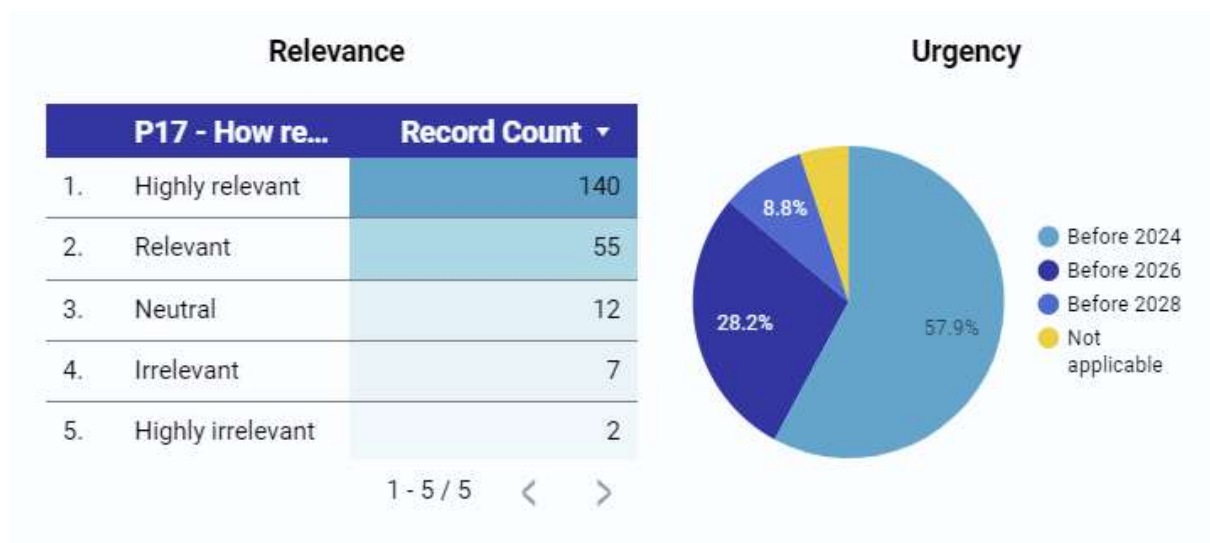


Figure 2. Community feedback on the relevance and urgency of the development of open science training and professionalisation of associated roles

To realise this vision of a strong digital research data ecosystem with data and software at its core, EOSC needs to launch a concerted effort in education and training to develop and upskill its human resources. The key actions needed for success are to:

- Promote transparency and recognition of skills and qualifications, as this is particularly relevant to the task of recognising FAIR and open science skills, and consequently the challenge to provide a framework to validate these skills.
- Foster an equitable and balanced digital research labour market, with equity and inclusiveness regarding geographical (career mobility), disciplinary, gender, ethnicity and age (career level) aspects.
- Strengthen cross-sector (research-industry-public sector) mobility and employability. Of particular importance are the transferable digital skills additional to data and Information and Communication Technologies (ICT) knowledge, such as communication and leadership. Industry and the public sector are key contributors to digital up-skilling (European Commission 2020e) and improved alignment will maximise the benefits of training provided by different sectors.
- Invest in people to create an ecosystem that promotes learning, experimenting and growth. This will include facilitating and cultivating FAIR and open science culture within research organisations (including Research Performing Organisations, funding agencies, academia) for researcher buy-in, by investing and prioritising training and collaboration tools for researchers.
- Build resilience into digital skills and training, to deal with both the "shock" of a new technology coming to the fore, or in the case of COVID-19, a suddenly need for a certain part of the population to increase a type of digital skills<sup>3</sup>. It will be necessary to design skills and training strategies that proceed at the same speed as technological developments.
- Embed the human/people factor in the design of future digital skills systems from the onset to enable recognition of step changes and work alongside the developing technology to develop training around it. EOSC will evolve as new technologies and sharing models emerge.

Against this background, the EOSC Skills and Training WG was established to address skills and training gaps in order for FAIR and open science practices to become the new normal. The WG refers to a set of concepts relevant to the Minimum Viable EOSC (MVE), which is defined below.

### **Box 2 - Minimal Viable EOSC (MVE) and associated concepts**

The Solutions for a sustainable EOSC: A FAIR Lady (olim Iron Lady) report from the EOSC Sustainability WG explores possible means for sustaining the EOSC beyond the end of 2020 (Directorate-General for Research and Innovation, European Commission, 2020). It recommends beginning with a first iteration to establish a MVE addressing the needs of publicly funded researchers exploiting openly available data. The MVE consists of the minimum set of components required for its deployment, according to a specification of the minimal functionality/features and quality of service, allowing collection of the maximum amount of EOSC stakeholder feedback with the least effort. Subsequent iterations would then expand the EOSC to address usage beyond openly available FAIR research and engage a wider user base including the public sector and the private sector.

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<sup>3</sup> COVID-19 has shown the need to upskill the most basic digital skills for a large part of the population, and for research it has demonstrated the need to upskill researchers in FAIR and open science, specifically those related to data sharing in order to respond more efficiently to the pandemic. Additionally, the pandemic has also shown a need to upskill researcher ability to interact with federated research infrastructures as a means to engaging in collaborative research.

### 2.2 Focus of the EOSC Skills and Training Working Group

The EOSC Skills and Training WG was tasked with providing a framework for building competence and capabilities for EOSC to increase alignment on key skills and training components, identify the skills and training structures needed to make EOSC sustainable, and determine how these could be embedded by different EOSC stakeholders. The WG met throughout 2020, with four task forces focusing on four priority areas:

- 1. Developing the next generation of FAIR and open science professionals.** This task force considered the development of a framework describing the skills required to develop the next generation of FAIR and open science professionals, to maximise the uptake and utilisation of EOSC for all the EOSC actors (roles) in the EOSC ecosystem.
- 2. Collaborating to enhance digital skills for FAIR and open science in Europe.** This task force evaluated approaches that organisations at different levels use to implement their skills and training programmes to facilitate FAIR and open science within the EOSC ecosystem.
- 3. Building a trusted and long-lasting knowledge hub and related tools.** This task force reviewed current initiatives to consider the development of a federated EOSC catalogue for training resources as a means for creating a knowledge hub.
- 4. Influencing national open science policy for skills by supporting strategic leaders.** This task force investigated the placement of Digital Skills for FAIR and open science within national strategies with the goal to support EOSC implementation. The final study was commissioned to LDK Consultants<sup>4</sup>.

In addition to conducting interviews and surveys with target groups on specific issues, the WG consulted with a range of initiatives from MS and AC, Horizon 2020 EOSC projects, international research discipline organisations and grassroots communities. WG engagement included presentations at the EOSC Consultation Day<sup>5</sup>, May 2020 (slides<sup>6</sup>); European Strategy Forum on Research Infrastructures (ESFRI) Research Infrastructures - EOSC Workshop<sup>7</sup>, October 2020 (slides<sup>8</sup>); and EOSC Governance Symposium<sup>9</sup>, October 2020 (slides<sup>10</sup>).

### 2.3 Gap analysis

EOSC will strive to shift the culture of research towards openness and transparency, and to build bridges between different organisational models, while working on existing initiatives and preconditions. It is therefore crucial to overcome existing gaps and barriers in digital skills for FAIR and open science and related training quickly, to lower the risks for Europe losing a leading position in open science. The WG conducted a gap analysis and identified the following issues:

**Lack of open science and data expertise:** Using or developing digital tools is becoming an increasingly important part of research (OECD 2020a; 2020b). However, there are not enough adequately trained people to meet current demand for FAIR and open science needs, let alone increasing demand. Legal, intellectual property rights and data ethics expertise is a challenge even among FAIR data and open science experts, while the

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<sup>4</sup> <https://www.ldk.gr/index.php/en/>

<sup>5</sup> <https://www.eoscsecretariat.eu/events/eosc-consultation-day>

<sup>6</sup> <https://repository.eoscsecretariat.eu/index.php/s/ZL9Do7ybejWaAXA>

<sup>7</sup> <https://www.esfri.eu/esfri-events/2nd-esfri-ris-eosc-workshop-research-infrastructures-shaping-eosc?qt-event=1#qt-even>

<sup>8</sup> [https://www.esfri.eu/sites/default/files/Manola\\_Session-2\\_ESFRI-EOSC\\_06.10.20.pdf](https://www.esfri.eu/sites/default/files/Manola_Session-2_ESFRI-EOSC_06.10.20.pdf)

<sup>9</sup> <https://www.eoscsecretariat.eu/events/eosc-governance-symposium-2020>

<sup>10</sup> <https://www.eoscsecretariat.eu/eosc-symposium-2020-programme>

research community is not equipped to explore opportunities presented in an interdisciplinary environment.

A concerted effort is still lacking to develop the skills and capacity which is crucially needed to build and exploit the full potential of EOSC. University curricula across domains (scientific, engineering, medical, socio economical, humanities, ethical and legal), and in particular at Bachelor and Master level, do not yet commonly include FAIR, open science skills or data-related skills (e.g., skills related to stewardship, data analysis, etc.) (Stoy et al. 2020). Whilst several universities do have curricula and PhD courses dedicated to data scientists, there is a lack of widespread training on multidisciplinary usage of digital research objects and on the interoperability of the textual and numerical datasets, software and workflows, that are at the basis of EOSC.

Interdisciplinarity, coordinated and coherent approaches to skills and competences building and of education and training provision is another area of concern. There is a need for a baseline approach to data stewardship. Finally, there is insufficient support for the technological development of 'FAIR by design' needed for digital research object acquisition in all the research infrastructures and laboratories ('smart technologies'). This is a key activity to enable open data, open source software and FAIR paradigms to become a reality on a large scale, and in the near future.

**Lack of a clear definition of digital professional profiles and career paths for these roles:** Data scientists, data stewards, data curators and research software engineers are some of the different actors needed for the development of FAIR and open science. Over the past few years several European initiatives have begun to fill the gap of data professional profiles and to identify the competences that will be required, amongst them the H2020 projects, EDISON and EOSCpilot. However, the EOSC community remains far from an agreement on how these correspond to different career paths and related certification accreditation mechanisms, and how these are therefore embedded in research settings.

Although the reliance on the emerging new scholarly data and software support profiles are cornerstone elements in the implementation of FAIR mandates (German Council for Scientific Information Infrastructures (RfII) 2019; OECD 2020b) there remains significant diversity in how skills and training to support these are addressed. It seems likely inequalities in building capacities for support staff and researchers (e.g., geographical, disciplinary, gender, age career stage) in the middle or long-term will remain without a coordinated and coherent approach.

**Fragmentation in learning and training resources:** Quality and FAIRness of learning and training resources remains a challenge. Research disciplines keep creating new learning and training resources without reusing the research data management (RDM) and open science learning and training resources that form a common basis to many materials, resulting in duplication of effort. Furthermore, as new practices or infrastructure emerge, learning and training resources become obsolete or need updating. As such fragmentation reduces impact, coordination with EOSC is much needed.



### 3 DEVELOPING THE NEXT GENERATION OF FAIR AND OPEN SCIENCE PROFESSIONALS

A key challenge for Europe in leveraging the potential of EOSC to increase FAIR and open science is ensuring the availability of highly and appropriately skilled people with an excellent knowledge of standards and best practices for delivering, using, sharing and analysing FAIR data, applications and tools (services). A sustainable EOSC skills and training strategy must address different professional and research roles as well as their functioning in an organisational or team setting.

Workforce capacity development is relevant to individual and institutional actors in the whole EOSC ecosystem. Institutional capacity in a broad sense (e.g., of organisations, units or teams) is crucial for the systematic and sustainable development of EOSC. Individual level skills and competences form the basis, but “the group as a whole is more than the sum of its parts”. Research data or ICT service management, for instance, require collaboration across different roles and responsibilities.

To help guide readers, sections 3-6 of this report include a reading guide to highlight the relevance of that section for various stakeholders. This section presents a Framework of Actors in the EOSC ecosystem for whom skills and training is relevant and will provide different stakeholders with the following information:

Policy makers & funders	Universities & research organisations	Competence centres	EOSC Association	EOSC projects
Identify actors/roles that need to be supported in the EOSC ecosystem	Consider diversity of employment and training needs of staff	Identify knowledge to be taught and skills to be learned	Understand range of roles that initiatives must address	Ensure projects consider appropriate roles for both their staff and users

#### 3.1 The need for a framework of actors in the EOSC ecosystem

Many different skills and roles are mobilised in the development of FAIR and open science. But what exactly are the different skills and roles required to develop and use a complex federated infrastructure such as EOSC? How will existing roles need to adapt and change - such as data-related competences of researchers - to make full use of EOSC? There is an urgent need to provide a clear definition of the professional profiles required to cover the complete research lifecycle and career paths for these roles.

This section aims to provide a community-endorsed vision of all the EOSC actors (roles) in the EOSC ecosystem for whom skills and training is relevant. This vision stems from extensive discussions within the WG and through external validation (including events listed in section 2.2). A set of EOSC roles is identified using the MVE definition (see Box 2) which also constitutes the base set of digital skills for FAIR and open science principles required for all actors described in this framework (Directorate-General for Research and Innovation, European Commission, 2020). Relevant EOSC skills are defined for each role. This delineation of roles also aims to recognise the collaborative nature of each role - after all, the creation and use of EOSC will be a team effort.

While a range of frameworks exist to detail the digital skills of different actors, the current framework was developed to consider this issue from an EOSC perspective. The WG developed the framework through examination of existing competence frameworks in the fields of data-intensive science, RDM, open science and FAIR data, which included:

- Building digital workforce capacity and skills for data-intensive science (OECD, 2020b)
- EOSCpilot FAIR4S Framework (FAIR4S, 2019)
- Data Skills Framework (Open Data Institute, 2020)
- EDISON Data Science Framework (Demchenko et al., 2017)
- DigComp (European Commission Joint Research Centre, 2018)

Additionally, the WG examined two national initiatives focusing on the data steward role and related training requirements:

- Denmark: National Coordination of Data Steward Education in Denmark (Wildgaard et al., 2020)
- Netherlands: Towards a community endorsed data steward profession description for life science research (Scholtens et al., 2019)

Most of those frameworks have also been analysed in a briefing on FAIR competences and synergies from the FAIRsFAIR<sup>11</sup> project (Principe et al., 2020).

### 3.2 Roles, skills and interactions of actors in the EOSC ecosystem: A Framework

The Framework of Actors in the EOSC Ecosystem identifies roles, rather than job titles, as it is likely that in some cases the same person could undertake different roles (e.g., trainer and researcher, data scientist and research software engineer, etc.). The functions and actions undertaken by each role are considered to be representative rather than exhaustive due to the constant evolution in this area. The roles identified address the needs of stakeholders from the whole EOSC landscape, including research infrastructures, technology providers, service providers, data managers, researchers, policy makers (including funders), and citizens in general.

The Framework identifies **ten roles** from four distinct areas of activity: ICT, library and information science, research and the general public (represented in the outer coloured ring of Figure 3 below). The roles have been grouped based on those areas of activity, with some intra-category variability. These ten roles are “hats” that the actors will “wear” when performing specific duties, and do not necessarily apply to different people in all circumstances. Boundaries between the broad categories are meant to be flexible. Using a “persona” approach illustrates, for instance, that the data scientist/data analyst and data research infrastructure support professional roles are both associated with the ICT area of activity. In addition, the data scientist/data analyst role also connects to library and information science and to specific disciplines, as represented in the tricolour ring framing the related persona in Figure 3.

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<sup>11</sup> <https://www.fairsfair.eu/the-project>



Figure 3. Framework of Actors in the EOSC Ecosystem

Achieving interdisciplinarity is key in EOSC. Some of the roles are interdisciplinary by definition, and in other cases the interdisciplinarity will be achieved through joint teams with different roles. Cutting across most research disciplines, a set of core transversal FAIR and open science skills are fundamental to many of the roles above. These transversal skills (which are defined below) are often acquired in other activities and/or in other curricula. As a consequence, the Framework does not try to address all of them in detail.


### Box 3 – Transversal FAIR and open science skills


Transversal skills or competencies are a broad set of skills that are not specifically related to a particular role but are critically important skills that can be used in a wide variety of situations. In the context of skills for FAIR and open science, these include digital literacy/proficiency, as well as skills related to communication, ethical and legal aspects (e.g., data protection, intellectual property, licensing, etc.). The MVE includes the development of the EOSC-Core as a set of services providing the means to discover, share, access and reuse data and services; and EOSC-Exchange as a set of services storing and exploiting FAIR research outputs and encouraging their reuse. Examples of services included in the EOSC-Exchange are those that store, preserve or transport research data as well as those that provide analytical and computational services.


In the following section the description of each role is shaped around the concepts of EOSC-Core and EOSC-Exchange, as these seem to be central in the thinking of the community and the implementation of EOSC as part of the MVE: EOSC-Core is a set of services providing the means to discover, share, access and reuse data and services that provides the functionality that is required to enable open science practices to occur across domains and countries according to the EIF (see Box 2). EOSC-Exchange builds on the EOSC-Core to offer a progressively growing set of services to exploit and reuse federated data. Specific scientific disciplines will build their own community-specific set of services built on top of EOSC-Core and EOSC-Exchange. Finally, EOSC-Discipline references thematic services related to specific scientific areas following EIF principles, standards and technologies.


### 3.3 Description of the roles and related skills


This section provides, for each of the ten roles within the EOSC ecosystem, a description of the role, one situational example and a list of required skills.


 <b>Researcher</b>	
<b>Overview</b>	The researcher is the main target of the EOSC ecosystem and interacts with it to obtain, process, produce, deposit and share research data, using mainly high-level services provided by the ecosystem.
<b>Examples</b>	A researcher would browse and identify data related to different genetic variants of the flu available in a FAIR data repository and perform a phylogenetic study on samples through a service from the EOSC marketplace, creating a graphical representation as a phylogenetic tree to include in an article, referencing the data sources and processing pipelines.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• General knowledge on the EOSC ecosystem, covering the EOSC-Core and EOSC-Exchange interdisciplinary services for data access, sharing, reuse and processing, and relevant discipline-specific services.</li> <li>• Knowledge of the added value that EOSC services provide to research and publication workflows.</li> <li>• Understanding of how to assess the FAIRness of services when searching for and producing research data.</li> <li>• Skills to apply EOSC services wherever they support the research and innovation lifecycle and contribute to their development.</li> <li>• Training and communication skills to teach and educate other researchers and students on how to conduct research in the frame provided by EOSC.</li> </ul>


 <b>EOSC Enabler</b>	
<b>Overview</b>	An EOSC Enabler is a researcher in a particular discipline with technical, open science and FAIR skills who can design and partially implement discipline-specific applications using EOSC services and data, who will act as a bridge between the scientific community and the technical services.
<b>Examples</b>	An EOSC Enabler could be a researcher with technical skills who integrates a common genomic data processing suite so it runs on EOSC federated research infrastructure, retrieving and storing data which is discoverable and is properly formatted, and is accessible and reusable using EOSC-Core and EOSC-Exchange services.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Skills to use EOSC-Core and EOSC-Exchange interdisciplinary services for data access (as defined in the EIF and RoP), sharing, reuse and processing.</li> <li>• Deep understanding of FAIR principles.</li> <li>• Skills to design and coordinate the development of new high-level EOSC discipline-specific services.</li> <li>• Training and communication skills to transmit and educate researchers and technicians on the open science, FAIR and EOSC ecosystem concepts and services, as well as their added value for research communities.</li> <li>• Data facility management skills to understand the services and resources needed to conduct the activity of a research group or institution in the context of open science.</li> </ul>


 <b>Data Scientist/Data Analyst</b>	
<b>Overview</b>	A Data Scientist or Data Analyst is an expert on data processing, not necessarily from a specific discipline, who is capable of evaluating data quality, extracting relevant knowledge from data and representing such knowledge.
<b>Examples</b>	A Data Scientist or Data Analyst could be an expert who develops a general-purpose machine learning algorithm that could efficiently run on the EOSC federated research infrastructures that are consuming data from EOSC services.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Technical skills to use EOSC-Core and EOSC-Exchange services for data access, sharing, reuse and processing.</li> <li>• Deep understanding of FAIR principles for both data and software.</li> <li>• Theoretical knowledge and technical skills to design, develop and deploy data related services that comply with EIF, and are registered and discoverable through the EOSC platform.</li> <li>• Training and communication skills to teach and educate researchers and technicians on how to use the tools or to transmit the outcome of the analysis.</li> </ul>


 <b>Research Software Engineer</b>	
<b>Overview</b>	A Research Software Engineer is an ICT expert who designs, implements, maintains and/or integrates services and software in the EOSC ecosystem to enable FAIR and open science, ensuring the fulfilment of software quality, reproducibility and sustainability.
<b>Examples</b>	A Research Software Engineer could be designing, building and maintaining software that is compiled and installed by someone else. Research Software Engineers may require other ICT skills of different roles such as ICT Managers, Development Operations Engineers or Database Programmers.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Ability to acquire knowledge necessary to implement, use and onboard EOSC-Core and EOSC-Exchange services.</li> <li>• Understanding of the requirements to implement FAIR principles for data and software.</li> <li>• Training and communication skills to teach and educate researchers and technicians on how to undertake research software engineering, and potentially how to use the software and services implemented.</li> </ul>


 <b>Data Research Infrastructure Support Professional</b>	
<b>Overview</b>	A Data Research Infrastructure Support Professional is an ICT expert who manages and operates research infrastructures and the necessary services for the storage, preservation and processing of research data.
<b>Examples</b>	A Research Software Engineer could be designing, building and maintaining software that is compiled and installed by someone else. Research Software Engineers may require other ICT skills of different roles such as ICT Managers, Development Operations Engineers or Database Programmers.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Knowledge of the EOSC ecosystem principles and concepts.</li> <li>• Technical skills to securely deploy and maintain EOSC-Core and EOSC-Exchange services related to processing and storage, or to data resources such as repositories and databases.</li> <li>• Training and communication skills to teach and educate any other actor on how to use research infrastructures.</li> <li>• Facility management skills to understand the services and resources needed to sustain research activity in the research infrastructures of scientific communities supported in the context of the EOSC ecosystem.</li> </ul>

 <b>EOSC Educator</b>	
<b>Overview</b>	An EOSC Educator is an expert who designs, organises, shapes content and manages and/or coordinates training activities in the context of EOSC, participating in the delivery of the training. The EOSC Educator deeply understands the EOSC ecosystem and supervises the training activities.
<b>Examples</b>	An EOSC Educator may be responsible for the training activities related to EOSC in a major project or initiative (including at institutional or national level) that would organise training and enrol trainers and trainees in summer schools and regular training, potentially providing sessions on EOSC awareness.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Deep understanding of the EOSC ecosystem and principles, i.e., EIF and RoP.</li> <li>• Deep understanding of FAIR and open science principles, for transferring knowledge and delivering training material according to these principles.</li> <li>• Awareness on EOSC-Core and EOSC-Exchange services and on the benefits of their application in an interdisciplinary context.</li> <li>• Knowledge of learning environments that can be applied efficiently within the EOSC context, in cross-disciplinary ways.</li> <li>• Good understanding of the needs of various stakeholders to design and apply learning and training resources appropriate to different learning pathways.</li> <li>• Communication skills.</li> </ul>

	<b>Data Curator</b>
<b>Overview</b>	<p>A Data Curator is an expert on the management and oversight of an organisation's entire data to ensure compliance with policy and/or regulatory obligations for long-term preservation and to provide higher-level users with high quality data that is easily accessible in a consistent manner.</p>
<b>Examples</b>	<p>A Data Curator could collect and publish a dataset of genomic samples related to influenza with geographic annotation using domain-specific standard formats, ensuring the FAIRness of the data.</p>
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Deep understanding of FAIR principles and ability to use services for data publication and preservation.</li> <li>• Ability to validate the fulfilment of open science principles in EOSC-Core and Exchange services related to data.</li> <li>• Training and communication skills to teach and educate any other actor on how to provide and exploit curated data.</li> <li>• Knowledge and technical skills to contextualise research results, i.e., exchange and reuse existing research-related metadata (on researchers, projects, publications, organisations, equipment, etc.) contained in research information systems (such as Current Research Information Systems) or others.</li> </ul>

	<b>Data Steward/Data Librarian</b>
<b>Overview</b>	<p>A Data Steward is an expert on the preparation and treatment of data including data selection, storage, preservation, annotation provenance and other metadata maintenance, and dissemination. Data librarians are professional library staff who are experts on RDM, using research data as a resource or supporting researchers dealing with data (description, archiving and dissemination). Other closely related roles will also be considered under this category.</p>
<b>Examples</b>	<p>A Data Steward could be an expert who validates, recodes, trims or applies any other action on each source dataset of genomic samples related to influenza to guarantee that they can be properly used and integrated according to domain-specific standard formats.</p>
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Deep understanding of FAIR principles to ensure that research data from various domains is aligned with FAIR and CARE (Collective benefit, Authority to control, Responsibility, Ethics) principles.</li> <li>• Ability to use EOSC-Core and EOSC-Exchange services for data publication and preservation and to facilitate the continued development of an infrastructure and library services to support data discovery, curation, preservation and sharing according to those principles.</li> <li>• Ability to validate the fulfilment of open science principles in EOSC-Core and EOSC-Exchange services related to data.</li> <li>• Ability to advise faculty and students on RDM according to the FAIR and CARE principles, including the discovery and reuse of existing datasets, through the EOSC services and ecosystem.</li> </ul>

 <b>Citizens</b>	
<b>Overview</b>	Citizens targeted in EOSC are any kind of people having interest in one or several scientific disciplines (including, but not limited to, the open source community or commercial companies undertaking research), who want to get information or contribute to a citizen science initiative or other initiatives of general public interest, or have their own interest in learning and addressing a specific challenge which is not part of his/her professional activity.
<b>Examples</b>	A citizen with an interest in open science may agree to anonymously sharing their health information and track some lifestyle indicators such as sport activity, in return for receiving feedback on their health status.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Basic knowledge on the concept of EOSC principles (with a special focus on privacy and legal boundaries).</li> <li>• Basic ICT skills to use generic and specific applications and tools for citizen participation.</li> </ul>

 <b>Policy Maker</b>	
<b>Overview</b>	Policy makers gather information through consultation and research and reduce and extract from the information a policy, set of policies or a strategic framework which serve to promote a preferred course of action and could include financial support to research.
<b>Examples</b>	A Policy maker could be the governing board of a public health directorate who provides information from clinical practice and accesses the incidence trends of a specific disease to implement their healthcare plans.
<b>Required skills</b>	<ul style="list-style-type: none"> <li>• Reasonable knowledge on the EOSC ecosystem, with special focus on open science, privacy and security and FAIR principles, and ability to understand the extent and limitations of EOSC discipline-specific and generic services to support the EOSC principles.</li> <li>• Facility management skills to understand the services and resources needed to conduct the activity of the scientific community in the context of EOSC.</li> </ul>

### 3.4 Roles in the context of an organisation

The realisation of EOSC depends on collaboration across a wide range of different organisations. At the highest level, these fall under six broad categories: research funding organisations, research performing organisations, service providing organisations, governmental organisations, company and businesses, and other organisations as defined in the SRIA (EOSC Executive Board, forthcoming). Within each category, further differentiation can be made between higher education institutions such as universities, research infrastructures, e-infrastructures, libraries and many other types. Often organisations such as large universities will perform several functions in relation to EOSC, effectively combining the role of a research performing and service providing organisation, or even a small-scale research funder.

This means that the EOSC roles and skills identified above will be needed across a range of different organisational categories, but there may be differences as to which kind of roles - and by that the respective competences and skills - apply in particular to a specific organisational category. Roles may vary even within an organisation at the unit or departmental level. However, none of the roles will work in isolation but will be embedded in a team and organisational setting, be it in a single research group or a research infrastructure.



How then will organisations be able to develop the required skills to engage with EOSC, to develop services or to benefit from it? The need for research organisations to strategically develop digital skills for all aspects of FAIR and open science is now well recognised (German Council for Scientific Information Infrastructures (RfII), 2019; OECD, 2020b). Many research performing institutions, such as universities, are working to employ more data stewards, though this is not yet a widespread phenomenon according to available survey data (Stoy et al., 2020). Especially in the field of data stewardship there is still a high need to increase the availability of data stewards, with some arguing that “5% of overall research costs should go towards data stewardship” (Mons, 2020). However, substantial investment in the entire spectrum of required skills and expertise is essential in order to leverage FAIR data management as a common research practice. It has been estimated that about 500,000 professionals will be required to support research through experimental design and data capture, curation, storage, analytics, publication and reuse of data (Mons, 2020). The implementation of EOSC adds an additional layer of complexity, in terms of connecting (meta)data across boundaries (e.g., disciplines, physical and digital space and time) in a semantically interoperable and continuous manner, thereby reinforcing the needs for a wide range of digital skills for FAIR and open science across stakeholders.

Recognising the need to help organisations navigating the complexity of EOSC competences and skills, the EOSC Skills and Training WG sought to develop an indicative overview of the roles discussed in the previous section and their relevance for the different types of organisations as defined in the EOSC SRIA. The purpose of this overview is to guide organisations seeking to prioritise skills development in relation to their role in the EOSC ecosystem.

A short survey (N=16) was carried out within EOSC Skills and Training WG members. For each role, respondents were asked to rank “how relevant do you think the different roles are for this type of organisation with regards to EOSC related skills”, with answer options on a five-point scale from 1 (not relevant) to 5 (highly relevant). The results are graphically displayed in Table 1 in the form of mean values for each role and organisation.

Role	Research performing organisation	Research funding organisation	Service providing organisation	Governmental organisation	Companies & Business	Other
Researcher	4,81	4,31	4,06	3,13	3,56	2,92
EOSC Enabler	4,13	3,75	4,44	3,69	3,56	3,69
Data scientist/analyst	4,63	3,25	3,88	3,50	4,56	3,00
Research Software Eng.	4,19	2,88	3,94	3,06	4,06	2,54
Data RI Support Pro.	4,31	3,44	4,31	3,31	3,94	2,92
EOSC Educator	4,06	3,56	4,06	3,38	2,94	3,62
Data curator	4,13	3,06	3,75	3,69	3,63	3,23
Data steward/librarian	4,06	3,06	3,47	3,47	3,34	3,04
Citizen	2,75	2,69	2,56	4,25	3,38	3,85
Policy maker	3,19	4,31	3,13	4,69	2,75	4,17

Table 1. Relevance of EOSC roles for organisations

The cells in the table indicate the average relevance of each of the ten roles identified in Figure 3 for the six broad categories of organisation with regards to EOSC related skills, on a five-point scale. The intensity of the colouring reflects the level of relevance of each role.

Some caveats must be taken into account when interpreting the results. First, the survey was developed within and responded to by EOSC Skills and Training WG members. On the one hand, this has facilitated consistent understanding of the terminology being used, enabling consistency throughout this report as there is less agreement by stakeholders on the terminology used in the international landscape. On the other hand, some bias might be introduced due to the fact that the survey developers and respondents are coming from the same WG. Secondly, the survey was mainly completed by research performing and service providing organisations, which might have resulted in a more precise annotation of the roles important to these organisational types as compared to the other organisational types.

With these caveats in mind, the results provide a sense of how relevant the availability of the roles and their associated EOSC skills are for the different types of organisations.

**Research performing organisations**, such as higher education institutions, research institutes, or research infrastructures will require a broad range of profiles and skills. Apart from skilling researchers who are the core of the data driven science ecosystem, these are needed first and foremost among supporting staff, such as data scientists/analysts, data stewards/librarians, data research infrastructure support professionals, research software engineers or data curators. This reflects the wide range of research and research-related activities (e.g., data stewardship or research infrastructures) carried out within research performing organisations, in particular large ones.

**Service providing organisations**, for instance research infrastructures, research institutes, e-infrastructures, higher education institutions, network providing organisations, or libraries, are also seen to require a highly diverse range of profiles. Most importantly EOSC enabler and data research infrastructure support professional roles may be needed, as well as EOSC educators and researchers, albeit to a lesser extent. Different supportive roles may be somewhat relevant. This reflects the important role of service providing organisations in developing and delivering research data-related services.

**Research funding organisations** are perceived to mostly need policy makers but also staff with a researcher profile. Supportive profiles and skills, e.g., EOSC educators or EOSC enablers are deemed somewhat relevant too. This may reflect a need for research funding organisations to monitor the implementation of FAIR data policies and also to develop strategic funding initiatives together with research communities, for which different types of skills and expertise are necessary.

**Governmental organisations** may mainly require skills for policy makers, showing a certain proximity to the skills needs of funding organisations. Citizen science roles may also be of use according to the survey results.

**Companies and businesses** such as commercial service providers may require more specific profiles for data scientists/analysts, research software engineers and data research infrastructure support professionals. Supportive roles, such as data curators may also be relevant. Some researcher and EOSC enabler roles can also be important to engage with EOSC and to use its services.

**Other organisations** including advocacy organisations are deemed to need mainly policy maker roles, as well as EOSC enablers, EOSC educators or citizen profiles.

The preliminary analysis shows that many different roles will indeed be required, with varying degrees of relevance, across organisations seeking to engage with EOSC. Research performing organisations and service providing organisations in particular may require a wide range of available skills. It should be noted that the estimated relevance of certain roles does not allow conclusions on the number of staff with certain skills and the level of expertise for these skills. The majority of researchers, for example, may only need a basic competence level in (discipline-specific) FAIR practices, whereas fewer staff with roles such

as EOSC enablers, data research infrastructure support professionals, or data curators may be needed but those may need to be highly proficient in the respective EOSC skills.

This highlights that from an organisational perspective, EOSC requires a wide range of skills across function groups and proficiency levels, which in turn may require strategic planning for hiring, training and up-skilling staff with digital skills for FAIR and open science as described. This should go hand in hand with professionalising emerging roles, for instance in the areas of data management or research software engineering and developing related career paths.

In this respect, the ranking of actors needed according to organisational type, as indicated in Table 2, may be used as a starting point to set priorities for the roles defined for these actors (see section 3.2).

Rank	Research Performing organisation	Research funding organisation	Service providing organisation	Governmental organisation	Companies and businesses	Other
1	Researcher (4.81)	Researcher (4.31)	EOSC Enabler (4.44)	Policy maker (4.69)	Data scientist/analyst (4.56)	Policy maker (4.17)
2	Data scientist/analyst (4.63)	Policy maker (4.31)	Data RI Support Professional (4.31)	Citizen (4.25)	Research Software Engineer (4.06)	Citizen (3.85)
3	Data RI Support Professional (4.31)	EOSC Enabler (3.75)	Researcher (4.06)	EOSC Enabler (3.69)	Data RI Support Professional (3.94)	EOSC Enabler (3.69)
4	Data steward (4.25)	EOSC Educator (3.56)	EOSC Educator (4.06)	Data curator (3.69)	Data steward (3.69)	EOSC Educator (3.62)
5	Research Software Engineer (4.19)	Data RI Support Professional (3.44)	Research Software Engineer (3.94)	Data steward (3.56)	Data curator (3.63)	Data curator (3.23)
6	EOSC Enabler (4.13)	Data scientist/analyst (3.25)	Data scientist/analyst (3.88)	Data scientist/analyst (3.5)	Researcher (3.56)	Data steward (3.08)
7	Data curator (4.13)	Data steward (3.25)	Data curator (3.75)	EOSC Educator (3.38)	EOSC Enabler (3.56)	Data scientist/analyst (3)
8	EOSC Educator (4.06)	Data curator (3.06)	Data steward (3.75)	Data librarian (3.38)	Citizen (3.38)	Data librarian (3)
9	Data librarian (3.88)	Research Software Engineer (2.88)	Data librarian (3.19)	Data RI Support Professional (3.31)	Data librarian (3)	Researcher (2.92)
10	Policy maker (3.19)	Data librarian (2.88)	Policy maker (3.13)	Researcher (3.13)	EOSC Educator (2.94)	Data RI Support Professional (2.92)

11	Citizen (2.75)	Citizen (2.69)	Citizen (2.56)	Research Software Engineer (3.06)	Policy maker (2.75)	Research Software Engineer (2.54)
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Table 2. Ranking of EOSC actors needed according to organisational type

Cells in Table 2 indicate the roles and their average relevance of each of the ten roles identified in Figure 3 for the six broad categories of organisation with regards to EOSC related skills, on a 5-point scale (as presented in Table 1). The preliminary findings from the survey suggest, unsurprisingly, that the researcher role is ranked first for research performing and research funding organisations, whereas the policy maker role is ranked first for governmental organisations and other organisations. Interestingly, the EOSC enabler role is ranked first for service providing organisations. Finally, the data scientist/data analyst role is ranked first for companies and businesses.

Given the diverse range of roles and skills, the EOSC contribution to skills development will take place at several levels. For instance, hands-on experience acquired through working on EOSC-related projects and activities already supports the development of a first wave of EOSC professionals and researchers. Trainings activities carried out in the course of projects across EOSC profiles, e.g., researchers being trained in FAIR RDM and adjacent data-related skills, also contribute to the wider uptake of skills. **Supporting the implementation and alignment of competence centres will facilitate the emergence of 'clusters' of EOSC skills within different organisations and communities.** Such activities should be continued and, where necessary, be expanded in order to build individual skills and organisational capacities.

The WG developed a set of recommendations for additional specific training and skills-related activities to be carried out and supported in the next phase(s) of EOSC. For organisations, this provides suggestions for the planning and implementation of training activities to fully engage with and benefit from EOSC. The recommendations related to this section of the report are included below, and the full list of WG recommendations is contained in section 7.

### 3.5 Recommendations

#### Recommendations for the development of the next generation of FAIR and open science professionals

1. Utilise the Framework of Actors in the EOSC Ecosystem (Figure 3) in the development of initiatives, skills, training, reward and recognition frameworks and career paths necessary to support further development and mainstreaming of FAIR and open science.
2. Coordinate and align relevant skills curricula and training frameworks by generating a consensus on a core European higher education curriculum to deliver FAIR and open science skills at university level.

## 4 COLLABORATING TO ENHANCE DIGITAL SKILLS FOR FAIR AND OPEN SCIENCE IN EUROPE

One of the aims of the WG was to review the approaches that organisations at different levels use to implement their training activities and programmes, utilising the concept of competence centres as the mechanism for this exploration. This section explains the competence centre concept and how a number of case studies were analysed by the WG to understand how best to support it. This section will assist stakeholders to achieve the following outcomes:

Policy makers & funders	Universities & research organisations	Competence centres	EOSC Association	EOSC projects
Consider how to support competence centres and encourage collaboration	Consider how to establish competence centres	Learn about governance, business models and alignment approaches of other competence centres	Consider how to encourage and support competence centres approach	Ensure projects consider FAIR and open science training

### 4.1 The competence centre concept

Competence centres are a useful way to enable provision of the training needed to support the EOSC vision. Using or developing FAIR and open science data and software is becoming an increasingly important part of research. However, at the moment, there are not enough adequately trained people to meet the current needs for FAIR and open science skills, let alone to meet increasing demand. For instance, legal, intellectual property rights and data ethics expertise is a challenge even among FAIR and open science experts, and the research community is not equipped to explore FAIR and open science opportunities presented in an interdisciplinary environment.

Competence centres address the above-mentioned gaps by providing training, guidance resources and advisory services, empowering trainers and serving as hubs for collaboration between stakeholders.

#### Box 4 – Competence centre

FAIRsFAIR identified requirements for FAIR data competence centres, which were defined as:

*Shared hubs of expertise in implementing FAIR data stewardship principles, offering leadership, coordination and cataloguing services to connect relevant people, guidance, learning resources and curricula in different thematic areas.*

(Herterich et al., 2019)

The EOSC Skills and Training WG built on the work on competence centres completed by FAIRsFAIR. The WG identified priorities for competence centres to provide advisory services, enable harmonisation, and support dissemination, in addition to the key features of competence centres identified by FAIRsFAIR (Figure 4).



Figure 4. FAIRsFAIR summary of competence centres features (based on the characterisation of 36 competence centres, (adapted from Herterich et al., 2019, p. 9)

In addition to FAIRsFAIR, EOSC-hub’s training strategy also considered competence centres as a model of engagement and support for research communities, based on distributed centres where infrastructure and technology experts joined forces to set up community-specific services, (Sipos, 2019), creating eight competence centres (EOSC-hub, n.d.).

#### 4.2 Case studies

The WG conducted 23 interviews to provide case studies for review of the approaches that organisations at different levels use to implement their skills and training programmes on FAIR, open science and EOSC. One of the aims of the interviews was to identify commonalities in the way that organisations approached these topics; however, analysis revealed the existence of a wide range of approaches so that common practices were difficult to identify. The interviews covered the following topics:

- Positioning/priorities in service offerings
- Skills and competencies focus
- Organisational structure and business models
- Coordination and alignment with other initiatives

Interviews were conducted with ten universities, research libraries and research organisations; six research infrastructures; five national/regional initiatives and two professional associations, which are listed in appendix 1. The breakdown of interviewees is shown in Figure 5.



Figure 5. Breakdown of case studies by organisational type

#### 4.2.1 Alignment with competence centres concept

The first set of interview questions focused on skills and competencies, initiatives and programmes, training approaches alignment and assessment and certification. Almost all case studies offered a range of the skills and competencies services commonly associated with competence centres:

- Provision of training
- Data services or research software engineering
- Guidance resources and advisory services (including policy advice and implementation)
- Development of communities (e.g., communities of trainers)
- Catalogues of resources, services or policies
- Creation or dissemination of standards
- Evaluation and assessment services (for trainers and trainees, training materials, etc.)
- Hub for collaboration between stakeholders<sup>12</sup>

A detailed breakdown of the competence centre services and functions provided by each case study follows in alphabetical order, with \* denoting any cases where a particular service is planned. The colours of each row correspond to organisation type.

Universities, research libraries and research organisations	Research infrastructures
National/regional initiatives	Professional associations

<sup>12</sup> This list was adapted from the FAIRsFAIR work (Herterich et al., 2019; Newbold et al., 2020).

## Digital skills for FAIR and open science

Case study	Training	Data services	Guidance services	Communities	Catalogues	Standards	Evaluation	Hubs
Flemish Research Data Network	X	X*	X	X	X	X	X	X
Bibliothèque Cantonale et Universitaire (BCU) Lausanne	X		X		X	X		
CESSDA	X	X	X		X	X	X	
CSIC	X	X	X	X	X	X	X	X
DARIAH	X	X	X	X	X	X	X	X
ELIXIR	X	X	X	X	X	X	X	X
Gdańsk University of Technology Library	X	X	X	X	X	X	X	X
GOBLET	X		X	X	X	X	X	X
Greece: Athena RC & CERTH	X	X	X	X	X	X	X	X
Hungary: HUNOR	X		X	X	X	X	X	X
Italy: ICDI	X	X	X	X	X	X	X	X
LIBER	X		X	X	X	X		X
Library & Information Centre, University of Patras, Greece	X	X	X	X	X	X		X
Libraries of University of Lille	X	X	X			X		X
LiDA	X	X	X	X	X	X		X
LifeWatch ERIC	X	X	X	X	X	X	X	X
OPERAS	X	X	X	X	X	X	X	X
Swiss Universities	X	X	X	X	X	X	X	
TU Delft	X	X	X	X	X	X	X	X
University Library of	X	X	X		X	X		X



Case study	Training	Data services	Guidance services	Communities	Catalogues	Standards	Evaluation	Hubs
Southern Denmark								
University Library "Svetozar Marković", University of Belgrade	X		X	X	X	X		X
University of Limerick Library	X	X	X	X	X	X		X
Universitat Politècnica de València (UPV)	X	X		X	X		X	

Table 3. Competence centre services/functions

This suggests that the breadth of the FAIRsFAIR characterisation of competence centres is a useful tool for defining competence centres. A number of organisations are beginning to define themselves as competence centres, such as the Digital Competence Centre at Delft University of Technology in the Netherlands. The Digital Competence Centre is an on-campus initiative set up to help researchers to develop the competencies needed to do FAIR research and provide hands-on support for implementing data management workflows and developing research software. The Digital Competence Centre is an initiative of the Open Science Program to help researchers at all levels.

The following case study on Gdańsk University of Technology Library further illustrates the types of services a competence centre may offer.

#### Case study: Gdańsk University of Technology Library

The Open Science Competence Centre at the Gdańsk University of Technology Library in Poland was established within the Bridge of Data project at the end of 2018 and it provides support to researchers on RDM and open science. It also helps to build legal and technical skills and competences (e.g., how repositories operate, metadata skills) and open access skills and competences (e.g., managing data as a part of publications, altmetrics and other new developments in research evaluation and metrics, etc). It provides training, one-on-one consultations, reviews Data Management Plans (DMPs) and provides advisory services that help researchers to comply with the national funder requirements. Library staff include data stewards from different disciplines and ICT support personnel. The Open Science Competence Centre collaborates with GO FAIR to ensure it utilises best practices.

#### 4.2.2 Skills and competencies focus

The second part of the case study interviews invited consideration of the following areas:

- The roles and skills that each case study aims to develop for its target groups, based on Figure 3.
- How training services are delivered.
- Certification provided, if any, and whether this integrates with university qualifications.

Almost all organisations target the roles listed in the previous section: Researchers (and students), Data Scientist/Data Analyst, EOSC educators (mainly librarians), also called EOSC promoters, Data Curators, Data Stewards and Data Librarians. Some organisations also train EOSC Enablers, Research Software Engineers, Data Research Infrastructure Support Professionals and Policy Makers.

There is some variation in the extent to which organisations provide certification leading to university qualifications. Evaluation and assessment services (for trainers and trainees, learning and training resources, etc.) are commonly offered at the level of the university and/or library in Switzerland and Serbia; and are usually provided in Ireland, Greece and Denmark where training is integrated in academic curricula. In Serbia, there is a legal obligation for library staff to undergo yearly training that is linked to evaluation and assessment. This is a collaborative effort between libraries, as staff can also be trained in/by other institutions. And at the University of Limerick Library, successful graduates of the Researcher Career Development Programme are awarded a digital badge which can be used in online resumes.

### **Case studies: Certification of training**

Universitat Politècnica de València (UPV) integrates FAIR data and open science training in curricula and through the lifelong learning programmes. UPV provides certification through national and university degrees for skills related to open science as follows:

- **Researchers:** Training provided for doctoral students through the transversal skills programme includes a basic training programme on UPV's open science services.
- **Data Scientists/Data Analysts:** UPV enrolls ~100 students each year in the Data Science Bachelor's degree or Master's degree in Big Data Analytics, Artificial Intelligence, Pattern Recognition and Digital Imaging, and Information Management.
- **Research Software Engineers:** A Computer Science and Engineering Bachelor's Degree serves over 450 students per year.
- **Data Research Infrastructure Support Professionals:** The management of research e-infrastructures is considered in the Master's degree in Cloud and High-Performance Computing and Network and Computing Engineering (with a total yearly number of students around 30) as well in optional courses of the Computer Science and Engineering degree.
- **Data Curators and Data Stewards:** These skills are covered in the Master's degree on Information Management, with an average of 20 students annually. The Data Science Bachelor's degree also partially covers some of these skills.

Lille University libraries follow a strategy to be as systematic as possible and to first target the PhD students (researchers of tomorrow), the researchers and project coordinators/managers. With regard to the latter, the long-term goal is for all projects to include standard elements of open science and for services, and for each research department to then choose ones applying to their specific needs. There are three training programmes about open science:

- **Open science programme for PhD students:** The training programme in scientific information is quite developed and targets 500 PhD candidates every year. It was previously undertaken in collaboration with three other French universities and is now offered with Université Polytechnique Hauts-de-France. It offers seven teaching units (four of which tackle open science) and supports PhD students in the dissemination of their PhD thesis. It provides students of all fields with training on copyright and open access publishing, publishing their works within the scope of ethical rules, and data management. This programme relies on 22 trainers

(librarians) and 10 non-librarian researchers and specialists. It targets approximately 200 PhD students per year. ECTS are granted to the doctoral students.

- **Open science training towards project coordinators/managers:** this programme offers support to project coordinators/managers of EU and French funded projects. It offers collective training for project coordinators on open access and RDM, and on tools to check the compliance of projects with funder requirements. It targets approximately 60-80 project coordinators per year.
- **Fabrique de la science ouverte:** This “factory” of open science proposes workshops with an interdisciplinary focus, e.g., how to download and reuse qualitative data. It targets researchers/research units and mainly provides training on open access and RDM. The programme started in 2019 and trains approximately 40-50 researchers per year. It is also open to personnel from other universities.

Ligue des Bibliothèques Européennes de Recherche – Association of European Research Libraries (LIBER) provides certification for its leadership programmes. There is no certification for its webinars and workshops, while for project-related activities certification exists on an ad hoc basis. LIBER offers several skills and competencies initiatives and activities through its renowned leadership programmes, annual conference, webinars and the production of numerous practical resources. A dedicated WG on digital skills for library staff and research operated for two years, while LIBER also leads and/or participates in training and skills building activities through funded projects.

Some organisations **link training to performance evaluation**. For example, the Lithuanian Social Sciences Data Service (LiDA) training certificates provide proof of qualifications in performance evaluations for researchers in Lithuania. Similarly, the Spanish National Research Council (CSIC) staff utilise training diplomas when they request a promotion. However, the majority of case studies had little or no linkage between their training and formal qualifications, and improvement is needed in the following areas:

- Alignment of national and EU level incentives and skills recognition: Widely accepted standards for different aspects of training and skills (for both content and delivery) are needed to assist standardisation and recognition. Whilst the development of Europe-wide certification and quality assurance aspects would be challenging, certification and acknowledgement of RDM skills could be embedded in Horizon Europe evaluation, recognition of career paths and certification schemes.
- Development of career paths that reward open science approaches and skills: Whilst some postgraduate courses now exist for functions such as data scientist or data steward, there is no defined curricula.
- Integration of digital skills training in undergraduate courses and/or professional development: Whilst a new cadre of digitally skilled professional staff is emerging, researchers across all domains also need to acquire basic skills for open science. Even when this becomes embedded in undergraduate courses to provide a new generation of researchers with these skills, ongoing professional development (life-long learning) will be required as technologies continue to evolve.

### 4.2.3 Organisational structure and business models

Interviewees were asked to identify the main lessons from the development of their current organisational structure that they would pass on to similar organisations with regard to business models and sustainability approaches, and to share their long-term plans to ensure sustainability of operations.

The case studies included a wide range of operating structures: grassroots initiatives, collaborative projects, single research-led institutions, national level (libraries, archives, data centres), research infrastructures, international bodies and professional associations.

**Some lessons learned:** Institutional support at financial, administrative and human resource levels is crucial so as to embed training and teaching as a part of daily staff duties. Policy-level commitment to training also helps, for example, at CSIC in Spain the design of an open access policy (institutional deposit mandate) and an agenda to advance training for research institutes was a key step.

Skills and training programmes are funded by a wide range of sources, including government and other external funders, the institution itself, in-kind contributions from members and mixed sources. There were also several examples of funding through *fee-for-service* models. The drivers for change also vary, and can be top down and/or bottom up. For example, whilst the policy for building skills is top down in the University Library of Southern Denmark, the approach followed for the implementation is bottom-up. There is a high level of coordination across different areas to support and encourage research staff in the implementation of open science approaches. The following case study also demonstrates the benefits of top-down approaches.

### **Case studies:** Government commissioning of training

In both Hungary and Poland, RDM training has been commissioned by funders. In 2019 the Hungarian government's National Research, Development and Innovation Office made inclusion of DMPs a requirement in their funding, and commissioned HUNgarian Open Repositories (HUNOR), a consortium established by the Hungarian higher education institutions and the Library of the Hungarian Academy of Sciences, to run RDM courses within the country to support implementation of this mandate. HUNOR trains researchers on how to write DMPs, keep them up to date, and practice FAIR and open science. The National Research, Development and Innovation Office also recognises HUNOR RDM training certificates at proposal evaluation and grant management stages.

Similarly, the Polish National Science Centre also encourages change in research practices through upskilling, facilitating training to ensure compliance with its DMP requirements. It issues official certificates of participation in their RDM and DMP training, which are provided by the Open Science Competence Centre at the Gdańsk University of Technology.

Analysis of case study approaches to these issues reinforced **that there is no one-size-fits-all solution to organisational structures and business models challenges for training programmes**, although collaboration across levels is clearly useful to improve sustainability, as shown in the next case study.

### **Case studies:** Organisational structure and business models of European research libraries

At the University of Limerick Library several partners participate in the governance, decision-making, engagement and accountability process, including the vice-president of research, each faculty, and the open science group that works leads the creation of science policy for the university. Collaborating with research projects is considered the key to ensuring implementation of policies.

At the Lille University Libraries, central university services work very closely with the library, facilitating strong engagement and exchange of input with stakeholders, external actors and services. Activity progress, projects, decision-making, budget, reporting on strategy and implementation are evaluated and assessed by the head of University, as well as at research council and library council levels. The central services work very closely with the library team, which input into other services, such as the bibliometrics

hub, thus contributing to developing the links between open science and the bibliometrics related to career progression.

At the Library and Information Centre, University of Patras, Greece, governance and decision-making processes stem from the rector and the vice-rector of the university. The main funding comes from the government and in-kind contributions from colleagues coming from other libraries. At the national level the libraries in Greece coordinate on the provision of training through the HealLink association.

A formal mechanism of accountability does not exist in the case of University Library "Svetozar Marković"; however, it does take place informally. Training librarians every year is mandatory by law, and a formal training structure exists. To ensure long-term sustainability it is considered important that training becomes part of librarians' everyday work.

#### 4.2.4 *Collaboration and alignment with other initiatives*

The final part of the interviews examined alignment with broader national initiatives to create digital skills for FAIR and open science, collaboration with initiatives with a similar focus, and the type of alignment and/or coordination by EOSC that would be beneficial. It was found that the provision of training services is frequently done in collaboration with each of the other levels (other institutions, national organisations, international organisations). Some examples are:

- The Flemish Research Data Network utilises a joint events calendar to promote training beyond institutions, encourages sharing of learning and training resources, and provides a catalogue of learning and training resources. Joint training events are organised with stakeholders including universities, higher education colleges, research institutes, strategic research centres and the Flemish consortia partners in ESFRI clusters.
- LiDA partners with the Consortium of European Social Science Data Archives (CESSDA) for discipline specific services, and at a range of levels, including attendance at train-the-trainer sessions and reuse of CESSDA learning and training resources (including some translations into Lithuanian).
- OPERAS relies on national training programmes from its national contact points and Digital Research Infrastructure for the Arts and Humanities (DARIAH) Campus and other training programmes. OPERAS is part of the Committee for Open Science in France and also collaborates with Common Language Resources and Technology Infrastructure (CLARIN), CESSDA and EGI.
- The Athena Research Centre (Athena RC) in Greece brings an open science perspective to its involvement in a National Digital Skills and Jobs Coalition as a part of OpenAIRE National Open Access Desk and RDA activities. Together with the Centre for Research and Technology Hellas (CERTH), which is a key training facility for life sciences (Elixir GR), nine national academic and research organisations, and 26 research infrastructures and non-governmental initiatives, they are part of the Open Science Task Force, a collaborative bottom-up initiative that released a proposal for a National Plan for Open Science which also includes and emphasises skills and training components.
- At national level, the Lille University Libraries collaborate with the national structure for ORCID, Couperin, RDA France, and national committees on open science.
- University Library "Svetozar Marković" partners with initiatives of the Ministry of Education related to open science and open access.

- At the University of Limerick Library, the initiatives/programmes the library offers are aligned with the national open research forum that works towards creating a national open research policy for the country. The local environment aligns with the national open research forum and the national funding agencies.
- Bibliothèque cantonale et universitaire - Lausanne (BCU) participates in the SWITCH Connectome pilot together with other Swiss libraries and the Swiss Data Science Center. University library representatives state collaboration at European level with LIBER, OpenAIRE, RDA, Confederation of Open Access Repositories, Transkribus and EU funded project-driven initiatives, such as FOSTER.
- LIBER collaborates with other European and global initiatives and associations, such as International Alliance of Library Associations (IARLA) and Scholarly Publishing and Academic Resources Coalition (SPARC) Europe.

Case studies made a number of suggestions of ways in which EOSC could assist in increasing alignment and/or coordination:

- **Setting up a collaboration platform:** A permanent coordination structure would be useful after EOSC Skills and Training WG terminates in 2020 to prioritise community development. Networking with similar organisations was found to be useful to maximise knowledge sharing, and to extend beyond disciplines and regions.
- **Inventorisation of learning and training resources:** A catalogue of reusable learning and training resources relevant to EOSC would be very valuable. These materials should be up to date, fully aligned with the FAIR principles<sup>13</sup>, should clearly identify target audience, access and reuse rights, and be available in different languages for different levels (beginners, intermediate, etc.) with clear licensing.
- **Alignment of training methodologies,** learning outcomes and learning paths, reusing e.g., The Carpentries<sup>14</sup> approach.
- **Regional and EOSC-level coordination:** Regional initiatives and institutions develop their FAIR and open science practices using different approaches and at different speeds. It would be useful at regional level to align topics, but not content.
- **Coordination of disciplinary and cross-disciplinary initiatives:** Disciplinary RDM support, training and guidelines are useful, but should not be developed or used in disciplinary silos. EOSC by design promotes interdisciplinarity, therefore it is important to cross-fertilise with different domain specific skills to facilitate interoperability and cross-disciplinary collaborations.
- **EOSC awareness raising:** Uncovering the right connections at local level is needed to facilitate the uptake of EOSC and translate it into the institutional, national and regional contexts. EOSC needs to be more deeply understood and more widely shared with the research community, and supporting structures such as libraries. Training as awareness raising creates a critical mass of EOSC users. Infrastructures should invest in training. And libraries are perfectly positioned to assist in mediating between the local and the general structures of EOSC.

Some of these suggestions align with recommendations of this WG with regard to development of a federated training catalogue and integration of national strategies. A case study of ELIXIR provides a good example of the increased impact that can be achieved through international collaboration and utilisation of a standardised training approach.

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<sup>13</sup> For a description of how to make training materials FAIR refer to Garcia et al., 2020a.

<sup>14</sup> <https://carpentries.org/>

### **Case study: ELIXIR**

ELIXIR unites Europe's leading life science organisations in managing and safeguarding the increasing volume of data being generated by publicly funded research. ELIXIR-GR (in Greece) is one of the ELIXIR nodes, which are the scientific communities within each country in ELIXIR. The nodes run national services and support local users, including offering training activities that are coordinated across all ELIXIR Nodes. ELIXIR-GR training aligns with and is complemented by other efforts at the national level, such as the Greek RDA Node, the RDA-EU Ambassador Programme and OpenAIRE. ELIXIR utilises a set of standards for offering training, including the training approach of The Carpentries where instructors lead learners through hands-on problem-solving. Since 2015 ELIXIR has trained over 30,000 participants over nearly 4,000 days of training, involving nearly 4,500 trainers (ELIXIR, 2020).

2019 analysis of the impact of ELIXIR training evidenced the very high value of this work: "The majority of survey respondents indicated that they use the tools and/or resources covered in the training 'frequently (weekly to daily)' (31.2%) or 'occasionally (once in a while to monthly)' (58.9%) in comparison to 'never' (45.8%) before having attended the training, which indicates positive uptake of the resources covered in the training. The majority of respondents indicated that they had already recommended the training to others or intended to do so (92.5%) and indicated that they had shared the training with others (60.4%)." (Gurwitz et al., 2020)

### *4.3 Recommendations*

#### **Recommendations for the enhancement of digital skills for FAIR and open science in Europe**

3. Encourage and support the competence centres approach as a framework for increasing coordinated provision of aligned training to support FAIR and open science.
4. Facilitate increased integration of open science courses with university qualifications.

## 5 BUILDING A TRUSTED AND LONG-LASTING FEDERATED KNOWLEDGE HUB OF LEARNING AND TRAINING RESOURCES AND RELATED TOOLS

Key into building a workforce that possesses the digital skills to utilise EOSC and further develop its services, is the realisation of a pan-European Knowledge Hub which will act as the backbone of a pervasive training infrastructure. It is envisaged as a distributed set of trusted training resources, which are accessed and re-used through a federation of catalogues, where both trainers and researchers will discover and share materials and tools to improve data management and sharing practices and increase the uptake of EOSC resources.

This section provides a set of detailed recommendations to different stakeholders for realising such an EOSC federated catalogue of learning and training resources, with user-centred design principles and interoperability, quality assurance and FAIR in the core. Stakeholders will find this section relevant in the following ways:

Policy makers & funders	Universities & research organisations	Competence centres	EOSC Association	EOSC projects
Recognise the need for investment in hubs for training resources	Know how to provide and access learning and training resources	Learn how to maximise interoperability, FAIRness and usage of learning and training resources	Facilitate interoperability and discovery of learning and training resources	Identify and engage key stakeholders, and build learning and training catalogues according to their goals and actions

### 5.1 The learning and training catalogues landscape

The need for learning and training catalogues was identified in the first phase of EOSC implementation and was strongly driven by the EOSC community. This was particularly conveyed by the ESFRI cluster projects (ENVRI-FAIR, PaNOSC, EOSC-Life, ESCAPE, SSHOC)<sup>15</sup>, the INFRAEOSC-05 projects (EOSC-synergy, EOSC-Pillar, EOSC-Nordic, NI4OS-Europe, ExPaNDS, FAIRsFAIR, and EOSC Secretariat)<sup>16</sup>, and the trainer community, mainly through the Community of Practice of training coordinators<sup>17</sup> coordinated by OpenAIRE. Different disciplinary communities have already identified user needs and have recognised thematic catalogues for learning and training resources as key elements also at national level, often associated with the design of EOSC competence centres.

In this varied context, the EOSC Skill and Training WG acknowledged the need for setting the principles and specifications for the federation of EOSC catalogues for learning and training resources. More specifically, the WG's goal was to map the current situation and deliver recommendations for the realisation of interoperable catalogues, i.e., to understand the interoperability and harmonisation elements required by existing and emerging catalogues. Similar to data and service catalogues in EOSC, the goal is to offer multiple access points for training, each targeting their own discipline/regional specific communities, with users (both researchers and trainers) navigating seamlessly from one to another. Learning and training resources descriptions will be aligned and available to humans and machines, ensuring their easy discoverability and re-use for composability in constructing cross-disciplinary learning paths, according to defined standards, open access and reusability in terms of formats and licences. With this in mind, it is envisaged that an **EOSC federated learning and training catalogue** (i.e., a catalogue of catalogues)

<sup>15</sup> <https://www.eosc-portal.eu/news/five-new-esfri-cluster-projects-eosc-panorama>

<sup>16</sup> <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/infraeosc-05-2018-2019>

<sup>17</sup> <https://www.openaire.eu/cop-training>



would be the mechanism to facilitate the uptake of community accepted standards and practices and provide cross-discipline and cross-national discovery for all actors described in Figure 3.

### **Box 5 – EOSC learning and training catalogue**

An EOSC learning and training catalogue will provide a federated and machine-actionable layer of metadata, aggregated from the providers of the learning and training resources who are best placed to create and deliver them and have a shared interest in pooling the curation and management of information about these resources to better support discovery by the user. It will not centralise the provision of learning and training resources.

As a federated resource, the EOSC catalogue of learning and training resources will be available for reuse in machine-actionable form by any provider and will thereby stimulate the development of new discovery services that offer added value. In essence, establishing a common metadata description of learning and training resources is about making these resources FAIR. The Open Educational Resources (OER) community has established standards that may be applied to help make these resources discoverable, even where access to them is not completely open (e.g., where enrolment or registration or fees are applicable).

The WG's work was based on related projects and initiatives who have been working on various aspects of learning and training catalogues, or have been implementing them in specific contexts as follows:

- RDA Education and Training on handling of research data Interest Group (ETHRD-IG)<sup>18</sup> whose aim is to the exchange of information about existing developments and initiatives and promotion of training/education to manage research data throughout the data lifecycle.
- H2020 INFRAEOSC-05 Training and Skills Task Force: members from EOSC-synergy, EOSC-Pillar, EOSC-Nordic, NI4OS-Europe, ExPaNDS, FAIRsFAIR, and EOSC Secretariat<sup>19</sup>, who are setting up national and regional catalogues of training material on RDM.
- H2020 INFRAEOSC-04 science cluster projects (ENVRI-FAIR, PaNOSC, EOSC-Life, ESCAPE, SSHOC)<sup>20</sup>
- which are creating learning and training resources and catalogues for domain discipline use. In particular, the ELIXIR TeSS<sup>21</sup> is a thematic registry for browsing, discovering and organising life sciences training resources, aggregated from ELIXIR nodes and 3rd-party providers and ENVRI-FAIR provides community training platform<sup>22</sup>, also based on third party resources.
- Community of Practice of training coordinators<sup>23</sup> (OpenAIRE), an informal network of research and e-infrastructures training experts to share training experiences.

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18 <https://www.rd-alliance.org/groups/education-and-training-handling-research-data.html>

19 <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/infraeosc-05-2018-2019>

20 <https://www.eosc-portal.eu/news/five-new-esfri-cluster-projects-eosc-panorama>

21 <https://tess.elixir-uk.org>

22 <https://training.envri.eu/>

23 <https://www.openaire.eu/cop-training>

In particular, WG members actively participated in all above initiatives and were able to accelerate the work by adopting community recommendations from the following workshops which set the foundation principles:

- February 2020, Community of Practice of training coordinators workshop: participants provided recommendations for a federated EOSC learning and training catalogue and its training resources ([Grootveld et al., 2020](#)).
- October 2020, “Workshop on Training Resources Catalogues Interoperability”, organised by the INFRAEOSC-05 Training and Skills Task Force, based on a proposal by FAIRsFAIR ([FAIRsFAIR, 2020](#)): attendees agreed to set up a permanent and continuous venue for exchanging information and coordinating on important topics such as interoperability, quality and sustainability. The different participants highlighted the need for a mechanism for this community to structure feedback to the various stakeholders involved (especially, but not limited to EOSC governance).

### 5.2 User-centred design

Users must be at the heart of the design for a successful EOSC learning and training catalogue infrastructure. To design the optimal EOSC learning and training catalogue federated infrastructure, it is crucial to understand how the various EOSC actors might interact with it. The Framework of Actors in the EOSC Ecosystem described in Figure 3 provides a granular view of roles, which may be either at the giving or receiving end of training, or both, depending on the topic at hand or the context. A way to better understand users is through the development of individual user stories/scenarios. The RDA ETHRD IG Focus Group on Minimal Metadata for Learning Resources<sup>24</sup> has created a metadata comparison by user stories<sup>25</sup> which serves as a starting point to develop user stories for the different EOSC actors involved in training and distinguish between the following:

1. **Learners:** Researchers as the main end-users.
2. **Trainers:** Researchers, research support staff and librarians holding the role of intermediary, enabler, multiplier and trainer
3. **Services providers:** Training service providers contributing with skills and services in providing training on all matters related to EOSC<sup>26</sup>.

Consequently, the RDA ETHRD IG analysis can serve as a starting point to develop user stories for the different EOSC actors involved in training.

In order to ensure that the voices of the users are at the centre of the development of the learning and training catalogue infrastructure, the involvement of experienced user experience (UX) professionals is recommended to inform the development at all stages. Most importantly the users should be engaged from the beginning. Installing a User Forum/User feedback group that can advise in the process and will stay involved once the EOSC Learning and Training Catalogue is up and running is also recommended.

### 5.3 Metadata, interoperability, and FAIR considerations

The interoperability of learning and training catalogues is paramount to providing their federation in EOSC, where users and machines can seamlessly discover and access constituent learning and training resources. The EOSC Interoperability Framework lays out the minimum requirements and recommendations for interoperability of all digital objects, including the need for: availability in multiple general-purpose formats (metadata); use of

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<sup>24</sup> <https://www.rd-alliance.org/group/education-and-training-handling-research-data-ig/wiki/ethrd-ig-focus-group-materials>

<sup>25</sup> <https://docs.google.com/spreadsheets/d/1oJTejTDIPTk3o0gqv-95DealvMMtUArwqGDLmwrTMOM/edit#gid=51724188>

<sup>26</sup> Adapted from Grootveld et al., 2020.

open specifications including open and/or standard APIs; and clear protocols and building blocks for the federation/harvesting of semantic artefacts catalogues (Corcho et al., 2020).

### 5.3.1 Metadata schemas

The “Workshop on Training Resources Catalogues Interoperability” identified **classification and exposure of metadata** of training resources as one of the most challenging, yet highest priority aspects to ensuring the interoperability of training catalogues (FAIRsFAIR, 2020).

Metadata for describing learning and training resources are already fully defined in a number of standards that have been developed in the OER community. Learning and training catalogues that are already well-established use different standards: e.g., ESFRI cluster project ENVRI-FAIR uses IEEE LOM - Learning Object Metadata<sup>27</sup>, ELIXIR’s TeSS uses Bioschemas<sup>28</sup>, Foster Open Science<sup>29</sup> uses SCORM<sup>30</sup>, while a major US-based catalogue in earth sciences, the Data Management Training Clearing House<sup>31</sup> uses Learning Resource Metadata Initiative (LRMI)<sup>32</sup> from the Dublin Core Metadata Initiative (DCMI). In short, the fragmentation has already started.

The adoption of varying standards by catalogue services reflects their relative advantages and disadvantages for the training communities, which have different practices and priorities (e.g., search engine visibility). Mapping between these standards will be essential if an EOSC federated learning and training catalogue is to be interoperable with community-specific catalogues.

Similar to developments related to research data catalogues, where options for canonical schema representation such as DCAT2, CERIF, DDI-CDI, schema.org are presiding, recent work in ENVRI-plus and FAIRsFAIR have identified the need to map each variant standard to a **superset**, in preference to mapping each variant to every other variant (Newbold et al., 2020). RDA ETHRD IG addresses this issue of fragmentation by seeking to establish a **minimum metadata application profile** for learning and training resources. The approach is to identify those properties of learning and training resources that are considered necessary to fulfil requirements derived from user stories across different groups of data management specialists/professionals. Starting from a broad list of terms, the IG narrows down to terms used by existing catalogue services that describe learning and training resources according to published standards for OERs (currently LRMI/DCMI, LOM and Bioschemas) identifying commonalities and potential mappings.

Table 4 provides a first attempt of key common metadata elements. The ones highlighted in blue indicate that further review and analysis is needed to reach a cross-discipline community consensus for their representation.

Descriptor	Type	Cardinality	Description
Title	Text	one	The title of the learning and training resources
Description	Text	one	A short summary describing the learning and training resources, their structure, and any information or resources required to use or deliver
PID	Text, URL, PropertyValue	one	Persistent identifier of learning and training resources, e.g., DOI

<sup>27</sup> [https://standards.ieee.org/standard/1484\\_12\\_1-2002.html](https://standards.ieee.org/standard/1484_12_1-2002.html)

<sup>28</sup> <https://bioschemas.org/>

<sup>29</sup> <https://www.fosteropenscience.eu/>

<sup>30</sup> <https://adlnet.gov/projects/scorm/>

<sup>31</sup> <https://dmtclearinghouse.esipfed.org/>

<sup>32</sup> <https://www.dublincore.org/specifications/lrmi/1.1/>

Url	URL	one	Link to the learning and training resources, if available
Author	Person, Organisation	many	Author(s) of the learning and training resources, affiliation and contact details
Date modified	Datetime, Date	one	Date/time of most recent change of learning and training resources excluding metadata
Keywords	Text	many	Keywords describing the learning and training resources
Licence	CreativeWork, URL	one	The licence of the learning and training resources
Access conditions	Text	one	Open, closed, restricted e.g., login required
Domain	Text	many	A field of science or expertise from re3data subject classification
Level	Text	one	expertise level: basic, intermediate, or expert
Learning outcome	Text	many	Statements describing the measurable achievements that the learner will be able to understand after the learning is complete. These achievements should be connected to the different roles as defined within the EOSC Skills and Training WG.
Learning objective	Text	many	Statements describing what knowledge, skills or abilities a learner should acquire from using the resource. Preferably drawn from a competence framework or vocabulary e.g., terms4FAIRskills (when available).
Target group	Audience	many	Based on EOSC actors (Framework of Actors in the EOSC)
Language	Text	one	Language code based on ISO 639

Table 4. Minimum metadata for learning and training resources (adapted from Newbold et al 2020, Garcia et al 2020)

### 5.3.2 FAIR learning and training resources

Similar to other scholarly objects, learning and training resources form a rather heterogeneous group with great differences in terms of volume, size, location and digitalness, ranging from ephemeral, physical events such as face-to-face workshops through training books to well documented, digital and multimodal OERs to training catalogues. All these characteristics pose serious challenges in their findability, accessibility, interoperability and reusability as well as their generic sustainability that is implicitly included in the FAIR acronyms. Interestingly, however, the almost explosive increase in the availability of learning and training resources *about* FAIR scholarly objects and research data management best practices<sup>33</sup> did not automatically give rise to a rich, Europe-wide discussion on the sustainability and FAIRness of learning and training resources themselves.

The importance of creating learning and training resources that are FAIR has been explicitly identified, to ensure they are made available as OERs to enable reuse and adoption by others (European Commission, 2018, p. 47). Work has already been undertaken to apply FAIR to learning and training resources (Kühn & Streit, 2017; Whyte et al., 2019), including recent work in the life science community (Garcia et al., 2020b). Providers of education, training and professional development material (i.e., learning and training resources) that aims to enhance the digital skills of actors in the EOSC should ensure these resources are FAIR where possible, in the interests of boosting skills development capacity and efficiency. Making learning and training resources FAIR can also benefit providers by establishing an

33 <https://www.fairsfair.eu/events/training>; <https://www.fairsfair.eu/news/layered-cake-fair-coordination-how-many-too-many>; Hellström et al. 2019.

online record of their activity, facilitating analysis of gaps in provision, and providing a more navigable environment for learners.

This becomes more urgent, both in terms of building the EOSC federated learning and training catalogue, but also in terms of building and empowering the community of trainers who are expected to enhance the digital skills of all actors in the EOSC ecosystem.

To make their resources FAIR, providers should:

1. Consider the potential benefits of describing the resources sufficiently to enable others to reuse them
2. Obtain an identifier for the resource by depositing it with a repository
3. Share information about the resource by registering it in a catalogue
4. Ensure access conditions are clearly stated
5. Use interoperable formats
6. Apply an appropriate licence to enable others to reuse or adapt the resource
7. Clearly identify the learning outcomes for users of the resource online

### 5.3.3 *Interoperation of catalogues*

The technical interoperability of the federated learning and training catalogues is paramount to providing a centralised place where EOSC users can search training resources. To access information about a learning and training resource in a machine-readable way requires it to be discoverable, i.e., its metadata structured using an adopted schema (see the previous section) to be exposed via an API. The EOSC Interoperability Framework lays out the minimum requirements and recommendations for interoperability including the need for: digital objects to be available in multiple general-purpose formats, use of open specifications including open and/or standard APIs, and clear protocols and building blocks for the federation/harvesting of semantic artefacts catalogues ([Corcho et al., 2020](#)).

Focusing on the training specific problems, different communities and projects have different approaches to building their repositories and catalogue for learning and training resources. Thus, the need to align these approaches by making the existing learning and training catalogues discoverable and machine readable in a standardised way has been the main topic of the Workshop on Training Resources Catalogues Interoperability. The outcomes of these discussions envision the creation of the EOSC Learning and Training Catalogue by using harvesting and aggregation to gather the information from existing training catalogues. The initial step towards harvesting is the definition of a process for onboarding a learning and training catalogue with the harvester.

Similarly to the service onboarding procedure for the service catalogue, the learning and training catalogue onboarding procedure needs to ensure that the minimum requirements are met in terms of quantity and quality of the resources when adding a learning and training catalogue to the list of harvested ones. Because the preparation for harvesting of existing learning and training catalogues requires time and further development, an initial transition period may be needed during which manual registration of learning and training resources can be allowed to training providers that adhere to the RoP.

### 5.4 *Quality assurance*

Efforts should be made to maintain the quality of the learning and training resources, and a community endorsed framework for quality assurance is needed as learning and training resources can quickly become obsolete and regular updating might be resource intensive.

The proposed framework can be based on ongoing work in RDA ETHRD IG which has produced the “Core Characteristics of Learning Resource Collectors” draft report<sup>34</sup>, focusing on the evaluation and understanding of how a certain collection of learning and training resources is selected, managed and sustained over time (RDA ETHRD IG, 2020). Divided into four sections - content, descriptions, governance and operations – these characteristics could also help to structure collections of learning and training resources. For example, does the catalogue/registry

- Make publicly available its selection criteria or collection policy, including criteria for deselection, i.e., removing the resource from public view?
- Have a publicly available document explaining procedures for quality assurance?
- Have a publicly available policy for access requirements?
- Have a continuity plan to ensure ongoing access to and preservation of its metadata?
- Have rules of participation for submitters of content?
- Support end user feedback and/or annotation/grading of the resources (e.g., star or other rating system)?
- Have a Code of conduct (if adding annotations or ratings by content users)?
- Have a clear governance model? Is there a quality check: quality assurance / review process for the learning or training resource? And for the metadata?

### 5.5 Recommendations

#### Recommendations for a trusted and long-lasting federated knowledge hub of learning and training resources and related tools

5. Build a learning and training catalogue utilising the specifications for development recommended by this WG to maximise interoperability.

6. Include learning and training resources in the EOSC Interoperability Framework (EIF).

This section provides a set of detailed recommendations for realising a federated EOSC Learning and Training Catalogue. These should be considered by Competence Centres, EOSC projects, EOSC governance and training service providers. The recommendations are based on a federated approach as part of the MVE. Existing models were considered (Whyte et al., 2019, p. 5) as well as industry standards (e.g., IEEE LOM, SCORM) defining metadata, formats, application programming interfaces, and the curation, certification, and preservation of learning and training resources. Sustainability models were also taken into account. Appendix 2 contains a more detailed list that links recommendations to key areas and breaks down actions needed to implement the recommendations and plan for sustainability, which is an issue for many learning and training catalogues established with project funding.

#### Recommendations for EOSC Learning and Training Catalogue implementation

##### Embrace user centricity from the outset

- Develop an understanding of how users will interact with the learning and training catalogue
- Involve EOSC users at all stages of development
- Ensure users’ needs are incorporated into design of learning and training catalogue

##### Align metadata of learning and training resources and ensure they become FAIR objects

- Provide federated catalogue standard through mapping of community standards

<sup>34</sup> [https://docs.google.com/document/d/1gc5zIrMN-V6sdfTO37\\_JiEFTR9vaP7C8Ue\\_IQHB5Mn0/edit](https://docs.google.com/document/d/1gc5zIrMN-V6sdfTO37_JiEFTR9vaP7C8Ue_IQHB5Mn0/edit)

- Provide descriptive metadata as linked open data
- Provide a minimal set of learning and training resource metadata
- Integrate the FAIR principles into learning and training catalogue development

### **Ensure technical interoperation of catalogues and underlying processes**

- Outline the process for onboarding a learning and training catalogue
- Define a set of supported harvesting channels
- Ensure machine discoverability and harvestability of learning and training resources
- Use open APIs to enable interoperability, adhere to open standards and use open-source software

### **Embed quality assurance mechanisms in selecting and exposing learning and training resources**

- Create and make publicly available curation and quality assurance policies
- Define quality criteria for training service providers and learning and training resources (as a community effort) and implement quality assessment

### **Ensure sustainability and future development**

- Set up community governance structure and create trust
- Engender a coordinated approach among stakeholders in skills development in order to share learning and training resources in a FAIR way, promote broader application of useful resources and avoid duplication of effort
- Ensure revenue is based on services, and not on data; data should be a community property
- Conduct cost-benefit analysis in maintaining the EOSC federated Learning and Training Catalogue and set it up according to the current best practice and economy of scale
- Enable well-structured feedback and collaboration mechanisms

## 6 INFLUENCING NATIONAL OPEN SCIENCE POLICY FOR SKILLS BY SUPPORTING STRATEGIC LEADERS

A key challenge to maximising the potential of EOSC to support FAIR and open science is ensuring the availability of highly and appropriately digitally skilled personnel, enabled by appropriate policy and programmes. The WG sought to frame the digital skills required in EOSC in the wider European agenda for skills and provide recommendations for MS and AC on how to include EOSC in national skills policies and strategies.

### Box 6 – Skills and training in the new ERA for Research and Innovation

The vision of a stronger European Research Area for the future is based on four strategic objectives. One of them consists of deepening the ERA in existing priorities, including open science and research careers. The Communication from the European Commission sets as a goal “to further progress on the free circulation of knowledge in an upgraded, efficient and effective R&I system, in particular by moving from an approach of coordination towards deeper integration between national policies. The ERA will continue to promote adequate framework conditions and inclusiveness, help develop the skills that researchers need for excellent science, and connect all actors across Europe, including in education, training and the labour market.” (European Commission 2020f, p. 5).

This section details the work undertaken by LDK Consultants to deepen the WG’s gap analysis and contains WG recommendations to be applied by various stakeholders to improve research outcomes. This section can provide the stakeholders with insights as follows.

Policy makers & funders	Universities & research organisations	Competence centres	EOSC Association	EOSC projects
Identify actions to advance national policies on FAIR and open science	Consider how to encourage and/or implement national approaches	Understand the importance of aligning with national programmes and policies	Identify ways to increase international alignment	Not relevant

### 6.1 Methodology of the LDK study

The LDK study was developed according to the following process:



An initial **Desk Research** was conducted on ongoing Digital Skills initiatives in MS/AC, accompanied by an investigation of the digital maturity of each country, its digital competitiveness and future readiness, as well as the effective impact of ICT on society and its development. A shortlist of 12 countries covering representative regions of Europe was proposed to the EOSC WG to be further analysed. Following consultations with the EOSC WG, the number countries were reduced to nine. Based on a list of experts and reference points provided by the EOSC WG for each selected country, **interviews** were conducted,



and **specific country reports** were drafted, including findings from **literature/desk review** as well.

Having completed the mapping of the nine countries, a comparison was performed, mainly qualitative, to the priorities set by EOSC. The **potential gap** or overlap has indicated whether additional emphasis should be put to the alignment of the national plans. It has also indicated whether suggested common actions were to be considered within the recommendations of EOSC.

Based on the results of the previous tasks and the emerging EOSC SRIA (EOSC Executive Board, forthcoming) and EOSC Partnership Proposal in Horizon Europe, an analysis provided insights on how to best position EOSC in national strategies and agendas. Through a **structured consultation**, insights on the following aspects:

- Data intensive science and open science: role and connection with public and industry sectors.
- Data profiles in research track. Role of university curricula in building profiles/capacities.
- Role and placement of EOSC related skills in institutional, national, thematic, industry Digital Competence Centres in the wider national scheme. Special consideration for HPC and AI related competence centres was given.
- Best use of existing human and technical infrastructure (e.g., libraries, data centres).

The consultation was accompanied by a **focus group discussion** to validate its outcomes and the resulting draft recommendations.

The framework, within which the recommendations were deployed, has taken into account:

- The COVID-19 pandemic and the rapid changes in the digital transformation of key areas, science and research included, revealing the role of data: FAIRness and OPENess, Artificial Intelligence expansion, Data Science, e-infrastructures, e-services, interoperability (technical-human), digital skills for all. This is much more relate to the development of the competent human capital to practice and facilitate EOSC Open Science principles.
- EOSC digital skills ecosystem as depicted in Figure 3 and the skills needs associated to run and use data for research (Researchers, ICT professionals, Libraries & Information Scientists).
- EOSC training infrastructure components: organisation, processes, content, resources (human and technical).
- The key thematic areas (building blocks) for human resource development and upskilling: People & Actors, Policies, Governance & Processes, Technology & Learning Environments and their translation into the assessed complexity of the EOSC ecosystem regarding digital upskilling for researchers.

### 6.2 *The national digital skills landscape*

The magnitude of the digital skills challenge requires a long-term strategy and new partnerships between European, national, regional, public and private players including civil society. The European Commission is promoting various initiatives aimed at increasing training in digital skills for the workforce and for consumers; modernising education across the EU; harnessing digital technologies for learning and for the recognition and validation of skills; and anticipating and analysing skills needs. MS and AC have also started initiatives

to upskill their workforce through national strategies, policies and implementation activities.

The following shows the importance the EU is placing on re/up-skilling its workforce within the context of Europe's digital transformation. Even though data related skills at university level plays some role when shaping national agenda, these are viewed mainly as a potential contributor to AI, especially in relation to industry and the public sector, and EOOSC is seemingly not very relevant in policy and funding considerations.

### Digital Skills in 2021 and beyond in the EU

July 2020, EC European Skills Agenda for sustainable competitiveness, social fairness and resilience<sup>35</sup>

To implement the actions and meet the objectives of the Skills Agenda, the EU will need estimated additional public and private investments in skills of around €48 billion annually.

In particular, to tackle the digital skills gap, significant investments are needed. In the new EU budget, the Commission proposes coherent and comprehensive support for building up the digital skills needed to support reskilling and upskilling in Europe for a successful digital transformation. Different funds will target different skills needs.

The EC proposal for NextGenerationEU<sup>36</sup> provides significant resources as part of a major budgetary initiative to tackle the economic and social consequences of the crisis. EU funds can act as a catalyst for investing in people's skills. In the context of the EU Recovery Plan, unprecedented financial resources are proposed to support a sustainable recovery, and investment in skills should be at the heart of these efforts. Throughout the 2021-2027 period, EU instruments such as the European Social Fund Plus with a proposed budget of €86 billion, Erasmus with a proposed budget of €26 billion and InvestEU's Social Investment and Skills window with a proposed budget of €3.6 billion can all be mobilised to help people gain better or new skills.

In particular, the European Social Fund Plus will support EU Member States to improve the quality, effectiveness and labour market relevance of national education and training systems to support the acquisition of key competences, including digital skills. It will also promote upskilling and reskilling opportunities for all, placing a particular emphasis on digital skills.

The European Global Adjustment Fund will support training, which will all have a digital skills component, to help laid-off workers find another job or set up their own business.

Erasmus+ will support digital learning from early childhood to vocational education and university education. It will also continue to support the acquisition of digital skills through cross-border experiences.

Horizon Europe will finance grants for master, PhD and post-graduate research activities in all fields including digital through Marie Skłodowska-Curie actions as well as the European Institute of Innovation & Technology.

The new Digital Europe Programme with a proposed budget €8.2 billion (€9,2 billion actual prices) will invest in advanced digital skills development to master technologies.

- Master's Programmes in cutting-edge digital technologies developed together with EU excellence centres in artificial intelligence, cyber and high-performance

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<sup>35</sup> <https://ec.europa.eu/digital-single-market/en/policies/digital-skills>

<sup>36</sup> [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_20\\_1196](https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1196)

computing. The aim is to offer 160 new master programmes training 80,000 digital specialists.

- Short-term specialised training courses in advanced digital technologies for around 150,000 job seekers and employed people especially in SMEs. The aim is to equip them with the competences that will enable the deployment of digital technologies across all sectors of the economy.
- 35,000 job placements in companies or research centres where advanced digital technologies are developed or used. The aim is to give people the opportunity to learn specialists' skills working with the latest available technologies.

Moreover, the Recovery and Resilience Facility<sup>37</sup>, powered by €560 billion in grants and loans, provides Member States with ample opportunity to fund upskilling and reskilling initiatives, with the appropriate reforms in place.

The WG commissioned LDK Consultants to produce a landscape report of national Digital Skills Initiatives in Europe (LDK SA., 2020d). The analysis targeted the extended national area, beyond EOSC or the research sector boundaries. The report considered case studies in nine MS/AC in order to provide insights on the initiatives under investigation and to serve as a baseline for an analysis on how to place EOSC in the national agendas (Figure 6).



Figure 6. Case studies for national Digital skills initiatives

The case studies focussed on the following topics related to digital skills and upskilling:

- Policy context
- Governance model
- Initiatives at national and regional level
- Implementation: instruments and infrastructure
- Certification / accreditation / competence frameworks
- Interventions for research, data, and open science

<sup>37</sup> [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_20\\_1196](https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1196)

The landscape analysis provided valuable insights with major findings on the selected countries as follows:

### **Fragmentation of governance and diverse priorities in upgrading digital skills**

- There seems to be a fragmentation regarding the establishment of a governance system for the upgrade of digital skills across sectors, on a national-wide basis.
- Many efforts and initiatives are in progress; however, no aligned approach is identified.
- Focus is given in different target groups per country, mainly addressing public services users, schools, students and teachers, labour force, and business.

### **Absence of national policy on competency building**

- It is difficult to identify the most suitable approach for upgrading digital skills. No one size fits all.
- This absence is influenced by the fact that responsibility for digital skills, research and education is often split across different national authorities.
- This stresses upon the need to establish national strategies with an integrated overview of objectives.

### **Absence of a stand-alone national strategy for digital skills in almost all countries assessed**

- In most of the countries the policy for digital skills development is usually part of the overall national strategy for the digital transformation and the extent to which focus is given on digital skills varies.
- Digital skills ecosystems are complex. In many cases, the priorities of different actors in the ecosystem in relation to FAIR and open science are not shared or aligned due to siloisation.

### **Diversity in the participation of stakeholders in each country**

- No single pattern (i.e., type of organisations involved) could be identified for stakeholder participation in the digital skills ecosystem.
- National Coalitions for Digital Skills and Jobs<sup>38</sup> gather a variety of stakeholders and provide a point of reference for coordination of disparate policies and initiatives. Even though not always active, they seem to drive the next step for the majority of initiatives that are being integrated in a single strategy.

### **Significant amounts of training are available and a single certification framework is acknowledged**

- Many training programmes exist, each possibly targeting a different group, both in the public and private sector.
- Universities offer a variety of post-graduate studies in data/big data and statistics.

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38 <https://ec.europa.eu/digital-single-market/en/national-coalitions>

- European Commission’s Digital Competence Framework for Citizens ([DigComp 2.0](#)) (European Commission, 2016) is endorsed in almost all countries assessed as the competence framework related to certification of digital skills.

**A major gap in combined action for digital skills, and education and digital skills for FAIR and open science**

- Digital skills and digital literacy programmes are more focused on the education, labour market and general public, whereas data skills are most referred to in open science.
- There is disparity in the digital skills enabled through training programmes for scientists.
- New reward systems and career paths are needed to meet the needs of new roles in the science sector, such as data scientists,
- In several scientific areas more emphasis is given to FAIR data than open science.

**Open science strategies are mostly focused on research and infrastructure, with few references in relation to digital skills**

- Skills are required at multiple levels: individual scientists, research teams, institutional services, research infrastructures, etc.
- Libraries play a crucial role not only for upgrading the necessary infrastructure (repositories) and access for open data, but also for implementing training programmes for researchers.

6.3 *Gap analysis*

A gap analysis from LDK (LDK SA., 2020c) further examined and assessed the performance in the countries under consideration, for the purpose of identifying the differences between the actual status and the EOSC goals on digital skills and training. Specific questions were developed to inform the gap analysis, and answers on country performance were assigned a maturity level as per the classification system below, detailed in Figure 7 and Figure 8.

Maturity Level	Score	Description
<b>Awareness</b>	1	There is an understanding of the need for and the benefits of the issue, but concrete action has yet happened
<b>Exploring</b>	2	The issue is explored through initiatives (including pilots) at any level (national, regional, communities, etc.) and/or by any type of stakeholder (university, local authority, government, etc.)
<b>Developing</b>	3	Key stakeholders across different levels are committed to supporting and implementing initiatives. Planning efforts for new policies and strategies are in place or some of these have been implemented
<b>Integrated</b>	4	Practices and policies are regularly reviewed and updated to ensure an integrated ecosystem

The scoring assigned to each country and question were then averaged across all countries to identify areas where action should be taken (where the lowest score is the area of the biggest gap and thus the highest priority).

## Digital skills for FAIR and open science

Question	Avg. Score (4 max)
Is there a rewarding career process for researchers who are practising open science?	<b>1.89</b>
Are digital skills profiles standardised?	<b>2.22</b>
Is there any legislation on digital skills?	<b>2.44</b>
Are there modules on FAIR and open science in the universities curricula or other university training systems?	<b>2.56</b>
Is there any academic education on data science/engineering?	<b>2.67</b>
Is there any accreditation system for data scientists, especially for public employees?	<b>2.67</b>
Are any digital skills initiatives included in national policies on FAIR and open science, AI and cybersecurity?	<b>2.67</b>
Is there any cross-sector (research-industry-public sector) cooperation to enable employee mobility and employability?	<b>2.67</b>
Are there any important initiatives on FAIR and open science, AI, cybersecurity?	<b>2.78</b>
Is there a formal policy on digital skills and training?	<b>2.78</b>
Is there any cooperation for digital upskilling with the private sector, the public sector and the research?	<b>2.78</b>
Are there any national platforms on training provision?	<b>2.89</b>
Are there advanced learning environments in place that are applying open data principles?	<b>2.89</b>
Is there a coordination or central governance mechanism on digital skills and training development?	<b>2.89</b>






Questions Related to the item									
Is there any academic education on data science/engineering?	Developing	Developing	Developing	Exploring	Exploring	Exploring	Developing	Developing	Developing
Is there a lifelong learning system on digital skills and training, and if so, is there any one targeted to public employees?	Integrated	Integrated	Developing	Exploring	Developing	Exploring	Developing	Integrated	Developing
Is there any accreditation system on data scientists, especially for public employees?	Developing	Developing	Developing	Exploring	Exploring	Exploring	Developing	Developing	Developing
Are digital skills profiles standardised?	Exploring	Developing	Developing	Exploring	Developing	Awareness	Awareness	Exploring	Developing
Is there a coordination or central governance mechanism on digital skills and training development?	Developing	Developing	Developing	Developing	Developing	Exploring	Developing	Developing	Developing
Is there any legislation on digital skills?	Integrated	Integrated	Developing	Exploring	Developing	Awareness	Developing	Exploring	Exploring
Is there a formal policy on digital skills and training?	Developing	Developing	Exploring	Exploring	Integrated	Integrated	Exploring	Integrated	Developing
Are there initiatives included in other national policies on digital skills and training?	Integrated	Integrated	Developing	Integrated	Integrated	Developing	Integrated	Integrated	Developing
Are there any important initiatives on digital skills by other stakeholders?	Integrated	Integrated	Integrated	Integrated	Developing	Developing	Integrated	Integrated	Developing
Are there any national platforms on training provision?	Developing	Developing	Developing	Developing	Developing	Awareness	Developing	Developing	Integrated
Is there any official content provider?	Developing	Developing	Developing	Developing	Exploring	Developing	Integrated	Developing	Developing
Are there educational modules on open science and open data practices in the universities curricula or other ongoing training systems of the universities?	Developing	Developing	Developing	Exploring	Exploring	Awareness	Developing	Developing	Developing
Is there a rewarding process for career researchers on open science practices?	Exploring	Developing	Exploring	Awareness	Awareness	Awareness	Exploring	Exploring	Developing
Is there any process for career development for researchers?	Integrated	Integrated	Integrated	Exploring	Exploring	Exploring	Integrated	Integrated	Developing
Is there any cross-sector (research-industry-public sector) cooperation for persons mobility and employability?	Integrated	Integrated	Exploring	Exploring	Exploring	Exploring	Exploring	Integrated	Exploring
Is there a coordination or central governance mechanism on open science or open data?	Developing	Integrated	Developing	Developing	Developing	Developing	Exploring	Integrated	Integrated
Is there any legislation on open data / science/ AI?	Developing	Developing	Integrated	Developing	Exploring	Developing	Exploring	Developing	Exploring
Is there any cooperation of the private sector, the public sector and the research?	Integrated	Integrated	Developing	Exploring	Exploring	Developing	Exploring	Developing	Exploring
Is there a formal policy on open data or open science?	Developing	Developing	Integrated	Exploring	Exploring	Developing	Exploring	Integrated	Integrated
Is there any formal policy on AI?	Integrated	Integrated	Integrated	Developing	Integrated	Integrated	Integrated	Integrated	Developing
Is there any formal policy on Cybersecurity?	Integrated	Integrated	Integrated	Integrated	Integrated	Integrated	Integrated	Integrated	Integrated
Are there initiatives included in other national policies on open data/science, AI, cybersecurity?	Integrated	Integrated	Developing	Exploring	Exploring	Exploring	Exploring	Developing	Exploring
Are there any important initiatives on open data/science, AI, cybersecurity?	Developing	Developing	Developing	Exploring	Exploring	Developing	Developing	Developing	Developing
Are there in place any advanced learning environments applying open data principles?	Developing	Integrated	Developing	Exploring	Developing	Exploring	Developing	Developing	Developing
Is there any mechanism/platform for researchers' cooperation based on open science principles?	Integrated	Integrated	Developing	Developing	Developing	Developing	Developing	Integrated	Developing

Figure 7. An indicative comparative analysis illustrating different "maturity" levels in terms of digital skills including data/open/FAIR within 9 MS/AC countries (LDK report LDK SA., 2020c)










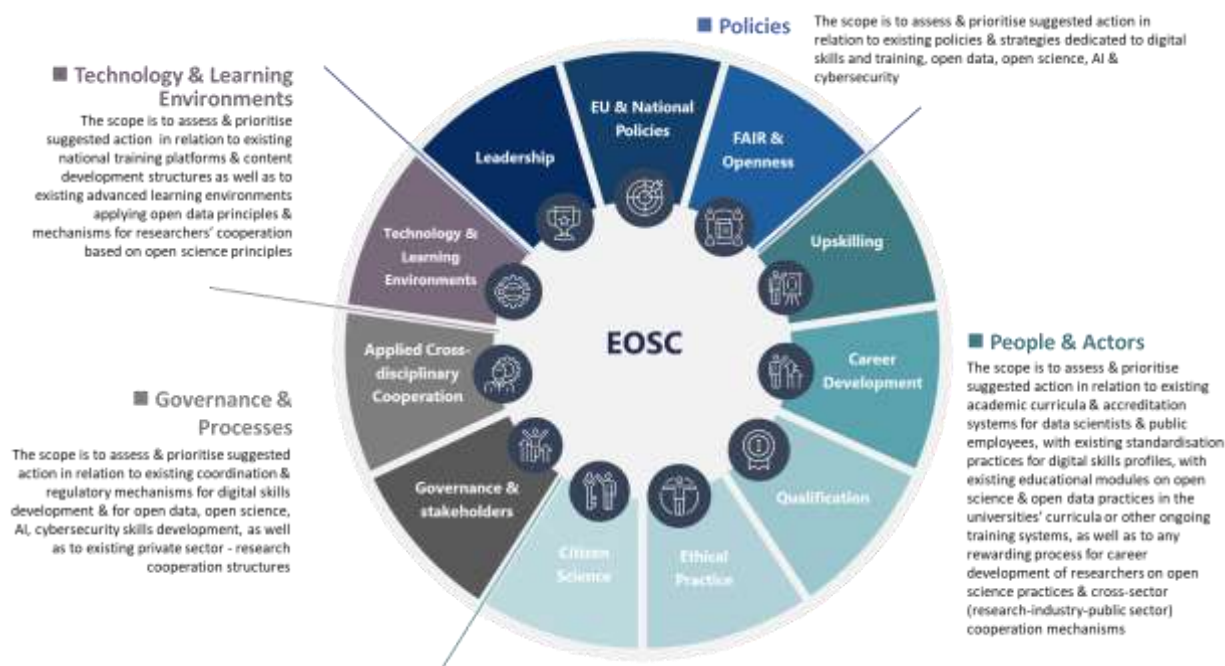
Questions Related to the item										Ave
Is there any academic education on data science/engineering?	3	3	3	2	2	2	3	3	3	2,67
Is there a lifelong learning system on digital skills and training, and if so, is there any one targeted to public employees?	4	4	3	2	3	2	3	4	3	3,11
Is there any accreditation system on data scientists, especially for public employees?	3	3	3	2	2	2	3	3	3	2,67
Are digital skills profiles standardised?	2	3	3	2	3	1	1	2	3	2,22
Is there a coordination or central governance mechanism on digital skills and training development?	3	3	3	3	3	2	3	3	3	2,89
Is there any legislation on digital skills?	4	2	3	2	3	1	3	2	2	2,44
Is there a formal policy on digital skills and training?	3	3	2	2	4	2	2	4	3	2,78
Are there initiatives included in other national policies on digital skills and training?	4	4	3	4	4	3	4	4	3	3,67
Are there any important initiatives on digital skills by other stakeholders?	4	4	4	4	3	3	4	4	3	3,67
Are there any national platforms on training provision?	3	3	3	3	3	1	3	3	4	2,89
Is there any official content provider?	3	3	3	3	2	3	4	3	3	3,00
Are there educational modules on open science and open data practices in the universities curricula or other ongoing training systems of the universities?	3	3	3	2	2	1	3	3	3	2,56
Is there a rewarding process for career researchers on open science practices?	2	3	2	1	1	1	2	2	3	1,89
Is there any process for career development for researchers?	4	4	4	2	2	2	4	4	3	3,22
Is there any cross-sector (research-industry-public sector) cooperation for persons mobility and employability?	4	4	2	2	2	2	2	4	2	2,67
Is there a coordination or central governance mechanism on open science or open data?	3	4	3	3	3	3	2	4	4	3,22
Is there any legislation on open data / science/ AI?	3	3	4	3	2	3	2	3	2	2,78
Is there any cooperation of the private sector, the public sector and the research?	4	4	3	2	2	3	2	3	2	2,78
Is there a formal policy on open data or open science?	3	3	4	2	2	3	2	4	4	3,00
Is there any formal policy on AI?	4	4	4	3	4	4	4	4	3	3,78
Is there any formal policy on Cybersecurity?	4	4	4	4	4	4	4	4	4	4,00
Are there initiatives included in other national policies on open data/science, AI, cybersecurity?	4	4	3	2	2	2	2	3	2	2,67
Are there any important initiatives on open data/science, AI, cybersecurity?	3	3	3	2	2	3	3	3	3	2,78
Are there in place any advanced learning environments applying open data principles?	3	4	3	2	3	2	3	3	3	2,89
Is there any mechanism/platform for researchers' cooperation based on open science principles?	4	4	3	3	3	3	3	4	3	3,33
Ave	3,36	3,44	3,12	2,48	2,64	2,32	2,84	3,32	2,96	

Figure 8. An indicative comparative analysis illustrating “quantified” scores in terms of digital skills including data/open/FAIR within 9 MS/AC countries (LDK report LDK SA., 2020cc)



The analysis enabled a more detailed consideration of issues in a range of areas described below.



## **EOSC people and actors**

- **Data science/engineering curricula in academia:** Very few curricula related to EOSC advanced, core expertise data skills for scientists were identified.
- **Lifelong learning related to digital skills:** Even though important activities exist in the related lifelong learning policies, little advanced training was identified to be targeting researchers or supporting personnel.
- **Data science skills certification:** No certification on advanced digital skills was identified; almost all qualification and certification systems are related to national policies for lifelong learning.
- **Standardisation of digital skills profiles:** In almost all countries, there was no evidence for the establishment of national competency frameworks related to digital skills.
- **Educational modules and curricula:** Skills development for open science as part of university education or training is regarded as a major factor towards capacity building and establishing a critical mass of professionals to serve the current demand. The analysis suggests that in the vast majority of cases the courses related to open science and open data practices are actually part of an ICT or business-related curriculum (spearheaded by courses related to data analytics and data science) and not "fit for purpose" courses towards open science that actively focus for example on educating on and promoting FAIRness principles.
- **Rewarding process for career research staff on open science practices:** Providing clear incentives and rewards for researchers' career advancement for adopting and practicing open science in their work, constitutes an important motive towards pursuing improvement of their digital skills for open science. Very few countries have established clear, specific incentives for complying with open science principles (Finland, Denmark, Switzerland). Other countries, such as the Netherlands, are clearly planning specific award schemes based on open science related performance, but most of the countries do not yet differentiate their reward structures to align with adoption of open science.
- **Research staff career development:** Most countries have a very firm and developed process for the career advancement of researchers, usually under a formal legal

framework. What is clearly missing is a set of guidelines or similar support measures to help policy makers develop and formalise clear career pathways that are custom designed to target new research staff profiles aligned with open science.

- **Cross-sector (research-industry-public sector) cooperation:** Several countries are developing specific mechanisms and measures to promote collaboration between academia, industry and government as well as mobility between researchers from foreign countries, but without providing strong coordination or support to ensure sustainability. In some countries the efforts are quite limited both in scope and in impact.

### Governance and processes

- **Coordination and governance on digital skills and training development:** There is not a unified approach on how digital skills development and training provision coordination are performed at national level, while each country seems to adopt different approaches and techniques for digital skills and competences' interdisciplinarity. There seems to be a fragmentation regarding the establishment of a governance system for the upgrade of digital skills. The National Coalitions for Digital Skills have a limited role in coordinating the efforts for digital upskilling of the various target groups.
- **Legislation on digital skills:** In almost all countries there is not any legislative/regulatory framework in place, that addresses the digital skills and competences building in a holistic approach, and no indication on the quality framework involving the digital knowledge upskilling process.
- **Coordination and governance on open science:** A dedicated and integrated coordination entity for open science or open data policies has been established in only two countries, while in other countries this role undertakes the general-purpose organisation accountable for digital strategy.
- **Legislation on open science:** Almost half of the countries of the sample are far from establishing legislation on open science / access or open data, while only two have set up a statutory scheme on data, even though their policies are not fully integrated into the legislation.
- **Cooperation of the private, public sector and the research:** Only three of the countries seem to perform well and efficiently regarding cooperation among research – public – private domains.

### Policies

- **Formal policies on digital skills and training:** The absence of a stand-alone national strategy and policy for digital skills in almost all countries assessed is revealed. In several cases, the priorities of different actors of the digital skills ecosystem lay in silos in relation to open science and open data.
- **Initiatives on digital skills and training included in other national policies:** Initiatives on digital skills and training are also identified in the national strategies for lifelong learning as well as in strategic plans for artificial intelligence and cybersecurity.
- **Initiatives on digital skills implemented by stakeholders:** In most cases, no coordination has been identified in the consolidation of outputs towards policy formation.
- **Formal policies on open science:** The need for developing and adapting an open science policy has been recognised as a key priority in all countries, but less than a third of them have moved forward with an integrated and well-planned open science

policy, while another third has in place either open science policies limited to research or scholarship communities or open access policies.

- **Formal policies on artificial intelligence:** The majority of the countries have recently developed national policies on AI, but they yet to correlate with open science skills as an enabler of open/FAIR data availability for use in applications.
- **Formal policies on cybersecurity:** All countries have recognised the need to develop and integrate cybersecurity policies. Training and skills development on cybersecurity is an inherent priority of those policies.
- **Initiatives on open science, AI, cybersecurity included in other national policies:** There is limited elaboration of the enhancement of principles on open data/science, AI, or cybersecurity sciences into other national strategies.

### Technology and learning environments

- **National platforms on training provision.** There is a wide disparity between the different platforms under which a “learning environment” is conceptualised or materialised in the various countries studied and this is probably due to the fact that there is no clear definition of scope, a national gap to cover or a “blueprint” to be followed.
- **Digital skills content providers.** There are a number of examples supporting the provision of content for the upgrade of digital skills. The ‘owner’ in each country differs in status, thus leading to different approaches to the planning and the development of the content.
- **Advanced learning environments applying open data principles.** Few coordinated entities or groups of stakeholders have the institutional, organisational and operational capacity to *immediately* undertake the role of *an all-encompassing*, central hub (such as a competence centre) to foster education and training initiatives specifically targeting all aspects of open science.
- **Research cooperation mechanisms based on open science principles.** A key requirement for promoting open science is the existence of advanced, cloud-based platforms to facilitate collaboration, data sharing, knowledge exchange, learning and access to other related value-added services for the community. Considerable difference has been observed; however, in the degree to which infrastructures are available implement open science in an out-of-the box manner.

### 6.4 Recommendations

The LDK Consultants report (LDK SA., 2020a) has produced a detailed list of recommendations that address various types of policy makers with the purpose of providing well-rounded, all-inclusive (research-government-industry-public) options to include in national strategies for Digital Skills and upskilling. They include the following aspects:

- Human capital development, including digital skills and leadership programmes.
- Cross-sectoral employability and demand driven competences development.
- Learning environments and infrastructure to support upskilling.
- Shared costs and funding structures.

The following is a list of recommendations narrowed down to the needs of EOSC skills, specifically focusing on how it can be placed in the wider national policy ecosystem.

### Recommendations for national open science policies for skills

7. Develop an EOSC Skills and Training Leadership Programme to:

- Increase coordination of European and national policies, programmes and networks supporting the skills elements of FAIR and open science.
- Develop and promote an EOSC Skills and Training Ambassadors programme to advise national decision-makers.
- Advocate for the inclusion of skills and training of FAIR and open science into major European and national funding instruments.

The following provides a set of detailed recommendations on how to include and implement in national policies the EOSC digital skills agenda, specifically describing tools that will help policy makers design and embed open science related skills in the national digital infrastructure.

### Recommendations for implementing EOSC skills agenda

Develop a mechanism (such as a maturity model) for providing data to evaluate the effectiveness of skills and training policies and initiatives.

Coordinate and align relevant skills curricula and training frameworks by generating a consensus on a core European higher education curriculum to deliver digital skills for FAIR and open science at university level

Develop reward and recognition frameworks that are integrated with new career paths to incentivise FAIR and open science practices for all research sectors staff across MS and AC.

Complement digital upskilling for open science with a robust, coordinated support network (utilising existing initiatives) for supporting infrastructures (e.g., a federated training catalogue).

Foster a robust, transparent, and participative governance structure for digital skills for FAIR and open science that supports the diversity of requirements across all disciplines, provides clear channels for feedback, and is compatible with other related initiatives at national and European level.

### 7 FINAL RECOMMENDATIONS

This section provides the final recommendations of this WG. These have a high degree of alignment with the skills and training priorities contained in the SRIA (EOSC Executive Board, forthcoming), as the WG efforts throughout 2020 have complemented the development of the SRIA.

#### Main recommendations

1. Utilise the Framework of Actors in the EOSC Ecosystem (Figure 3) in the development of initiatives, skills, training, reward and recognition frameworks and career paths necessary to support further development and mainstreaming of FAIR and open science.
2. Coordinate and align relevant skills curricula and training frameworks by generating a consensus on a core European higher education curriculum to deliver FAIR and open science skills at university level.
3. Encourage and support the competence centres approach as a framework for increasing coordinated provision of aligned training to support FAIR and open science.
4. Facilitate increased integration of FAIR and open science courses with university qualifications.
5. Build a learning and training catalogue utilising the specifications for development recommended by this WG to maximise interoperability.
6. Include learning and training resources in the EOSC Interoperability Framework (EIF).
7. Develop an EOSC Skills and Training Leadership Programme to:
  - Increase coordination of European and national policies, programmes and networks supporting the skills elements of FAIR and open science.
  - Develop and promote an EOSC Skills and Training Ambassadors programme to advise national decision-makers-
  - Advocate for the inclusion of skills and training of FAIR and open science into major European and national funding instruments.

## **8 CONCLUSION**

Developing and sustaining the skills of researchers, research support staff and EOSC service providers is essential for the success of the EOSC vision. An EOSC network of skilled professionals, forming a coordinated training infrastructure, is essential to bring a culture change for sharing research outcomes, and to empower individuals and institutions to develop and maintain EOSC competences science and capabilities.

Significant work is still needed by the EOSC Association, its members and a wide variety of stakeholders to not only achieve the vision of EOSC, but to maximise research impact internationally. Whilst this report identifies the next steps to overcome existing gaps and barriers to vital skills and training development, a major focus is needed to continue to advance this area in the future.

**APPENDIX I. COMPETENCE CENTRES CASE STUDIES**

<b>Organisation/country</b>	<b>Sector served</b>
<b>Research and e-infrastructures</b>	
Consortium of European Social Science Data Archives (CESSDA)	Social sciences
Digital Research Infrastructure for the Arts and Humanities (DARIAH)	Humanities
ELIXIR	Life sciences
LifeWatch ERIC	Environment
Lithuanian Archive for Social Sciences and Humanities (LIDA)	Social sciences
OPERAS	Social sciences & humanities
<b>Professional associations</b>	
Global Organisation for Bioinformatics Learning, Education and Training (GOBLET)	Bioinformatics
Ligue des Bibliothèques Européennes de Recherche – Association of European Research Libraries (LIBER)	Libraries
<b>National/Regional</b>	
<b>Countries</b>	
Flemish Research Data Network	Belgium
Athena Research Centre (ARC) and Centre for Research and Technology Hellas (CERTH)	Greece
HUNGarian Open Repositories (HUNOR)	Hungary
Italian Computing and Data Infrastructure (ICDI)	Italy
Swiss universities	Switzerland
<b>Institutional</b>	
Bibliothèque Cantonale et Universitaire (BCU) Lausanne	Switzerland
Spanish National Research Council (CSIC)	Spain
Gdańsk University of Technology	Poland
Delft University of Technology	Netherlands
Library and Information Centre, University of Patras	Greece
Politècnica de València (UPV)	Spain
University Libraries, University of Lille	France
University Library of Southern Denmark	Denmark
University Library "Svetozar Marković", University of Belgrade	Serbia
University of Limerick Library	Ireland





<p>Create publicly available curation and quality assurance policies</p>	<p>Training service providers</p>	<p>Define and make publicly available:</p> <ul style="list-style-type: none"> <li>- Collection policy or learning and training resources selection criteria (including criteria for deselection, i.e., removing the resource from public view)</li> <li>- Rules of participation for submitters of content</li> <li>- Procedures for quality assurance / check / review process for the learning or training resource and for the metadata</li> <li>- Workflow for the end user feedback and/or annotation/grading of the resources (e.g., star or other rating system)</li> <li>- Code of conduct (e.g., for adding annotations or ratings by content users)</li> <li>- A continuity plan to ensure ongoing access to and preservation of content and metadata (if this is for the lifetime of the project only, this should be clearly indicated)</li> </ul> <p>Provide information about authority / organisation providing the catalogue/registry and contact details, funding statement. Keep learning and training resources up-to-date and comply with FAIR principles.</p>
<p>Define quality criteria for training service providers and learning and training resources (as a community effort) and implement quality assessment</p>	<p>EOSC governance</p>	<p>Assess</p> <ul style="list-style-type: none"> <li>- Technical integrity of learning and training resources (completeness of metadata, PIDs, FAIRness, etc.)</li> <li>- Quality of content (including date of last updates)</li> </ul> <p>Provide usage metrics. Develop a self-assessment checklist for quality control for training service providers.</p>
<p>Engender a coordinated approach among stakeholders in skills development<sup>39</sup></p>	<p>EOSC governance</p>	
<p>Set up community governance structure and create trust</p>	<p>EOSC governance</p>	<p>Ensure strategic governance that allows community input on the direction of the service and operational governance with community representation and decision-making power.</p>
<p>Use open APIs and open-source software</p>	<p>EOSC governance</p>	<p>Make all software required to run the infrastructure available under an open source license. Commit to a patent non-assertion covenant.</p>
<p>Create revenue based on services not data</p>	<p>EOSC governance</p>	<p>Identify appropriate revenue sources, for example value-added services, consulting, API Service Level Agreements or membership fees. Make data available under the CC0 waiver. Make data easily available via periodic data dumps.</p>
<p>Conduct cost-benefit analysis to establish best practice and economy of scale</p>	<p>EOSC governance</p>	<p>Calculate general and development costs:</p> <ul style="list-style-type: none"> <li>- Maintenance (day-to-day operations and developments if needed)</li> <li>- Content provision (content acquisition, metadata management)</li> </ul> <p>Ensure broad engagement; the breadth of scope and service-related coverage; adoption of community-supported machine-readable standards; and semi-automated approach for updates</p>

<sup>39</sup> This was also a recommendation of previous work (Whyte et al., 2019).

## Digital skills for FAIR and open science

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		Give back to the community - e.g., widgets and APIs (organisations readily import information about relevant events and materials to their site using widgets, or may create custom feeds using our API)
Enable well-structured feedback mechanisms	EOSC governance, EOSC projects	Define the structure for a community driven feedback mechanism. Identify and set up the venue for providing feedback and input to the various stakeholders

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This document has been developed by the Interoperability Task Force of the EOSC Executive Board FAIR Working Group, with participation from the Architecture WG.

Achieving interoperability within EOSC is essential in order for the federation of services that will compose EOSC to provide added value for service users. In the context of the FAIR principles, interoperability is discussed in relation to the fact that “research data usually need to be integrated with other data; in addition, the data need to interoperate with applications or workflows for analysis, storage, and processing”.

The WGs view on interoperability does not only consider data but also the many other research artefacts that may be used in the context of research activity, such as software code, scientific workflows, laboratory protocols, open hardware designs, etc. It also considers the need to make services and e-infrastructures as interoperable as possible.

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